COMPETITION MISSIONS

ROVs and the Offshore Oil & Gas Industry

Highlighting the Challenges that ROVs Faced During the Gulf of Mexico Oil Spill

This document contains information about the EXPLORER and RANGER class missions. Information about the SCOUT class missions can be found within the **SCOUT Class Competition** document.

COMPETITION SCORING OVERVIEW

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)

COMPETITION MISSIONS

The Deepwater Horizon drilling rig explosion and the oil spilled and vented from the wellhead into the Gulf of Mexico represents a very tragic and challenging time in our history. The largest ecological disaster in the U.S. resulted in the loss of eleven lives and the livelihoods of thousands of workers; the devastation of miles of ocean, beaches, and shoreline; the destruction of thousands of birds, sea turtles, fish, mammals, and invertebrates (not to mention the long-term effects on these and hundreds of other species that have yet to be determined); ongoing health issues for residents as well as clean-up workers and volunteers; and severe economic impacts on local tourism and seafood industries. From the reports, it is evident that the spill was the result of both technology and human failures.

In spite of a strong push toward renewable energy sources, we will probably continue to rely on oil for at least the next 50 years. In the meantime then, we must continue to pursue oil reserves in deeper and deeper waters of the Gulf of Mexico and elsewhere on our ocean planet. To do this successfully, not only will we need to continue to advance technology, we will need qualified individuals to design, build, operate, and maintain those technologies. And should such a tragedy ever occur again, we will need qualified people to develop and implement effective technological solutions and response practices that mitigate and minimize its impact.

COSEE's "OIL SPILL IN THE GULF" EDUCATIONAL RESOURCES

Before embarking on your mission, take some time to educate yourself on the offshore oil and gas industry and Deepwater Horizon oil spill. One excellent resource is the Center for Ocean Science Education Excellence Networked Ocean World (COSEE NOW) blog located at

http://coseenow.net/blog/oil-spill-resources/. The "Trouble in the Gulf" PowerPoint presentation is particularly helpful in explaining what led to the spill and how it was eventually contained.

THINK OF YOURSELVES AS ENTREPRENEURS

From deepwater oil drilling to space exploration, individuals who possess "entrepreneurial skills" are in high demand and stand out in the crowd of potential job candidates. What are entrepreneurial skills? They include the ability to understand the breadth of business operations (from finances to research and development), work as an integral part of a team, and apply technical skills in new and innovative ways.

To help you to better understand and develop these skills, the MATE ROV competition is asking you to think of yourself as an entrepreneur. Your first task is to create a company or organization that specializes in solutions to real-world marine technology problems. Use the following questions as a guide.

- What is your company name?
- Who are its leaders – the CEO (chief executive officer – the leader) and CFO (chief financial officer who oversees the budget and spending)?
- Who manages Government and Regulatory Affairs (i.e. who's in charge of reviewing the competition rules and making sure that they are understood and followed by everyone)?
- Who is responsible for research and development (R&D)?
- Who is responsible for system(s) engineering? Design integration? Testing? Operations?
- What other positions might you need? (Depending on your personnel resources, more than one person may fill more than one role.)
- What products and services do you provide?
- Who are your potential clients?

In this case, the MATE Center is your "client" and has defined the rules, as well as the products and services you need to provide to solve the "problem."

The MATE competition is challenging your company to develop specialized tools (including ROVs) for oil spill mitigation and to demonstrate the utility of these tools in an oil spill response training mission.

The specifics of your product design and rules of operation are included within the **Design & Building Specifications and Competition Rules** document. The specifics of the training mission – that is, the tasks that you must accomplish – are described below.

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TRAINING MISSION OVERVIEW

The scope of the Deepwater Horizon spill was beyond anything that we could have imagined. It was the realization of a worst case scenario, and one that our existing technologies and practices were, unfortunately, not able to address in timely manner. We learned the hard way that it is important to be

prepared for the worst, even while hoping for the best.

However, we *are* making progress. For example, a Massachusetts-based company has developed a robotic control system that is now being tested on an automated drilling and exploration platform[1]. The new rig is designed to operate on the ocean floor, enabling unmanned, and therefore safer, exploration of deepwater regions. And ROV training and operations manuals are being modified to incorporate "worst-case" scenarios that anticipate the challenges of deepwater technology and find solutions that minimize the impact in the event of a problem.

And this is exactly what the MATE ROV competition is asking your company to do.

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

Task #1: Remove the damaged riser pipe (70 points)
Task #2: Cap the oil well (120 points)
Task #3: Collect water samples and measure depth (80 points)
Task #4: Collect biological samples (30 points)

You must complete mission task #1 before attempting mission task #2. Tasks 3 and 4 can be attempted at any time during the mission performance period. See the mission task descriptions below for more details.

Your company will get up to **TWO** attempts to complete this single training mission (contact your regional coordinator to confirm the number of attempts that you will receive). The higher of the two scores will be added to your engineering and communication score (see the **Engineering & Communication** document) to determine the total, overall score for the competition.

