



MATE
MARINE
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CENTER

2008 MATE International ROV Competition

www.marinetech.org/rov_competition/index.php



Diving to the Deep: Uncovering the Mysteries of Mid-Ocean Ridges

June 2008

Scripps Institution of Oceanography –University of California, San Diego



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 2008 [General Information](#) document. Please review these requirements carefully.

The MATE Center is partnering with Ridge 2000 (www.ridge2000.org) to create a competition that challenges student teams to design and build ROVs to uncover the mysteries of Earth’s mid-ocean ridges. The mission scenario centers on the biology, chemistry, and geology of deep-sea hydrothermal vent environments.

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

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

Information about the **EXPLORER** and **RANGER** class competition missions, including the mission props, is included in *this* document, [Competition Missions](#); the [Engineering & Communication](#) document contains information about the technical report, engineering evaluation, and poster display.

HYDROTHERMAL VENTS: OASES OF THE DEEP

In 1977, scientists made a stunning discovery on the bottom of the Pacific Ocean that forever changed our understanding of planet Earth and life on it. They found seafloor vents gushing warm, shimmering, mineral-rich fluids into the cold, dark depths. And, to their complete surprise, they found that the vents were brimming with extraordinary, unexpected life.

Hydrothermal vents are found along the ridges of the seafloor where the plates that make up the earth's crust are either spreading apart (during the creation of new seafloor) or being pushed together (at subduction zones where one plate is sliding beneath the other). The dynamic movement of these plates creates cracks and fissures through which seawater travels into the earth's interior where it is heated and emerges as super-hot springs. Temperatures at these sites have reached as high as 403°C (757°F), and the water is laden with minerals and chemicals acquired during its sub-seafloor journey. It is the precipitation of the minerals and chemicals, such as iron, copper, and zinc sulfides, as the super-hot vent fluid comes in contact with the cold ocean water that creates the infamous "black smokers." Black smokers are the tall, chimney-like structures seen so often in photographs of hydrothermal vents. Other minerals, such as barium, calcium, and silicon, mix with seawater to form smaller chimney structures called "white smokers." White smoker fluid is usually cooler (250-300°C) and flows more slowly than black smoker fluid.

Hydrothermal fluids do not always flow out of chimneys. In some places, they seep out of the ocean floor in what are called "diffuse flows." Diffuse flows are usually much cooler than the fluids emerging from black or white smokers. They also flow far slower, mixing with seawater below the sea floor, so that most of the minerals have precipitated out before the fluid emerges from the ocean floor.

The biology associated with hydrothermal vents is equally as unique and intriguing as the geology, geophysics, and chemistry. The four are inevitably tied together; it is the chemicals found in the hot vent fluids that support the oases of life found at these sites. Specialized microbes utilize hydrogen sulfide supplied by the vent fluids as an energy source to manufacture food – and it is these microbes and the food they create that sustains the life of the vent communities. Just as plants use sunlight as an energy source to transform atmospheric carbon dioxide into simple sugars during the process of photosynthesis, vent microbes use hydrogen sulfide as an energy source to transform carbon dioxide dissolved in the ocean water into food during the process of –appropriately named – chemosynthesis.

The sulfur-oxidizing microbes, so named because sulfide is oxidized during chemosynthesis, are found at vent sites in both free-living and symbiotic forms. In the free-living form, mats of these microbes are the first organisms found at new vent sites. As symbionts, these microbes are part of a mutualistic relationship with the dominant organisms of vent communities. The giant, blood-red tubeworm *Riftia pachyptila* houses the microbial symbionts within a specialized organ called a trophosome. *Riftia* takes in hydrogen sulfide, carbon dioxide, and oxygen through its bright red gill-like plume and delivers these compounds to its symbionts that use them to create food. This food nourishes the worm and allows it to grow at phenomenal rates, up to 85cm (~34in) per year, making it the fastest growing marine invertebrate alive today. The clams (*Calyptogena magnifica*), mussels (*Bathymodiolus thermophilus*), and a few gastropod (snail)

species at vent sites also harbor microbial symbionts within their tissues – namely their gills, where they can ensure an adequate supply of hydrogen sulfide, carbon dioxide, and oxygen for their guests.

Vents are also home to other, “non-chemosynthetic” organisms – that is, organisms that do not contain symbiotic microbes within their tissues, but rather feed on (living or dead) tubeworms, clams, mussels, and gastropods. For example, crabs (*Bythograea thermydron*) and several species of fish make their homes at vent sites. While these organisms do not rely directly on the microbes for their nutrition, they are benefiting from the microbial food chain in these oases of the deep.

In addition to the Pacific, evidence for deep-sea hydrothermal venting has been found along the spreading centers and subduction zones in the Atlantic, Indian, and Arctic oceans. Although they may vary in organism composition, it is the microbes – and the process of chemosynthesis – that fuels these communities.

Although it’s been more than 30 years since their initial discovery, hydrothermal vents and the geological, geophysical, chemical, and biological processes that drive them continue to intrigue scientists, engineers, and technicians from around the world. With persistence and ingenuity, these individuals – and scientists, engineers, and technicians to come in the future – will continue to uncover the mysteries of these unique environments, helping us to better understand them and our planet Earth.

References:

- 9 Degrees North (http://www.marinetech.org/nine_degrees/index.php)
- Woods Hole Oceanographic Institution’s (WHOI) *Dive and Discover* (<http://www.divediscover.whoi.edu/>)
- University of Delaware’s *Extreme 2000: Voyage to the Deep* (<http://www.ocean.udel.edu/deepsea/home/home.html>)

OVERVIEW

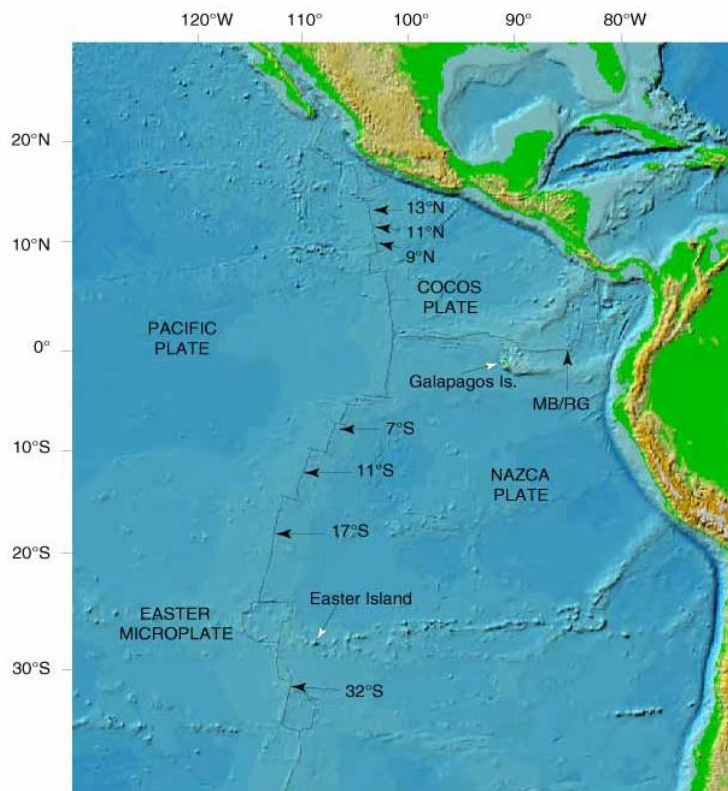
EXPLORER and **RANGER** class teams will compete in ONE mission that consists of three distinct mission tasks. Both **EXPLORER** and **RANGER** class teams will get **TWO** attempts to complete this single mission. The higher of the two scores will be added to the engineering and communication score to determine the total overall score for the competition.

The time allotted to complete the mission tasks (i.e., the mission performance period) is 15 minutes, plus 5 minutes to set up your system and 5 minutes to demobilize your equipment and exit the control shack. Your team will receive a time bonus for successfully completing the missions and returning your ROV to the surface and touching the side of the pool by the control shack before the mission performance period ends. You may complete the missions in any order. Your ROV does not need to return to the surface between mission tasks.

EXPLORER CLASS

In Hot Water: Rescue Mission on the East Pacific Rise

The East Pacific Rise (EPR) is a mid-ocean ridge that forms the boundary between the Pacific (western side of the ridge) and the Cocos and Nazca (eastern side of the ridge) tectonic plates and runs from the Gulf of California to south of Easter Island. The main portion of the EPR lies about 3,200 km (2,000 miles) off the coast of South America. To the north, the rise lies in part under the Gulf of California and the southern-most part of the Salton Sea, where it terminates at its junction with the San Andreas Fault. To the south, the eastward moving Cocos and Nazca plates are being subducted under the westward moving Caribbean and South American plates, respectively. The belt of volcanoes along the Andes and the arc of volcanoes through Central America and Mexico are the direct results of this collision.