TIME
You will have 5 minutes to set up your system, 15 minutes to complete the mission tasks, and 5 minutes to demobilize your equipment and exit the control shack. During the 5-minute set-up, you may place your vehicle in the water for testing and/or trimming purposes, provided that a member of your company has a hand on the vehicle at all times and uses extreme caution. The 15-minute mission period will begin after the full 5 minutes of set up time expires, regardless of whether you are ready to start the mission.

At any time during the mission, you may pilot your ROVs to the surface and remove the vehicle from the water for such things as buoyancy adjustments, payload changes, and trouble shooting, but the clock

[1] www.masshightech.com/stories/2009/05/25/daily29-Energid-digs-up-deal-with-Seabed-Rig.html and www.prnewswire.com/news-releases/seabed-rig-and-energid-technologies-developing-a-safer-oil-drilling-system-93678419.html

will only be stopped by a judge who determines it's necessary for reasons beyond your 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 member of your company at the launch station has physically touched the vehicle. Your ROV is not required to return to the surface between mission tasks.

Your 5-minute demobilization will begin as soon as the 15-minute mission time ends, regardless of where your ROV is located (i.e., still at depth, on the surface, etc.).

TIME BONUS

Your company will receive a time bonus if you:

1) successfully complete all four mission tasks;
2) return your ROV to the surface under its own power so that it touches the side of the pool; and
3) physically touch your vehicle before the mission time ends.

Your company 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 is physically touched by a member of your company. Time bonus points will be awarded accordingly.

GOOD LUCK!

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Task #1: Remove the damaged riser pipe

One attempt to stop the flow of oil at the Deepwater Horizon wellhead involved placing a device called a Lower Marine Riser Package (LMRP) cap onto it. Before the LMRP cap could be installed, a portion of the damaged riser pipe had to be cut and removed. The procedure is described here:

www.youtube.com/watch?v=fosYeR9__4A&feature=related
www.youtube.com/watch?v=e_qfLypiENE&playnext=1&list=PLD0FA525A32A632E8&index=11
www.youtube.com/watch?v=a5pc7um4Io8&list=PLD0FA525A32A632E8&index=13&playnext=2

Your company's task is to make a cut close to the wellhead, then remove the damaged riser pipe.

This mission task involves:

- **Transporting and attaching a line to a U-bolt on the damaged riser pipe.**
- **Simulating cutting the riser pipe by removing a Velcro strip.**
- **Lifting and moving the cut-off portion of the pipe from the work area.**

Scoring – up to 70 points:

- Transporting and attaching a line to a U-bolt on the damaged riser pipe – 30 points
- Simulating cutting the riser pipe by removing a Velcro strip – 20 points
- Lifting and moving the cut-off portion of the pipe from the work area – 20 points

Mission notes

Your company must complete task #1 in order. You must first connect to the U-bolt on the riser pipe before you simulate cutting the pipe. After completing both of these tasks, you must lift the pipe and move it from the work area. "Moving it from the work area" is defined as moving the pipe so that it does not physically touch any part of the wellhead or cement base. You can touch the wellhead or cement base while moving the pipe, but, if you choose to leave the pipe on the bottom, once you release it, it should not be touching any part of the wellhead or cement base.

Oil, simulated by water, will be flowing through the wellhead and riser pipe as you attempt to complete this task. Details on the flow rate are included within the mission prop specifications under task #2.

The wellhead rises vertically from a cement base that simulates the ocean floor. The riser pipe is simulated by PVC. It attaches to the top of the wellhead, extending vertically approximately 40cm before it turns horizontally. The riser pipe extends horizontally for 24cm, before turning again and descending at a 45^{o} angle back to the seafloor. Once it reaches the seafloor, the riser pipe turns again and extends horizontally along the seafloor for more than 1 meter.

The "working" portion of the wellhead is constructed from 1 ½-inch PVC pipe and ¾-inch PVC pipe. The EXPLORER riser pipe is constructed of 1 ½-inch PVC pipe. The RANGER riser pipe is constructed of ¾-inch PVC pipe. A large U-bolt is secured on the top of the upper horizontal section of the riser pipe.

Your company must attach a line to the U-bolt on the riser pipe. You must provide this line, and design and construct a mechanism to attach it to the U-bolt. During the competition, a member of your company will hold onto the other end of this line as your ROV transports it to the bottom. Once your ROV has attached the line to the U-bolt, AND your ROV has simulated cutting the riser pipe by removing the Velcro strip, then one or more members of your company can pull on the line by hand to move the cut-off portion of the riser pipe from the work area.

You should determine the pool depth at their regional competition and at the international competition to determine the length of line your company will need. There are no restrictions on the design of this mechanism or the type of line to use, provided that you adhere to the general design and building specifications for your ROV and the rules on safety.

Cutting the pipe is simulated by removing a length of Velcro from the pipe. For the RANGER class, both the wellhead and the riser pipe will have a 0.3cm wide, 10.5cm long piece of Velcro hooks attached around the PVC on each side of the "cut." For the EXPLORER class, only the riser pipe will have a length

of Velcro hooks. A 1cm-wide, 21.5cm long piece of Velcro hooks will attach around the bottom of the PVC just above the "cut."

For both RANGER and EXPLORER, a 10cm long, 5cm wide piece of Velcro loops will cover the Velcro hooks. A 1cm-wide ring of 1 ½-inch PVC coupling will be attached to the Velcro loops, centered in the middle of the strip. The strip does not completely surround the PVC pipe (see the mission prop photos). You can use this ring to grab onto the Velcro strip and remove it. The Velcro strip will be attached to the riser pipe by a 0.5meter length of 1/8-inch nylon and polypropylene rope. Once the Velcro strip is removed from the pipe, it may be released by your vehicle.

Once the line is connected to the pipe and the riser pipe is "cut," a member of your company can pull on the line to move the riser pipe away from the work area by hand. Your vehicle is NOT required to lift the fallen riser pipe from the wellhead, but it can if you wish. Once the riser pipe is removed from the wellhead, you may pull it to the surface or deposit it on the bottom away from the work area. If the riser pipe is discarded on the bottom, it must not be touching any part of the remaining wellhead or the cement base to the wellhead.

EXPLORER and RANGER mission prop specifications

The mission props specifications for task #1 are detailed in task #2 below.

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Task #2: Cap the oil well

Companies competing in the EXPLORER class must successfully complete mission task #1 before attempting and receiving full points for mission task #2. The cut-off riser pipe must be moved away from the wellhead, exposing it, before you can attempt to cap it. This is also true for companies competing in the RANGER class; however, those companies can still receive partial points for mission task #2. See the RANGER class task description below for details.

EXPLORER and RANGER tasks differ. The EXPLORER task is presented first.

EXPLORER

With the damaged riser pipe cut and moved from the wellhead, the Lower Marine Riser Package (LMRP) cap could be installed. The cap is shaped like an upside-down funnel and is designed so that its sheer weight holds it in place. Pipes that extend from the top of the cap to the surface 1) transport methanol[2] to the cap to prevent methane hydrates from forming and clogging the cap and 2) transport oil to the surface where it is collected by a drillship. The procedure is described here:

www.youtube.com/watch?v=SVgM1BwFK6o
www.youtube.com/watch?v=BRR-9pjKb7o (Bill Nye the Science Guy explains just how difficult this is!)

[2] Methanol lowers the temperature and increases the pressure at which hydrates will form. Those in snowy climates can relate it to putting salt on ice in the wintertime!

Your company's task is to design a cap to cover the wellhead that, once you install it onto the wellhead, will stop the flow of oil.

Note: In this scenario, your cap DOES NOT have to include pipes that extend to the surface. Your success will NOT be measured by how much oil is funneled to the surface, but rather by HOW LONG your cap STOPS the flow.

This mission task involves:

EXPLORER class:

- **Pre-competition, designing a cap to cover the wellhead and stop the flow of oil.**
- **At the competition,**
  - **Transporting that cap to the oil well and installing it onto the wellhead.**
  - **Stopping the flow of oil for at least some period of time.**

EXPLORER class scoring – up to 120 points:

- Designing a cap to cover the wellhead and stop the flow of oil – 10 points
- Transporting the cap to the oil well and installing it onto the wellhead – 30 points
- Stopping the oil from flowing – up to 80 points
  - Oil flow is stopped for the remainder of the mission – 80 points
  - Oil flow remains stopped once the ROV releases the cap, but starts flowing again before the end of the mission performance period – 40 points
  - Oil flow is stopped while the ROV is in contact with the cap, but starts again once the ROV releases the cap – 20 points

EXPLORER class mission notes

Your company must design and build a cap that fits onto the wellhead and stops the flow of oil (which is being simulated by water) emerging from the top of the wellhead. There are no restrictions on the design of this cap, provided that you adhere to the general design and building specifications for your ROV and rules on safety. Note that these specifications, and this event's rules, specifically DISALLOW the use of chemicals or other agents that might damage the pool or its filtration system or alter the water in any way, shape, or form. Such chemicals include adhesives, grease, oils, gels, resins, and other coatings. The cap must be able to be removed from the wellhead at the end of your mission performance period.

The EXPLORER wellhead is constructed from 1 ½-inch PVC pipe and 1 ½-inch PVC couplings set into a cement base. At the top of the wellhead, the water emerges from a hole approximately 4.1cm in diameter.

Your company will receive 30 points for installing the cap on the wellhead provided that the cap remains in place once your ROV releases it. Once you install and release the cap, you will need to demonstrate

to the mission judges that the cap is still in place by showing it to the judges on your ROV's video monitor. "Still in place" means that the cap sits on the wellhead and is concentric with the wellhead. It is not necessary to stop the flow of oil (water) from the wellhead to receive points for installing the cap, but it is necessary to stop the flow of oil to receive full mission points. Caps dangling or hanging on the wellhead will not be considered "installed."

EXPLORER class demobilization instructions:
Your company must provide a set of clear, step-by-step instructions for the competition support divers on how to remove your cap from the wellhead. These instructions must be in a minimum of 18 point Ariel Bold Font. Diagrams may be included if they increase the clarity. This instruction sheet must be laminated so that if necessary, the divers can take it into the water. You should hand the instructions to the mission judge during the 5-minute set-up time. The instructions will be returned to you when your cap is returned.

Companies not providing a demobilization instruction sheet will receive a 10 point deduction.