Map of EPR with several study sites noted

The crest of the EPR is a center of seafloor spreading; new oceanic crust in the form of basaltic lava is welling up along the crest, cooling, and moving away from the crest in either direction. Associated with this volcanic activity are a number of hydrothermal vents; it was along an eastward extension of the EPR near the Galapagos Islands that hydrothermal vents were first discovered in 1977.

While the Galapagos vents have received considerable attention from the scientific community, some scientists associated with the Ridge 2000 research program are particularly interested in a section of the EPR referred to by its latitudinal position – “9°N.” It is at this location where the

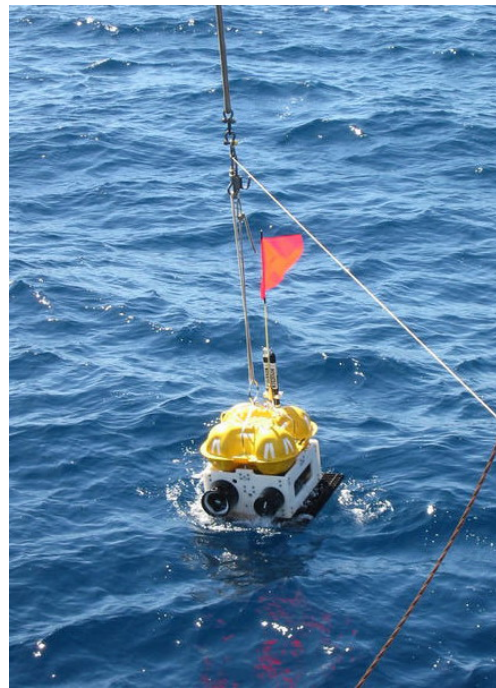
Pacific and the Cocos plates are moving apart at one of the fastest rates known anywhere on Earth – about 11cm (4.5 inches) a year. Because the tectonic plates are moving apart so rapidly, there is a greater chance that a geologic event, such as an eruption, will occur within the time scale of a decade. And, in April of 2006, scientists discovered that an eruption is precisely what took place.....

In 2005, 12 ocean bottom seismometers had been deployed over several square miles of seafloor at the 9°N study site, which is located approximately 450 miles south of Acapulco, Mexico. Ocean bottom seismometers, or OBSs for short, are instruments designed to monitor earthquake activity. About 90 percent of all earthquakes occur underwater, where great pressure and cold temperatures make measurements difficult. OBSs were developed for this task. Sitting on the seafloor, OBSs convert ground motions – from the tiniest flutters to major movements – into electrical signals that are digitally recorded by the instrument. Once the instruments are recovered and the earthquake recordings retrieved, scientists can use the data to gain a better understanding of volcanic processes and how these processes shape the planet.

Ocean-bottom seismometers are designed so they can be easily deployed and recovered from almost any research vessel. Sitting at 2,500 meters below the ocean surface, the 12 OBSs were due to be recovered during an expedition in April of 2006. Recovery is typically a routine task; the OBSs are equipped with an acoustic release transponder that helps scientists locate and retrieve them. The acoustic release essentially “holds on” to weights that anchor the instrument in place. During recovery, an acoustic signal is transmitted via a shipboard transponder and the release “lets go” of the weight, freeing the instrument from the bottom and allowing it to float to the surface.



OBS



OBS deployment

However, during this expedition recovery was anything but typical. Two-thirds of the OBSs could not be recovered and three of those were communicating acoustically with the ship but did not leave the seafloor. Scientists immediately suspected – and later confirmed – that an eruption had recently occurred and that lava flow had engulfed the instruments.....

One month later, scientists returned to the site in an attempt to locate and recover the remaining instruments and, most importantly, the data that would allow them to paint a more complete picture of the eruption and, possibly, to predict future seismic events. Fortunately, the OBSs were still responding to acoustic signals and the scientists were able to find them – stuck in a flow of hardened lava.

Now the challenge became freeing the instruments from the “glue” that held them steadfast to the seafloor. Scientists tried to pull them loose using a camera-equipped sled towed by a cable behind the ship – but with no success as this piece of equipment was not designed for the task.

However, images from the camera did provide important clues about what had unfolded. The eruption had covered large areas of the ridge with glassy new lava, indicating that the event must have happened very recently – but just how recently? This question was very important because it is very difficult to detect let alone study an underwater volcanic eruption – for some scientists, it may only happen once or twice during their lives.

Data collected by the trapped OBSs could help to answer how old the eruption was, but first they had to be recovered. The scientists were also interested in collecting lava samples and taking the temperature of the hot fluids from any new or surviving hydrothermal vents because these samples could also help to determine how long ago the eruption occurred.

These tasks clearly called for a more powerful, capable piece of underwater equipment – one that could not only free the trapped OBSs, but also sample both the lava and the temperature of waters emerging from any nearby hydrothermal vents. A powerful, capable piece of equipment...such as an ROV...

And this is where your mission begins...

References:

- Venture Deep Ocean (<http://www.venturedeepocean.org/>)
- Wikipedia (http://en.wikipedia.org/wiki/East_Pacific_Rise)
- SEAS: Students Experiments at Sea (<http://www.ridge2000.org/SEAS/index.html>)
- Encyclopedia Britannica (<http://www.britannica.com/eb/article-9031790/East-Pacific-Rise>)
- *Ridge 2000 Events* – Newsletter of the Ridge 2000 Program, For Informal Exchange of Information Related to Research of Earth’s Spreading Centers, Vol. 2, No. 1 (<http://www.ridge2000.org/science/info/newsletters.php>)
- WHOI’s Oceanus, the Magazine that Explores the Oceans in Depth – *Rescue Mission on the Seafloor* (<http://www.whoi.edu/oceanus/viewArticle.do?id=27286>)
- National Science Foundation – *Scientists Catch Underwater Volcanic Eruption “In Action” in Pacific Ocean Depths* (http://www.nsf.gov/news/news_images.jsp?cntn_id=106928&org=NSF)
- WHOI – Ocean Bottom Seismometers (<http://www.whoi.edu/instruments/viewInstrument.do?id=10347>)

- University of Rhode Island's *Discovery of Sound in the Sea* (<http://www.dosits.org/index.htm>)
 - University of South Carolina's Marine Sediments Research Laboratory (<http://www.geol.sc.edu/msrl/>)
 - *EPR photo courtesy of the Monterey Bay Aquarium Research Institute; OBS photos courtesy of Scripps Institution of Oceanography*
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EXPLORER MISSION TASKS

Task #1: Free an OBS from the seafloor.

Task #2: Collect up to 3 samples of lava.

Task #3: Measure the temperature of hydrothermal vent fluid.

Task #1: Free an OBS from the seafloor.

This task involves:

- **Removing pieces of lava from the OBS.**
- **Freeing the OBS so that it floats to and breaks the water surface.**

Scoring – 60 points*

- 60 points – freeing the OBS so that it floats to and breaks the water surface.

*No partial points will be awarded.

You must free the OBS using your ROV. Your ROV is not required to remove all of the lava pieces from the OBS, but it will need to remove enough pieces to free the instrument.

You are not permitted to use your ROV to attach a line to the OBS and free the instrument by pulling on the line by hand. You can hook or otherwise attach to the OBS with your ROV and use its thrust or buoyant force to free the instrument, but your team is not permitted to pull on the tether to free the OBS once the ROV has attached to it.

OBS prop specifications

The OBS will be positioned on the pool bottom near the hydrothermal vent site. It will be located far enough from the vent site that your vehicle will be able to move freely around it.

The OBS is constructed out of a PVC frame secured to a flat sheet of ABS plastic. The ABS sheet is 1/8-inch thick and measures 50cm x 50cm. The sheet serves as the base of the seismometer. The 1/2-inch PVC framework measures 25cm long x 25cm wide x 22cm high and is centered on the ABS sheeting. The framework is attached to the ABS base by screws. A horizontal 1/2-inch PVC crosspiece is located at 9cm above the base on two opposite sides.

The electronics and data recorders of operational OBSs are contained inside protective cylinders. The cylinders are simulated by two 28cm lengths of 3-inch black ABS pipe that are secured

above the PVC crosspiece. ABS end covers close each end of the 3-inch ABS pipe; however, these simulated cylinders will flood with water.

Cable-tied to the top of the OBS between the two instrument packages is the flotation package. The flotation package is a 13cm length of 3-inch ABS pipe, with a 3-inch PVC end cap on each end. The entire length of the flotation package, with end caps, is 20cm. The ABS pipe will flood with water; however, the appropriate amount of hard foam buoyancy is located inside the pipe so that the OBS, when freed of lava, is positively buoyant. The entire OBS, including the base, frame, instrument packages, and flotation, has a positive buoyant force of 3 Newtons.