EXPLORER class mission prop specifications – tasks #1 and 2

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

Oil pressure and flow rate:
Oil is simulated by water. At the surface, the water pressure outlet will be regulated between 1.73 to 2.42 bars. The regulator output will connect to the wellhead with a 1.6cm (internal diameter) hose. The "oil" flow rate is estimated to be between 132 – 192 barrels per day (5.5 – 8.0 barrels per hour).

Cement base:
The seafloor is simulated by a cement base constructed from a 40cm-diameter by 10cm-tall oil pan filled with cement. A 2-inch PVC coupling simulates the base of the wellhead emerging from the seafloor. To construct the base:

1. Fill the oil pan with wet cement.
2. Insert a 2-inch PVC coupling into the center of the oil pan, half submerged (3.6cm) in the cement.

Check auto supply stores or hardware stores for oil pans.

Design note: The cement base with the 2-inch coupling is the cement base used in the 2007, 2008, and 2010 competition missions.

Design note: Attaching the 2-inch coupling to a 2-inch PVC tee will help to stabilize the coupling in wet cement. The 2-inch PVC tee is not necessary, but will facilitate construction.

Wellhead:
The EXPLORER wellhead is constructed from 1 ½-inch PVC pipe. To construct the EXPLORER wellhead:

1. Push a 2-inch to 1 ½-inch PVC reducer bushing (Home Depot part #**232-769**, ACE Hardware part #**46188**) into the 2-inch coupling in the cement base.

2. Insert a 5cm length of 1 ½-inch PVC pipe into the top of the bushing. Attach a 1 ½-inch x 1 ½-inch x ½-inch tee, slip/slip/FIPT (Home Depot Part #**796-726**) onto this pipe.

3. Screw a ¾-inch FHT x ½-inch MNPT fitting (Home Depot part #**685-903** – Orbit brand name) into the side opening of this tee. Attach a hose to this fitting to provide water pressure for the wellhead.

4. Insert a 10cm length of 1 ½-inch PVC pipe into the top of this tee. Attach a 1 ½-inch PVC coupling to the end of this pipe. Insert a 7cm length of 1 ½-inch pipe into the coupling. Attach another 1 ½-inch PVC coupling to the top of this pipe.

5. Insert a 1 ½-inch to 1-inch reducer bushing (Home Depot part #**294-284**) into the top of the 1 ½-inch PVC coupling.

Design note: The five pieces of PVC at the top of the wellhead (two 1 ½-inch PVC couplings, two lengths of 1 ½-inch PVC, and one reducer bushing) will be glued together using PVC glue. This will provide companies competing in the EXPLORER class with a clean, unmarred surface to work with. Glue the 1 ½-inch to 1-inch reducer bushing into the topmost 1 ½-inch coupling. Glue the 7cm length of PVC into the topmost coupling, and glue a coupling onto the other end of the 7cm length of pipe. Be sure that the gap between these two couplings is exactly 1cm. Glue the 10cm length of 1 ½-inch PVC pipe into the bottom of the second PVC coupling. All other portions of the wellhead must be screwed together to resist the water pressure inside the pipe.

Design note: The 1 ½-inch x 1 ½-inch x ½-inch tee, slip/slip/FIPT (Home Depot Part #**796-726**) is a 1 ½-inch tee with the side opening a 1/2-inch female adapter fitting. The ¾-inch FHT x ½-inch MNPT (Home Depot part #**685-903** – Orbit brand name) screws into the female adapter opening and allows a hose to be attached to the fitting.

Riser pipe:

To construct the riser pipe:

1. Insert a 24cm length of 1 ½-inch PVC pipe into one end of a coupling. Attach a 1 ½-inch 90^{o} elbow to the other end of this length of pipe.

2. Take a 13cm length of 1 ½-inch PVC pipe and drill a pair of 7/16-inch holes. These holes must be spaced approximately 7cm apart and be parallel along the pipe. The distance between these two holes should correspond exactly to the length between the two ends of a 2.5-inch U-bolt. The EXPLORER class U-bolt is 8.1cm wide (ACE Hardware part# **5230214**, 3/8-inch x 2 ½-inch x 3 5/8-inch U-bolt). The U-bolt will rise 8cm above the fallen riser pipe. Use lock nuts to secure the U-bolt in place.

3. Take the pipe with the U-bolt and insert one end into the 1 ½-inch 90^{o} elbow. Rotate the pipe so that the U-bolt stands straight up over the pipe. Attach a 1 ½-inch 45^{o} PVC elbow to the other end of this pipe.

4. Insert a 110cm length of 1 ½-inch PVC pipe into this 45° elbow and rotate it so the far end of this pipe aims towards the ground/pool bottom. Attach a 45° elbow to the end of this pipe.

5. Insert a 100cm length of 1 ½-inch pipe into this elbow so that the pipe lays flat along the bottom.

A 2-inch PVC coupling holds the riser pipe onto the wellhead. To add this coupling to the riser pipe:

1. Insert the 2-inch PVC coupling 1cm over the 1 ½-inch PVC coupling at the bottom end of the riser pipe. Use small ¾-inch self tapping screws to hold the 2-inch coupling in place. This 2-inch coupling will fit over the PVC coupling and 1 ½-inch to ¾-inch reducer bushing that comprises the top end of the wellhead, holding the riser pipe in place.

2. Cut a 21.5 x 1cm length of Velcro hooks. Attach this Velcro around the bottom end of the riser pipe, 2cm above the bottom edge of the 2-inch PVC coupling. Make sure the Velcro is placed on the riser pipe above the point where the pipes connect and not on the wellhead itself.

Velcro strip:
To construct the Velcro strip that attaches to the riser pipe at the cut area:

1. Cut a 21cm x 5cm length of Velcro loops. Cut a 1cm deep notch out of the Velcro on both sides between the 10cm and 11cm mark.

2. Cut a 1cm length from a 1 ½-inch PVC coupling. Slide this thin ring around the Velcro strip until it rests in the two cut notches.

3. Cut a 1 meter length of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**140-287**, ACE Hardware part #**75851**). Tie one end of this rope to the thin PVC ring.

4. Remove the back of the Velcro to expose the sticky surface. Fold the Velcro over on itself, connecting the two sticky surfaces, securing the ring and the knot in the rope at one end of the Velcro strip. Attach the strip of Velcro loops, now 10cm in length, to the 21.5cm length of Velcro hooks on the riser pipe just above point where the wellhead and the pipe connect.

5. Drill a ¼-inch hole in the riser pipe, 8cm above the 1 ½-inch PVC coupling. Insert the other end of the 1 meter rope into this hole. Tie an overhand knot in this rope to secure it inside the riser pipe.

It will take less than 2 Newtons of force to remove the Velcro strip.

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RANGER

Another attempt to stop the flow of oil from the Deepwater Horizon wellhead involved a procedure known as a "top kill." During a successful top kill, heavy drilling mud is pumped from a surface vessel into the wellhead and drill pipe, slowing the flow of oil to a stop. Once the flow has stopped, concrete is pumped into the wellhead, effectively sealing the well. The procedure is described here:

www.youtube.com/watch?v=v4YG7J-Ws6k&feature=related
www.youtube.com/watch?v=n7tles0IoL4&feature=related
www.youtube.com/watch?v=PLhOb5yuiEk&feature=related
www.theoildrum.com/node/6505

Your company's task is to connect the hoses that carry the heavy drilling mud to the wellhead, turn a valve to start the mud flowing, and, once the flow of oil has stopped, place a cap on the wellhead to seal the well.

Note: In this scenario, you will not actually start mud flowing but rather turn a valve that will stop the flow of oil coming from the wellhead, allowing you to then cap it. So, the remainder of this task describes stopping the flow of oil, not starting the flow of mud.

This mission task involves:

RANGER class:

- **Removing the hose line from the top kill manifold that rests on the seafloor.**
- **Inserting the hose line into the port on the wellhead.**
- **Turning the valve wheel to stop the flow of oil.**
- **Installing the cap onto the wellhead.**

RANGER class scoring – up to 120 points:

- Removing the hose line from the top kill manifold – 20 points
- Inserting the hose line into the port on the wellhead – 20 points
- Turning the valve wheel clockwise from completely open to completely closed (approximately 1080°), stopping the flow of water coming from the wellhead – 60 points
- Installing the cap onto the wellhead – 20 points

Task 2 must be done in order.

RANGER class mission notes

If your company is unable to cut and remove the riser pipe in task #1, you will be unable to install the cap on the wellhead (the last part of this task). However, you can still proceed with (and receive points for) removing the hose line from the top kill manifold, inserting the hose line connector into the connection port, and turning the valve. The RANGER class wellhead is constructed from 1 ½-inch PVC pipe and ¾-inch PVC pipe set into a cement base. The port is constructed from 2-inch PVC. The diameter of the port opening is approximately 5cm and it is set at a 45° angle.

Your ROV must turn the valve wheel approximately three times around (~1080°) to close the valve. The valve wheel is constructed from ½-inch PVC pipe in the shape of an octagon. One of the PVC tees of the octagon is painted bright red to help you and the judges determine when one full turn (360°) is completed. The wheel is attached to a ¾-inch gate valve.

The top kill manifold is constructed from 1 ½-inch PVC surrounded by a ½-inch PVC framework. The holder for the hose line connector sits at a 45° angle in the top kill manifold. The hose is simulated by a 5m, 1/8-inch braided nylon and polypropylene rope attached from the top of the hose line connector to the center of the top kill manifold.

The hose line connector is constructed from ½-inch PVC.

Unlike the companies competing in the EXPLORER class, MATE will provide your company with the cap for the wellhead. The cap is constructed to easily fit over the ¾-inch coupling of the RANGER wellhead. The cap has an 8.5cm opening (3-inch PVC joint) that tapers to 3.8cm (1 ½-inch PVC pipe). The wellhead cap is topped off with an end cap. You can only install the cap on the wellhead when you have turned the valve wheel to completely stop the flow of oil.