The OBS will be held to the bottom by (8) 2-lb dive weights that simulate pieces of lava flow. These are soft, pellet-filled dive weights. The weights may be placed on any part of the OBS structure (i.e., the base, PVC frame, instrument packages, and flotation). There are NO attachments or handles to facilitate lifting or moving the weights.

OBS prop construction notes:

- Check local plastic or sign making stores for ABS sheeting.
- Teams may substitute 3-inch PVC for the 3-inch ABS pipe, provided that the entire OBS package has 3 Newtons of positive buoyancy.
- A common brand of soft weights is called **Soft Weights™** and is available at most SCUBA diving shops.

Task #2: Collect up to 3 samples of lava.

This task involves:

- **Collecting up to 3 samples of lava.**
- **Returning the samples of lava to the surface.**

Scoring – up to 60 points

- 10 points – for each sample of lava (up to 3) collected so that it is under the control of your ROV and no longer in contact with the bottom.
- 10 points – for each sample of lava (up to 3) returned to the surface under the control of your ROV so that one team member can retrieve the sample from the vehicle.

The lava that your team is sampling is the same lava (i.e., the 2-lb soft dive weights) that is covering the OBS. You are permitted to earn points for this task as you attempt to accomplish **Task 1** above. You are also permitted, but not required, to collect and/or return to the surface more than one sample of lava at a time.

Mission prop specifications

See **EXPLORER Task 1** above for a description of the lava.

Task #3: Measure the temperature of hydrothermal vent fluid.

This task involves:

- **Locating the hydrothermal vent.**
- **Inserting a temperature sensor into the venting fluid.**
- **Measuring the temperature of the venting fluid and displaying the reading on a video monitor or as a read-out at the control shack.**

Scoring – 80 points

- 10 points – placing your ROV’s temperature sensor in the vent flow
- 10 points – obtaining ANY temperature reading or temperature gauge movement
- up to 60 points for accuracy of the temperature reading
 - Temperature reading within $\pm 3.0^{\circ}\text{C}$ of benchmark – 60 points
 - Temperature reading within $\pm 4.0^{\circ}\text{C}$ of benchmark – 40 points
 - Temperature reading within $\pm 5.0^{\circ}\text{C}$ of benchmark – 20 points

You must measure the temperature with a temperature sensor either mounted on or “carried” by your ROV. It is recommended that you design your temperature sensor to measure a range of 0°C to 50°C .

The judge(s) should be able to see your temperature reading on your ROV’s video monitor or as a read-out at the control shack. The read-out can be a separate device or integrated into your ROV’s control system. Inform the judge(s) when you are preparing to take a reading and when you are ready to have your measurement scored. The judge(s) will confirm your measurement on the mission score sheet and assign a score based on the accuracy of your temperature measurement compared to the read-out on the judges’ temperature gauge (**called the benchmark**).

Hydrothermal vent prop specifications

The hydrothermal vent is a black smoker that will be located on the pool bottom near, but not obstructing, the OBS.

The venting fluid is simulated by low velocity, upward-moving water currents. The vent opening is large enough to accommodate enough volume of moving fluid to allow a temperature sensor to be placed within the flow to obtain a reading.

The black smoker chimney is constructed out of PVC and ABS pipe. There is both an internal and external structure to the smoker. The internal structure carries the venting fluid. The outer structure provides the “look” for the chimney and serves as a base for the **RANGER** class black smoker and crab sample retrieval tasks.

The base of the black smoker is a 2-inch PVC connector cemented into a plastic oil pan 40cm in diameter and 10cm tall. This cement-filled plastic oil pan will anchor the black smoker to the bottom of the pool. A 10cm length of 2-inch PVC extends from the 2-inch connector. A 1-inch diameter hole is drilled into the center length of the 2-inch PVC segment. This hole is large enough for the ½-inch PVC pipe described below to pass through it.

Internal Vent Structure

Water will enter the internal vent structure from a hose. A ¾-inch MHT – ½ inch slip PVC fitting is used to attach the hose to the PVC structure. This fitting is attached to a 19cm length of ½-inch PVC pipe. The other end of this pipe is fitted through the hole drilled through the center of the 2-inch PVC (described above) and connected to a 90° PVC elbow.

A 24cm length of ½-inch PVC pipe extends from the 90° PVC elbow. This leads into a small bend comprised of a PVC connector, a 45° PVC elbow, a 90° PVC elbow, another 45° PVC elbow, and finally a 7cm length of PVC pipe. All of these components are made of ½-inch PVC. Teams must insert their temperature probe into this 7cm length of ½-inch PVC pipe to obtain a measurement.

External Vent Structure

A 2-inch to 3-inch pipe increaser is attached to the 2-inch PVC connector cemented into the base. Attached to the pipe increaser is a 34cm length of 3-inch ABS pipe that simulates the outer structure of the black smoker. A 3-inch PVC end cap is used to enclose the top of the smoker. A 1-inch hole is drilled in the top of the 3-inch PVC end cap to allow the top of the internal vent structure to exit the outer structure.

The outside of the 3-inch ABS pipe is covered in black, industrial strength Velcro “loops.” Attached to the Velcro loops via 0.5cm x 0.5cm pieces Velcro “hooks” are small, round rocks designed to simulate samples of the black smoker. The rocks have a volume of ½ to 1 cubic inch and weigh up to 1.5 Newtons. These rocks are part of the **RANGER** class black smoker retrieval mission task, but are purely decorative for the **EXPLORER** class mission. **RANGER** class teams can select which rocks to collect and bring to the surface. It will take 2 Newtons or less to remove the rocks from the black smoker.

Hydrothermal vent prop construction notes:

- The base is constructed the same way as the cement base used for the 2007 competition subsea oil well mission (see www.marinetech.org/rov_competition/2007/Mission_3_FINAL.pdf).
- Use a 1-inch hole saw, or a very large drill bit, to make the hole. Other drilling methods can also be used, provided that the end result is a hole in the 2-inch PVC segment that is large enough for a ½-inch length of PVC to pass through.
- The slip fitting is simply an attachment to allow the hose to connect to PVC. Most national-chain hardware stores should have these fittings.
- The competition “benchmark” sensor will be located inside the ½-inch PVC connector. The bend is to ensure that teams’ temperature probes do not damage this benchmark sensor. Experiments show no significant difference in water temperature at the benchmark sensor and the top centimeter of PVC pipe.
- The rocks are sold as “Black Mexican Beach Pebbles” and can be purchased at landscaping and national-chain hardware stores as well as on-line.
- Do not rely on the adhesive on the back of the Velcro to secure it to the rocks. Also use 5-minute epoxy, superglue, contact cement, or other strong adhesive.

Time bonus

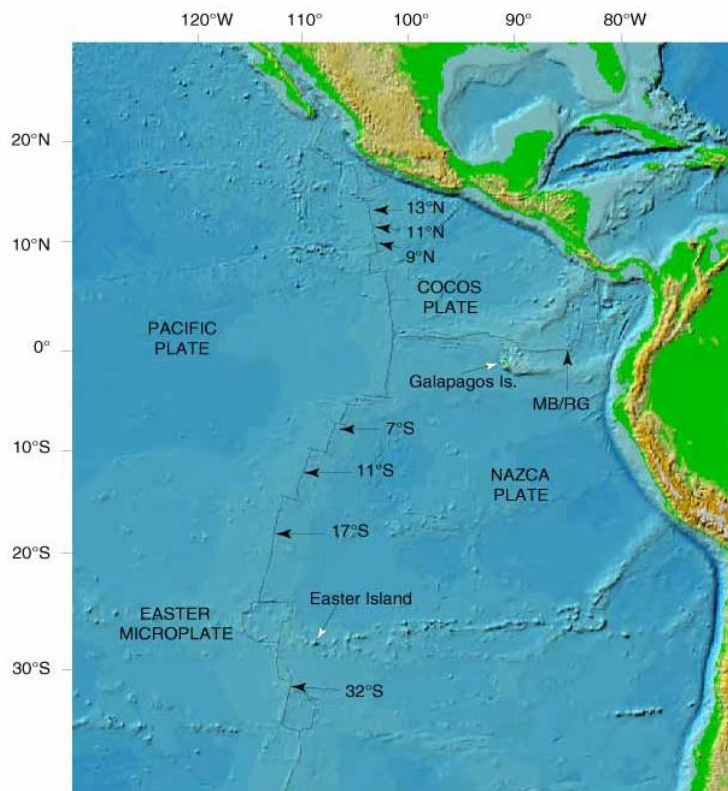
Teams will receive 1 point for every minute and 0.01 point for every second under 15 minutes remaining. Your mission performance period ends when your ROV has successfully completed the mission tasks, returned to the surface under its own power, and a team member at the launch station has physically touched the vehicle. Time bonus points will be awarded accordingly.

PHOTOS AND SOLIDWORKS ASSEMBLIES AND DRAWINGS OF THE MISSION PROPS ARE INSERTED AT THE END OF THIS DOCUMENT.

RANGER CLASS

Diving Deep: Science and Discovery on the East Pacific Rise

The East Pacific Rise (EPR) is a mid-ocean ridge that forms the boundary between the Pacific (western side of the ridge) and the Cocos and Nazca (eastern side of the ridge) tectonic plates and runs from the Gulf of California to south of Easter Island. The main portion of the EPR lies about 3,200 km (2,000 miles) off the coast of South America. To the north, the rise lies in part under the Gulf of California and the southern-most part of the Salton Sea, where it terminates at its junction with the San Andreas Fault. To the south, the eastward moving Cocos and Nazca plates are being subducted under the westward moving Caribbean and South American plates, respectively. The belt of volcanoes along the Andes and the arc of volcanoes through Central America and Mexico are the direct results of this collision.



Map of EPR with several study sites noted

The crest of the EPR is a center of seafloor spreading; new oceanic crust in the form of basaltic lava is welling up along the crest, cooling, and moving away from the crest in either direction. Associated with this volcanic activity are a number of hydrothermal vents; it was along an eastward extension of the EPR near the Galapagos Islands that hydrothermal vents were first discovered in 1977.

While the Galapagos vents have received considerable attention from the scientific community, some scientists associated with the Ridge 2000 research program are particularly interested in a section of the EPR referred to by its latitudinal position – “9°N.” It is at this location where the

Pacific and the Cocos plates are moving apart at one of the fastest rates known anywhere on Earth – about 11cm (4.5 inches) a year. Because the tectonic plates are moving apart so rapidly, there is a greater chance that some sort of geologic event, such as an eruption, will occur within the time scale of a decade. And, in April of 2006, scientists discovered that an eruption is precisely what took place.....

Scientists first suspected that an eruption had occurred when instruments deployed to the seafloor during a previous expedition appeared to fail. Sitting 2,500 meters below the ocean surface, these instruments, called ocean bottom seismometers (OBS), are designed to monitor and record earthquake activity, helping scientists to gain a better understanding of the volcanic processes that take place underwater.

The instruments were due to be recovered during a routine OBS “turn-around” expedition in mid-April of 2006. However, when a transponder on board the ship sent an acoustic signal to instruct the instruments to release their weights and float to the surface, the majority of them failed to respond. This led scientists to fear the worst – that the OBSs had been buried by lava.

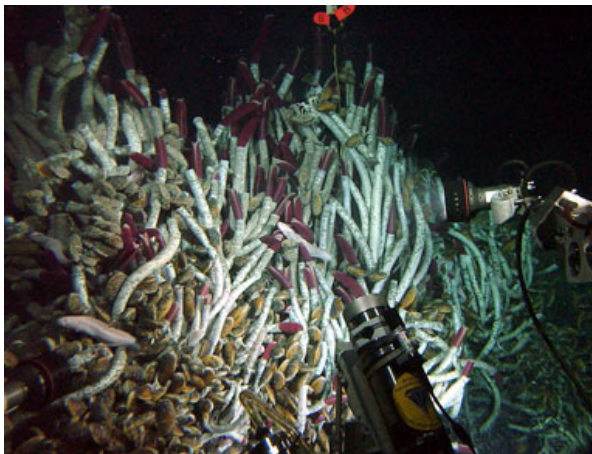
The loss of the instruments, coupled with tell-tale changes in seawater near the site, was strong evidence for an eruption. However, the expedition did not have the proper equipment – or enough fuel – to remain at the site and investigate further.

Fortunately, scientists were able to quickly organize a return expedition. Within two weeks this “rapid response” cruise set out for the 9°N study site, located approximately 450 miles south of Acapulco, Mexico. Arriving at the site, scientists immediately deployed and towed a camera-equipped sled behind the ship to get a first look.

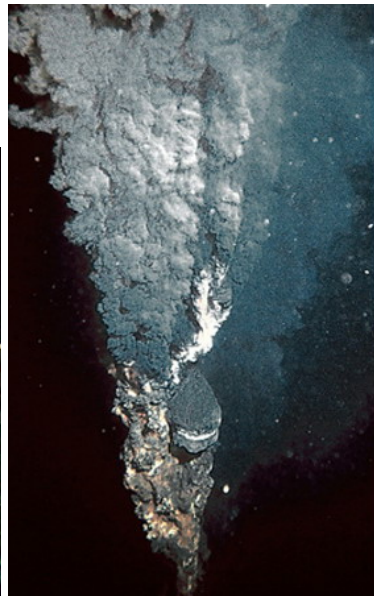
The landscape had changed dramatically. Lava from the eruption had covered many of the existing hydrothermal vents and wiped out the thriving biological communities. Where there had been colonies of tubeworms (*Riftia pachyptila*), clams (*Calyptogena magnifica*), and mussels (*Bathymodiolus thermophilus*) and black smoker chimneys, there were now icy-black flows of hardened lava. In many areas, the scene was reminiscent of a moonscape.

However, the camera also revealed signs of new life. White mats of microbes surrounded cracks and vents in the new lava where hot fluids emerged. Vent crabs (*Bythograea thermydron*) slowly crawled over the microbes and among clusters of tubeworms, pausing to snip at the blood-red tufts of plumes emerging from the white tubes.

Life was quickly returning to the devastated seafloor, and scientists now wanted to take advantage of the unique opportunity to monitor when different organisms arrive at new vent sites. Because different organisms are adapted to different temperatures, a critical component of this process involves knowing how the temperature of the venting fluids changes over time.



Vent tubeworms and mussels



Black smoker



Vent clams

To measure the vent fluids, however, would require equipment more sophisticated than a towed camera sled. Many of the new vents were located in areas where the lava had collapsed into the ridge itself, creating a trough fringed with hardened lava that would be tricky to navigate. The tasks of taking measurements and other biological and geological samples would require an underwater vehicle equipped with collection tools and sensors – an underwater vehicle such as an ROV. Equally as important, these tasks would require an operator with the dexterity to pilot the vehicle into the lava trough itself without the structure collapsing on the vent site – or, even more costly, on the vehicle itself.



Lava trough

And this is where your mission begins...

References:

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- Wikipedia (http://en.wikipedia.org/wiki/East_Pacific_Rise)
- SEAS: Students Experiments at Sea (<http://www.ridge2000.org/SEAS/index.html>)

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 - University of Delaware’s *Extreme 2000: Voyage to the Deep* (<http://www.ocean.udel.edu/deepsea/home/home.html>)
 - *EPR photo courtesy of the Monterey Bay Aquarium Research Institute; tubeworm photo courtesy of Woods Hole Oceanographic Institution; smoker and clam photos courtesy NOAA’s Ocean Explorer (center and right); and lava photo courtesy of E. Klein, Duke University; M. Perfit, University of Florida; and S. White, University of South Carolina.*
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RANGER MISSION TASKS

Task #1: Collect up to 3 vent crabs.

Task #2: Collect up to 3 samples of a black smoker.

Task #3: Measure the temperature of hydrothermal vent fluid.

Vent site description

The entire RANGER class vent structure will be located within a 3m long x 3m wide x 1m high enclosure designed to simulate a lava trough. The enclosure will be constructed of ½ inch PVC pipe with black plastic sheeting for walls. The top of the enclosure will be open for vehicles to enter the trough.

Task #1: Collect up to 3 vent crabs.

This task involves:

- **Collecting up to 3 vent crabs.**
- **Returning the vent crabs to the surface.**

Scoring – 60 points

- 10 points – for each vent crab (up to 3) collected so that it is under the control of your ROV and no longer in contact with the topography.
- 10 points – for each vent crab (up to 3) returned to the surface under the control of your ROV so that one team member can retrieve the crab from the vehicle.

The vent crabs are mobile organisms that may scurry and/or hide to evade capture. Your team may find them in the open or tucked into nooks and crannies in the bottom topography. (**Note:** The location of the crabs will be the same for all teams during the first mission attempt, and, if changed for the second mission attempt, will again be the same for all teams.)

Crab prop specifications

The crabs are simulated using 1 ½-inch ABS end caps for the bodies and brown pipe cleaners for the legs and claws.