RANGER mission prop specifications – tasks #1 and 2

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

Oil flow rate:

Oil is simulated by water. The flow rate of oil (water) could be as high as 120 barrels per day (5 barrels per hour) and as low as 34 barrels/day (1.4 barrels per hour). This flow may be created by using a hose from a poolside faucet or by connecting a bilge pump to the wellhead and supplying it at depth from the pool itself.

Cement base:

The seafloor is simulated by a cement base constructed from a 40cm-diameter by 10cm-tall oil pan filled with cement. A 2-inch PVC coupling simulates the base of the wellhead emerging from the seafloor. To construct the base:

1. Fill the oil pan with wet cement.
2. Insert a 2-inch PVC coupling into the center of the oil pan, half submerged (3.6cm) in the cement.

Check auto supply stores or hardware stores for oil pans.

Design note: The cement base with the 2-inch coupling is the cement base used in the 2007, 2008 and 2010 competition missions.

Design note: Attaching the 2-inch coupling to a 2-inch PVC tee will help to stabilize the coupling in wet cement. The 2-inch PVC tee is not necessary, but will facilitate construction.

Wellhead and connection port:

The RANGER wellhead is constructed from 1 ½-inch PVC pipe and ¾-inch PVC pipe. To construct the RANGER wellhead:

1. Push a 2-inch to 1 ½-inch PVC reducer bushing (Home Depot part #**232-769**, ACE Hardware part #**46188**) into the 2-inch coupling in the cement base.

2. Insert a 5cm length of 1 ½-inch PVC pipe into the top of the bushing. Attach a 1 ½-inch x 1 ½-inch x ½-inch tee, slip/slip/FIPT (Home Depot Part #**796-726**) onto this pipe.

3. Screw a ¾-inch FHT x ½-inch MNPT fitting (Home Depot part #**685-903** – Orbit brand name) into the side opening of this tee. Attach a hose to this fitting to provide water pressure for the wellhead.

4. Insert a 5cm length of 1 ½-inch PVC pipe into the top of this tee. Attach a 1 ½-inch PVC coupling to the end of this pipe. Insert a 1 ½-inch to ¾-inch reducer bushing (Home Depot part #**896-981**, Ace Hardware part #**44305**) into the top of the 1 ½-inch PVC coupling.

Design note: The 1 ½-inch x 1 ½-inch x ½-inch tee, slip/slip/FIPT (Home Depot Part #**796-726**) is a 1 ½-inch tee with the side opening a 1/2-inch female adapter fitting. The ¾-inch FHT x ½-inch MNPT (Home Depot part #**685-903** – Orbit brand name) screws into the is female adapter opening and allows a hose to be attached to the fitting.

5. Place a 2-inch PVC tee over the top of the wellhead pipe. The 2-inch PVC tee should just fit over the 1 ½-inch couplings and rest on the side opening of the 1 ½-inch x 1 ½-inch x ½-inch tee.

6. Insert a 5.5cm length of 2-inch PVC pipe into the side opening of the 2-inch tee. Attach a 2-inch 45^{o} elbow to the end of this pipe, with the end of the elbow angled up. Insert a 16cm length of 2-inch PVC pipe into the other side of the 45^{o} elbow.

This opening will serve as the port for the hose line.

7. Insert a 6cm length of ¾-inch schedule 40 PVC pipe into the 1 ½-inch to ¾-inch reduce bushing at the top of the wellhead.

8. Attach a ¾-inch male adapter to the top end of this pipe. Screw a ¾-inch threaded gate valve (Home Depot part# **868-020**) onto the male adapter. Screw another ¾-inch male adapter into the top of the gate valve.

9. Insert a 3.8cm length of ¾-inch schedule 40 PVC pipe into the male adapter. Attach a ¾-inch PVC coupling to the length of pipe. Insert a 3.8cm length of ¾-inch class 200 PVC pipe. Attach a ¾-inch PVC coupling to the length of pipe.

Design note: Schedule 40 PVC pipe is the standard, thicker walled PVC. Class 200 PVC pipe is thinner walled PVC rated for less pressure. ¾-inch class 200 PVC should be available at most hardware stores. It is important to use class 200 PVC pipe when it is called for in the specifications.

10. Cut a 10.5cm x 0.3cm length of Velcro hooks (0.3cm is 2 rows of hooks). Attach the 10.5cm length of Velcro hooks around the PVC pipe of the wellhead, 1cm below the top.

Hose line:

The hose line will connect the top fill manifold to the wellhead. To construct the hose line:

1. Cut a length of 15cm PVC pipe and two 5.5cm lengths of PVC pipe.

2. Insert one end of the 15cm pipe into the center opening of a ½-inch PVC tee. Attach a ½-inch PVC end cap to the other end of this pipe. Insert a 5.5cm length of PVC pipe into each side opening of the PVC tee.

3. Drill a ¼-inch hole into the top, center of the PVC tee. Insert a 5 meter length of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**140-287**, ACE Hardware part #**75851**) into this hole. Tie an overhand knot to secure the rope inside the PVC tee.

The hose line will be located on the bottom of the pool, resting in the top kill manifold. It will sit at an angle of 45°.

The hose line will weigh less than 0.5 Newtons in water. Flotation or weights can be inserted into the PVC pipe to achieve the desired weight and to provide stability.

Top kill manifold:

The top kill manifold is constructed out of ½-inch PVC. To construct the top kill manifold:

1. Start with four PVC side outs, male adapters inserted.

2. Cut two 18.5cm sections of ½-inch PVC pipe. Take one 18.5cm section of pipe and insert it into the long, male adapter end of the side out. Take another side out and attach the long, male adapter opening to the other end of the 18.5cm PVC pipe. Repeat this process with the other length of 18.5cm pipe and the other two side outs with male adapters.

3. Cut two 10cm lengths of ½-inch PVC pipe. Connect the PVC from above, 18.5cm lengths of PVC with side outs attached, with these two lengths of 10cm PVC to form a rectangle. This will form the base of the top kill manifold. All four openings remaining on the side outs should be facing upwards.

4. Insert a 3cm length of ½-inch PVC pipe into each opening. Attach a ½-inch 90° PVC elbow to each 3cm length of PVC pipe. Align these elbows so the opening faces the long way along the manifold, lining up with the male adapter end of the side out.

5. Insert a 3cm length of ½-inch PVC pipe into each opening on the 90° elbows. Attach the side opening of a PVC tee to each length of pipe.

6. Cut two 10cm lengths of ½-inch PVC pipe. Insert these 10cm lengths of pipe into the middle openings of the PVC tees, connecting them together.

7. Cut two 12cm lengths of ½-inch PVC pipe. Use these 12cm lengths to connect the side openings of the PVC tees, completing the manifold framework.

8. Cut two lengths of 15cm long 1 ½-inch PVC pipe. Connect these two lengths of PVC pipe with a 1 1/2-inch 45° elbow. This 1 ½-inch PVC pipe will hold the RANGER hose line at a 45° angle within a PVC framework.

9. Insert this 1 ½-inch 45° pipe into the center of the ½-inch PVC framework. One open end should stick up at a 45° angle; the other should be horizontal with the framework. Use 2-inch long screws to secure the horizontal section into the PVC framework.

10. Drill a ¼-inch hole in the 1 ½-inch 45° elbow. Insert the other end of the 5 meter length of 1/8-inch braided nylon and polypropylene rope (secured to the hose line) into this hole. Tie an overhand knot to secure the rope inside the 1 ½-inch 45° elbow.

The hose connection will sit in the 45° angled length of 1 ½-inch PVC.

Valve wheel:

The valve wheel is constructed from ½-inch PVC and is shaped like an octagon. The outer portion of the wheel is constructed from a series of PVC tees and 45° elbows. To construct the valve wheel:

1. Cut twelve 3cm lengths of ½-inch PVC pipe.
2. Connect two ½-inch 45° PVC elbows together using a 3cm length of ½-inch pipe. Rotate the 45° elbows so when connected, they make a 90° bend. Insert a 3cm length of ½-inch PVC pipe into each end of the 45° elbows.
3. Connect all the 45° elbows together with ½-inch PVC tees to form an octagon.

   There must be no gaps between PVC tees and PVC elbows. All open ends of the PVC tees must be facing inward.
4. Cut four 7cm lengths of ½-inch PVC pipe. Insert each length of pipe into an opening of a ½-inch PVC cross. Insert the other ends of the 7cm lengths of pipe into the four PVC tee openings in the octagonal wheel.
5. Paint one PVC tee and its corresponding 7cm length of pipe bright red. This will help to identify when one full turn (360°) is completed.

   Two #10-24 x 2-inch bolts are used to connect the PVC cross to the handle of the ¾-inch threaded gate valve (Home Depot Part #**868-020**).
6. Insert two #10-24 x 2-inch bolts up through two of the six inner holes located on the valve handle, making sure that the holes selected are directly across from each other.
7. Drill two holes completely through the ½-inch PVC cross to correspond to the placement of the bolts coming up from the valve handle. The distance between these holes needs to precisely match the distance between the two bolts. Push these bolts through the hole, and tighten the PVC cross onto the valve handle with #10-24 nuts. Use lock nuts to secure the handle in place.

Design note: It may be easier to secure the cross onto the valve handle without the wheel attached to it. Remove the wheel, attach the ½-inch PVC cross to the valve handle then replace the wheel.

8. Just below the wheel is a large brass nut that controls the force needed to turn the valve handle. Loosen this nut so the valve wheel is easy to turn. The valve wheel will take less than 0.5 Newton of force to rotate.

Riser pipe:

The RANGER riser pipe is constructed from ¾-inch class 200 PVC pipe. To construct the RANGER riser pipe:

1. Attach a ¾-inch coupling to a 28cm length of class 200 ¾-inch PVC pipe. Attach a ¾-inch 90° PVC elbow to the other end of this length of pipe.

2. Take a 20cm length of ¾-inch PVC pipe and drill a pair of 7/16-inch holes all the way through the pipe. These holes should be spaced approximately 10cm apart and be parallel along the pipe. The distance between these two holes should correspond exactly to the length between the two ends of a 3.5-inch U-bolt. The RANGER class U-bolt is 10.6cm wide (ACE Hardware part# **5007968**, 3/8-inch x 3 ½-inch x 4 5/8-inch U-bolt). Push the U-bolt all the way through the ¾-inch PVC pipe so the ends are protruding from the bottom end. With this design, the RANGER U-bolt will rise 8.5cm above the fallen riser pipe. Use 3/8-inch lock nuts to secure the U-bolt in place.