Ten holes are drilled in each 1 ½-inch ABS end cap, 5 on each side. These holes are attachment points for 8 legs and 2 claws. Each leg is a 30cm long pipe cleaner twisted in half to shorten and strengthen it. Approximately 2.5cm of one end of the pipe cleaner is left untwisted and inserted through one of the holes in the ABS end cap. The loose ends are twisted together inside the end cap to hold the legs in place. The overall length of each leg is approximately 13cm, 2cm of which is inserted inside the “body” of the crab.

Each crab claw consists of two pipe cleaners. These pipe cleaners are twisted together, except at each end. At one end, 2.5cm lengths are left untwisted and inserted through one of the holes in the ABS end cap. The loose ends are twisted together inside the end cap to hold the legs in place. At the other end, 9cm lengths are left untwisted and folded over to simulate an open claw.

Two small self-tapping screws (round top) are added to the ABS end caps to simulate eyes.

The entire crab is no more than 1 Newton negatively buoyant.

Crab prop construction note:

- Check local craft stores for pipe cleaners.

Task #2: Collect up to 3 samples of a black smoker.

This task involves:

- **Collecting up to 3 samples of a black smoker.**
- **Returning the samples of black smoker to the surface.**

Scoring – up to 60 points

- 10 points – for each sample of black smoker (up to 3) collected so that it is under the control of your ROV and no longer in contact with the smoker.
- 10 points – for each sample of black smoker (up to 3) returned to the surface under the control of your ROV so that one team member can retrieve the sample from the vehicle.

You are permitted, but not required, to collect and/or return to the surface more than one sample of black smoker at a time.

Black smoker sample prop specifications

See **EXPLORER Task 3** above for a description of the black smoker samples.

Task #3: Measure the temperature of hydrothermal vent fluid.

This task involves:

- **Locating the hydrothermal vent.**
- **Inserting a temperature sensor into the venting fluid.**
- **Measuring the temperature of the venting fluid and displaying the reading on a video monitor or as a read-out at the control shack.**

Scoring – 80 points

- 10 points – placing your ROV’s temperature sensor in the vent flow
- 20 points – obtaining ANY temperature reading or temperature gauge movement
- up to 50 points for accuracy of the temperature reading
 - Temperature reading within $\pm 4.0^{\circ}\text{C}$ of benchmark – 50 points
 - Temperature reading within $\pm 5.0^{\circ}\text{C}$ of benchmark – 40 points
 - Temperature reading within $\pm 6.0^{\circ}\text{C}$ of benchmark – 30 points

You must measure the temperature with a temperature sensor either mounted on or “carried” by your ROV. It is recommended that you design your temperature sensor to measure a range of 0°C to 50°C .

The judge(s) should be able to see your temperature reading on your ROV’s video monitor or as a read-out at the control shack. The read-out can be a separate device or integrated into your ROV’s control system. Inform the judge(s) when you are preparing to take a reading and when you are ready to have your measurement scored. The judge(s) will confirm your measurement on the mission score sheet and assign a score based on the accuracy of your temperature measurement compared to the read-out on the judges’ temperature gauge (**called the benchmark**).

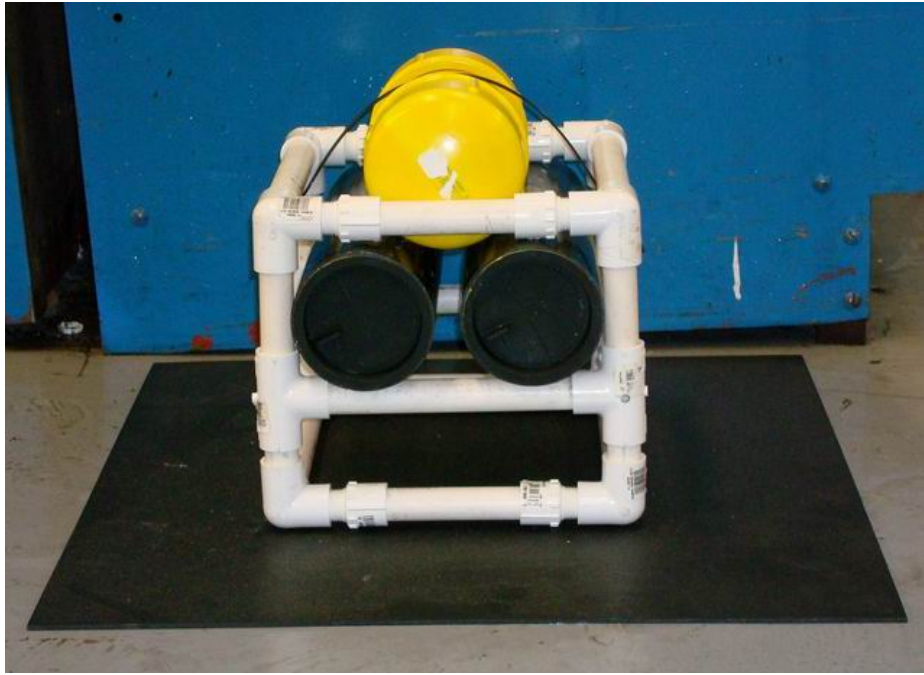
Hydrothermal vent prop specifications

See **EXPLORER Task 3** above for a description of the hydrothermal vent.

Time bonus

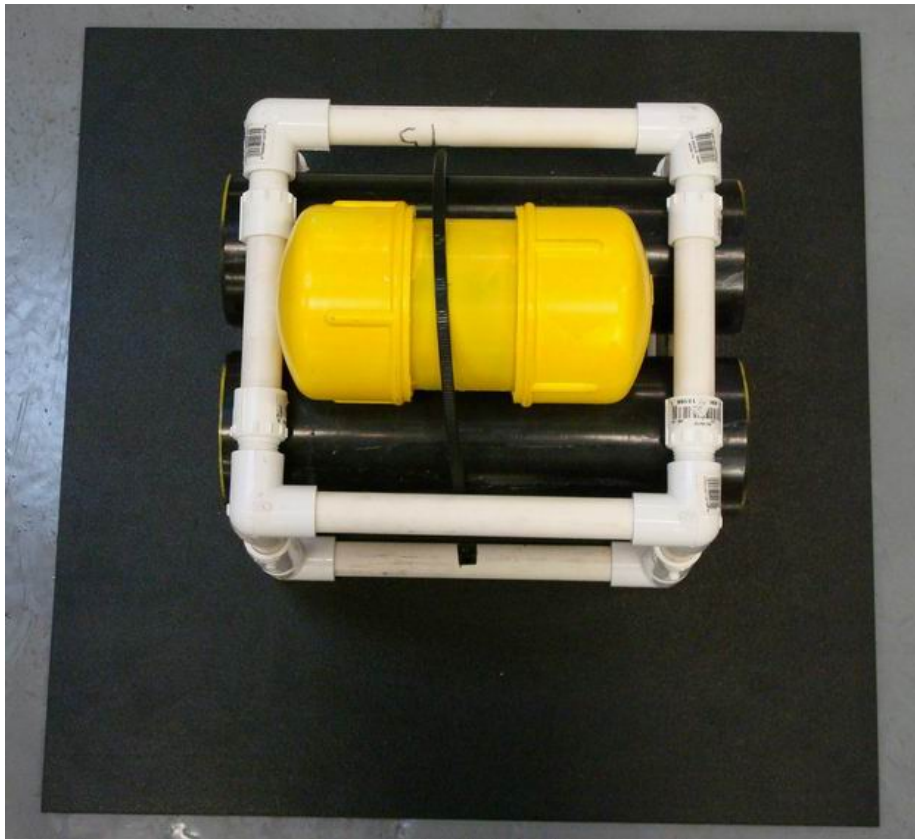
Teams will receive 1 point for every minute and 0.01 point for every second under 15 minutes remaining. Your mission performance period ends when your ROV has successfully completed the mission tasks, returned to the surface under its own power, and a team member at the launch station has physically touched the vehicle. Time bonus points will be awarded accordingly.

**PHOTOS AND SOLIDWORKS ASSEMBLIES AND DRAWINGS
OF THE MISSION PROPS FOLLOW.**



OBS – side views





OBS – top view



Soft dive weight

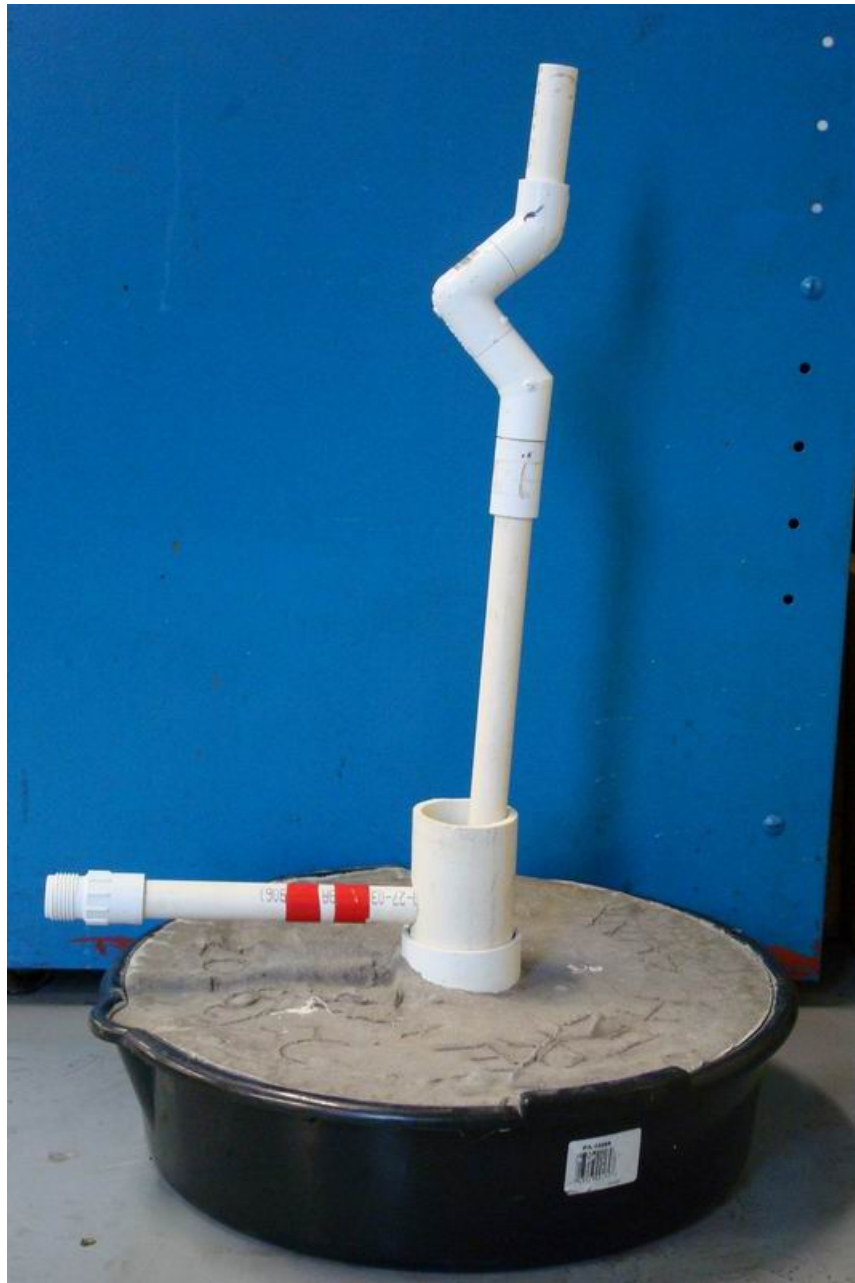
(Note: This is an example. The actual dive weights used may be a different color, but the weight will be no more than 2 lbs.)



Black smoker base – top view



Black smoker base – side view



Black smoker internal structure – side view



Black smoker external structure – side view



Black smoker external structure with samples – side view



Black smoker samples – top view



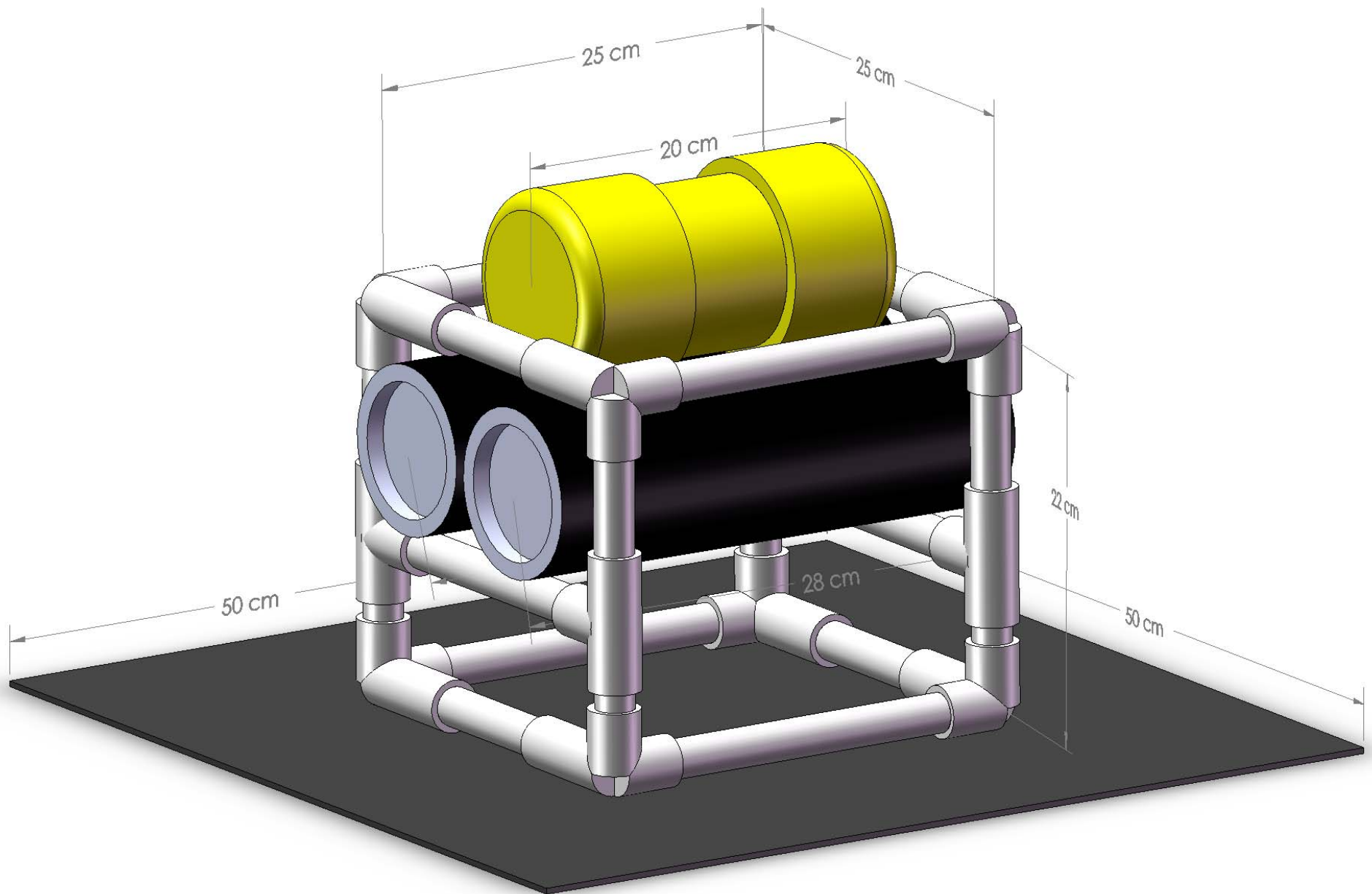
Vent crab – top view



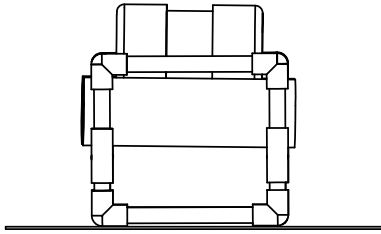
Vent crab – front view



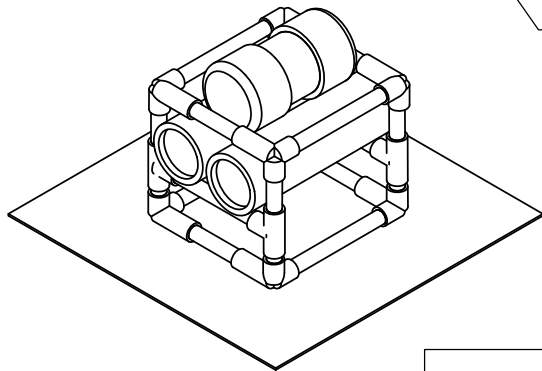
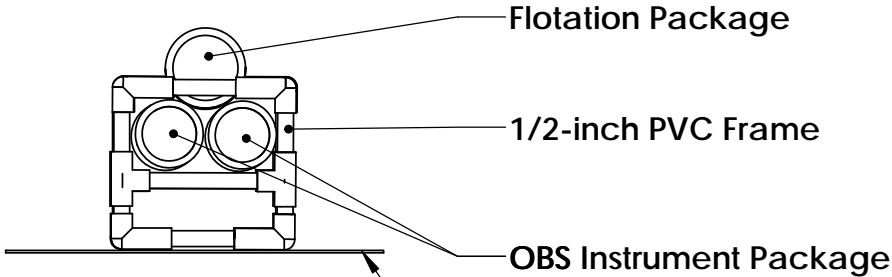
Vent crab leg and claw – top view



Side View



Front View



Flotation Package

1/2-inch PVC Frame

OBS Instrument Package

50cm x 50cm ABS Base

Ocean Bottom Seismometer

Base:

50cm x 50cm

1/8-inch ABS sheet

Frame:

1/2-inch PVC

25cm long x 25cm wide x 22cm high

Crosspiece at 9cm height

Instrument Packages (2):

3-inch ABS pipe

28cm long

End covers on both ends

Instrument packages flooded with water

Flotation Package:

3-inch ABS pipe

20cm long

End caps on both ends

Pipe flooded with water with appropriate amount of hard foam added for positive buoyancy

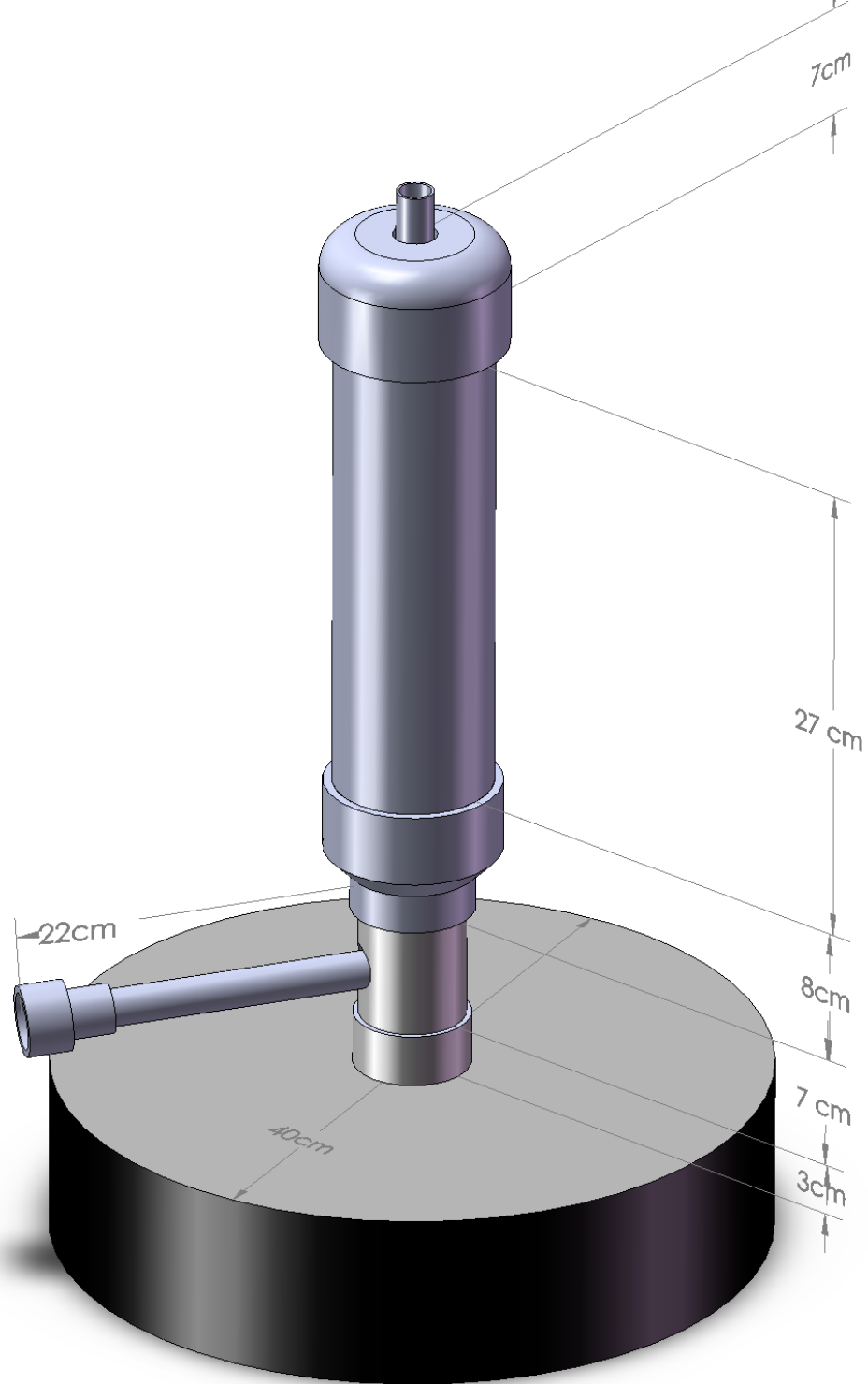
Lava Flow:

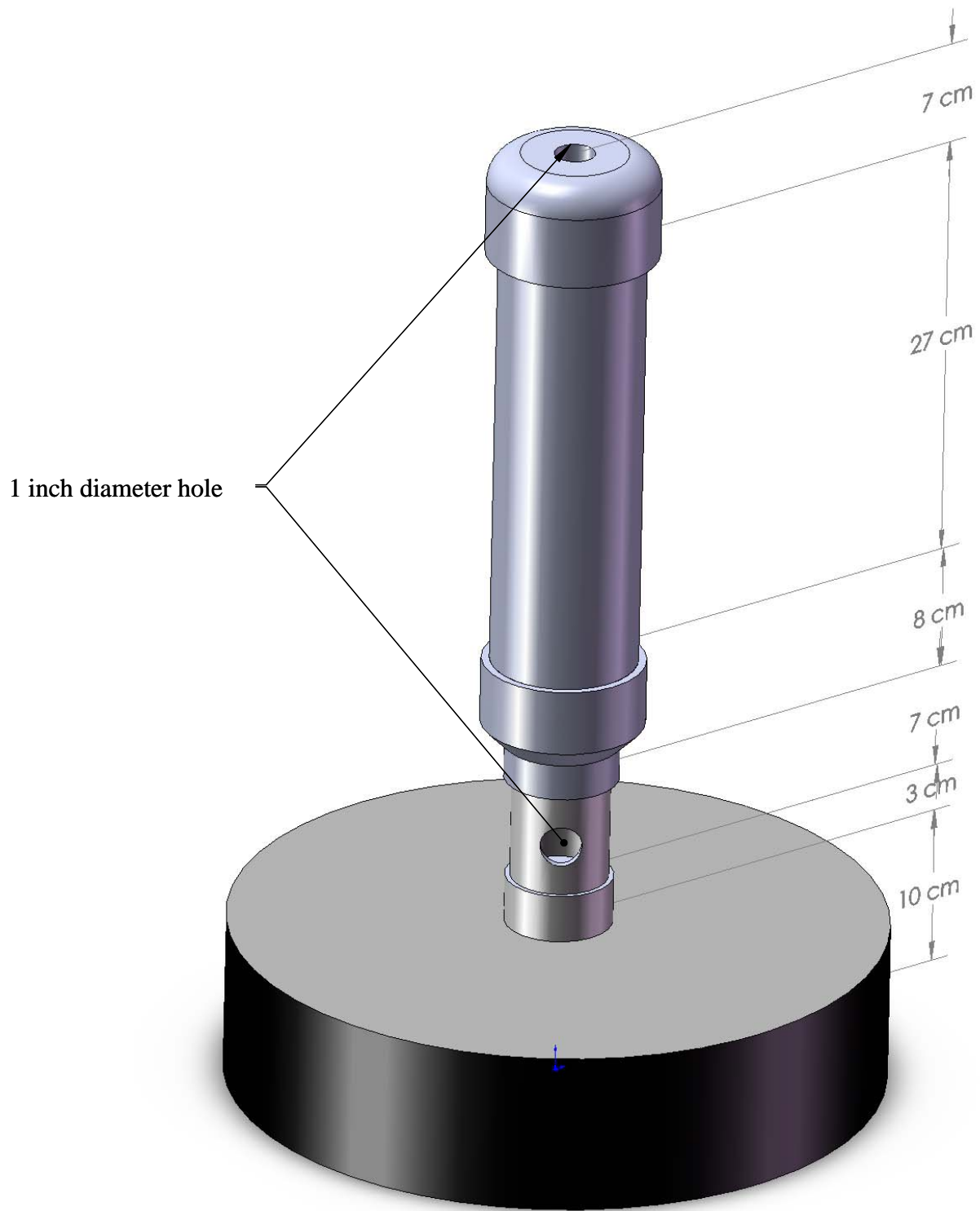
Simulated by (8) 2-lb soft dive weights

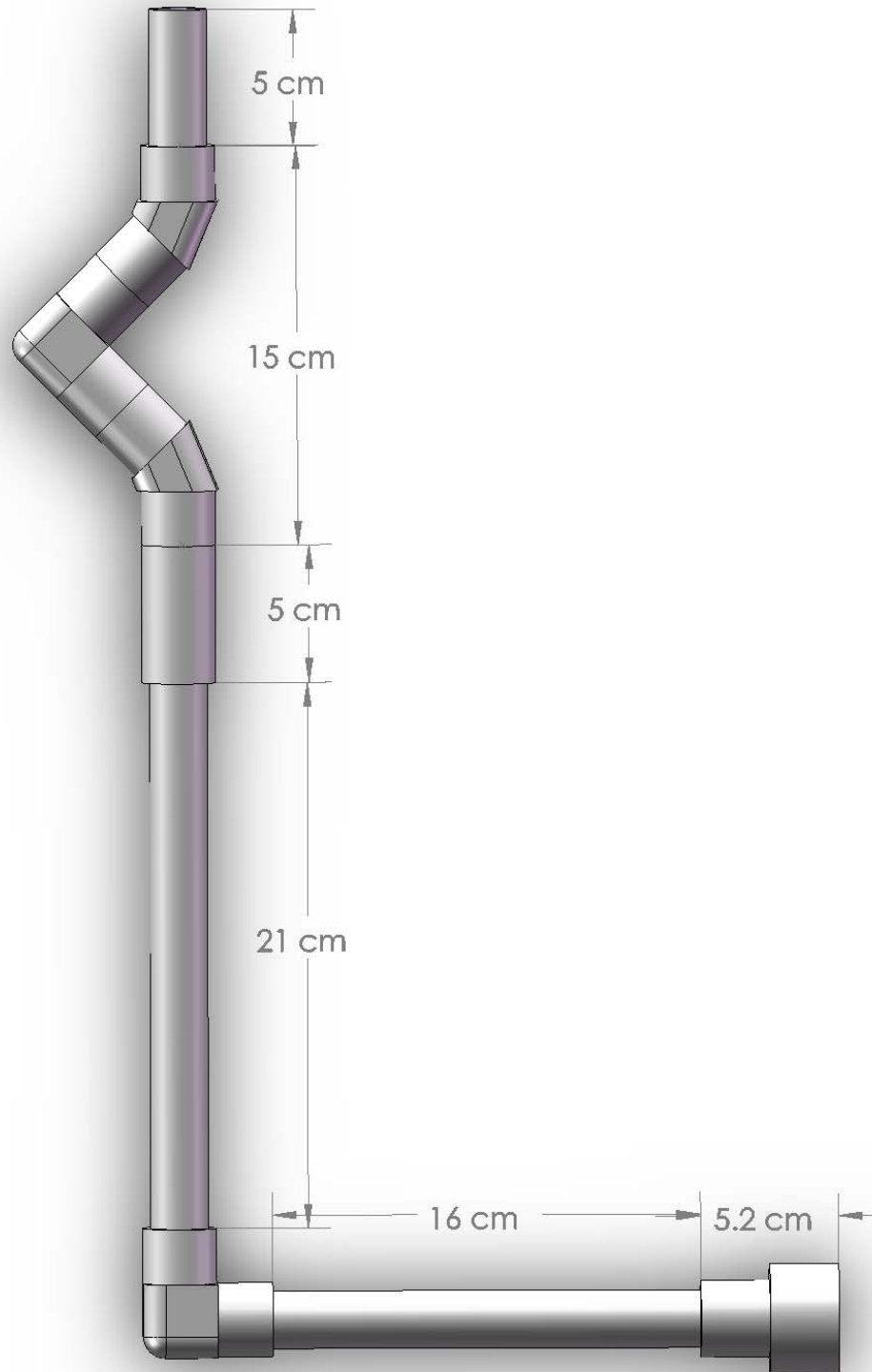
OBS has positive buoyancy of 3 Newtons

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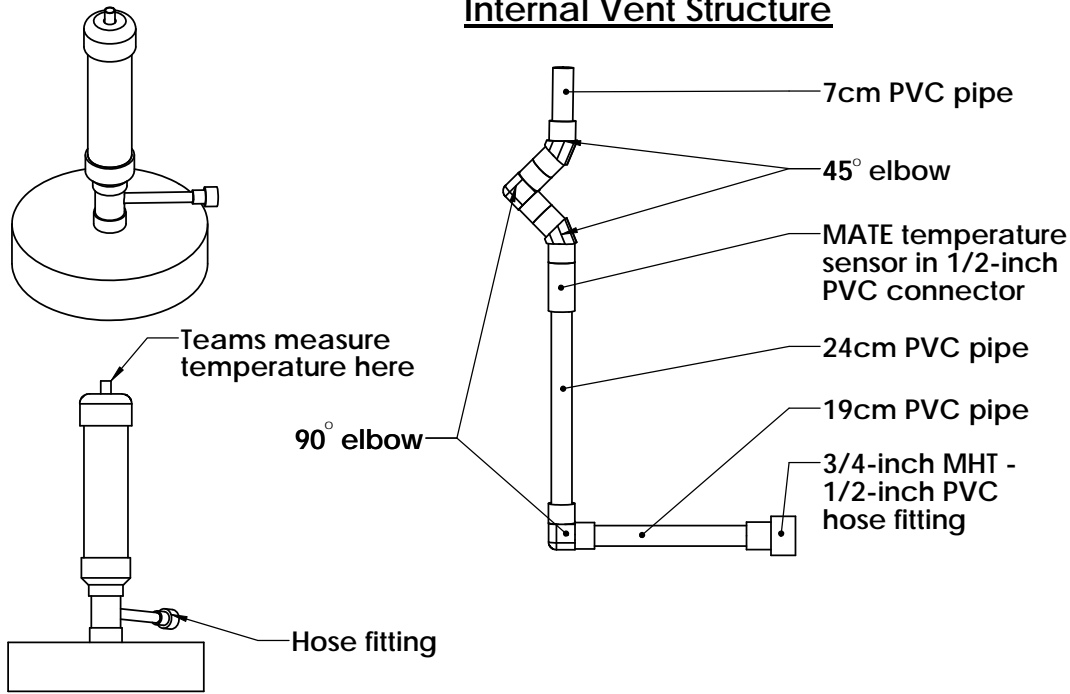
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
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			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS: created by Matthew Gardner			
		FINISH				SIZE DWG. NO. REV
NEXT ASSY	USED ON					AOBS Drawing
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:10 SHEET 1 OF 1



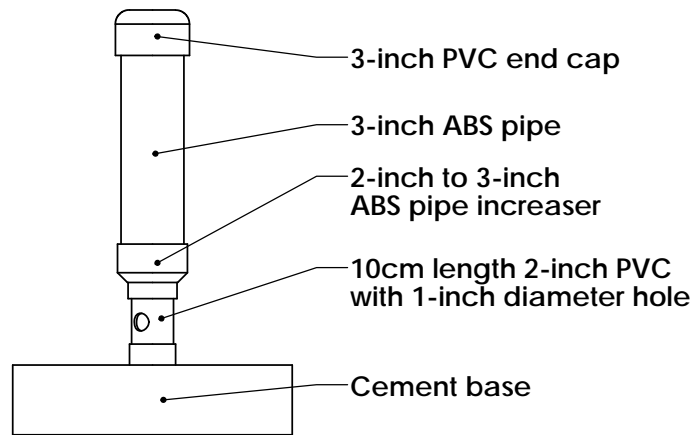




Internal Vent Structure



External Vent Structure



Hydrothermal Vent

Base:

Cement filled 40cm diameter oil pan.
Weight: 15 kg

Internal Vent Structure:

Constructed of 1/2-inch PVC.
Contains hot or cold water.
Water will enter from a hose at the base of the vent.
Water will exit from a 1/2-inch PVC pipe at the top of the vent.

External Vent Structure:

Constructed of 2-inch PVC and 3-inch ABS.
External surface of 3-inch ABS covered in Velcro loops.
Rocks (Black Mexican Beach Pebbles) will be attached to the Velcro.
RANGER teams must collect rock samples; they are purely decorative for EXPLORER teams.

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		UNLESS OTHERWISE SPECIFIED:		NAME	DATE		
				DRAWN		TITLE:	
				CHECKED		MATE CENTER	
				ENG APPR.		BLACK SMOKER	
				MFG APPR.			
				Q.A.			
		INTERPRET GEOMETRIC TOLERANCING PER:		COMMENTS:		SIZE	DWG. NO.
		MATERIAL		Created by Matthew Gardner		B	BLACK SMOKER
		FINISH				SCALE: 1:5	WEIGHT:
NEXT ASSY	USED ON					SHEET 1 OF 1	
APPLICATION		DO NOT SCALE DRAWING					