3. Take the pipe with the U-bolt and insert one end into the ¾-inch 90° elbow. Rotate the pipe so that the U-bolt stands straight up over the pipe. Attach a ¾-inch 45° PVC elbow to the other end of this pipe.

4. Insert a 122cm length of ¾-inch PVC pipe into this 45° elbow and rotate it so the far end of this pipe aims towards the ground/pool bottom. Attach a 45° elbow to the end of this pipe.

5. Insert a 100cm length of ¾-inch pipe into this elbow so that the pipe lays flat along the bottom.

A length of ½-inch PVC pipe holds the RANGER riser pipe onto the RANGER wellhead.

6. Cut a 12.5cm length of ½-inch PVC pipe. Insert 4cm of this ½-inch pipe into the center of the ¾-inch coupling on the riser pipe side, not the wellhead side. Approximately 8.5cm of pipe should stick down beyond the coupling. Use two or more screws to secure this ½-inch PVC pipe in place.

7. Insert the 8.5cm of ½-inch PVC pipe into the coupling at the top of the wellhead.

This length of ½-inch PVC pipe will hold the riser pipe in place until the simulated cutting takes place and the fallen riser pipe is removed.

8. Cut a 10.5cm x 0.3cm length of Velcro hooks (0.3cm is 2 rows of hooks). Attach the 10.5cm length of Velcro hooks around the ¾-inch PVC coupling at the bottom of the riser pipe, approximately 1cm above the bottom edge. This should match the first strip placed near the top of the PVC pipe of the wellhead.

Velcro strip:

To construct the Velcro strip that attaches to the riser pipe at the cut area:

1. Cut a 21cm x 5cm length of Velcro loops. Cut a 1cm deep notch out of the Velcro on both sides between the 10cm and 11cm mark.

2. Cut a 1cm length from a 1 ½-inch PVC coupling. Slide this thin ring around the Velcro strip until it rests in the two cut notches.

3. Cut a 1 meter length of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**140-287**, ACE Hardware part #**75851**). Tie one end of this rope to the thin PVC ring.

4. Remove the back of the Velcro to expose the sticky surface. Fold the Velcro over on itself, connecting the two sticky surfaces, securing the ring and the knot in the rope at one end of the Velcro strip. Attach the strip of Velcro loops, now 10cm in length, to the 21.5cm length of Velcro hooks on the riser pipe just above point where the wellhead and the pipe connect.

5. Drill a ¼-inch hole in the riser pipe, 8cm above the ¾-inch PVC coupling. Insert the other end of the 1 meter rope into this hole. Tie an overhand knot in this rope to secure it inside the riser pipe.

It will take less than 1 Newton of force to remove the Velcro strip.

Wellhead cap:

The wellhead cap is constructed from a 3-inch to1 ½-inch flexible drain coupling (Home Depot part **#687-979**). To construct the wellhead cap:

1. Remove the larger hose clamp from the end of the drain coupling; it is not needed. Insert an 8cm length of 1 ½-inch PVC pipe into the 1 ½-inch end of the drain coupling.

2. Attach a 1 ½-inch end cap to the end of the pipe.

3. Cut a 30cm long length of 1/8-inch braided nylon and polypropylene rope.

4. Drill two 3/16-inch holes into opposite side walls of the 1 ½-inch end cap, near the top. Insert one end of the 1/8-inch rope into one of the holes. Tie an overhand knot to secure the rope inside. Insert the other end of the rope into the opposite hole, and secure that with an overhand knot as well.

A small bit of foam, 0.5cm x 0.5cm x1cm, taped to the top center of the rope will provide flotation for the rope if the well head cap is dropped.

The wellhead cap will weigh less than 1 Newton when submerged in water.

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Task #3: Collect water samples and measure depth

During the spill, a number of technologies were used to collect information about the plume of oil on and below the water. Satellites and aircraft revealed the extent of the spill at the surface, while ship samples and autonomous underwater vehicles (AUVs), such as gliders, investigated the nature and extent of the oil plumes beneath the surface. Examples of these vehicles and what they discovered can be found here:

www.mbari.org/news/news_releases/2010/auv-gulf/auv-gulf-release.html
www.irobot.com/gi/more_information/gulf_oil_spill_response
http://rucool.marine.rutgers.edu/deepwater/
http://news.sciencemag.org/sciencenow/2010/08/report-paints-new-picture-of-gul.html
http://asascience.com/news/bulletins/clean-gulf-2010.shtml

Your company's task is to collect a water sample from a specific depth to test it for presence or absence of actual oil. You must verify the depth at which your ROV actually collected the sample.

This mission task involves:

- **Interpreting a graph to determine the correct depth at which to sample.**
- **Measuring the depth at the sample site.**
- **Collecting water sample.**
- **Returning the water sample to the surface.**

EXPLORER class scoring – up to 80 points:

- Interpreting a graph to determine the correct depth at which to sample – 10 points
- Measuring the depth at the sample site – up to 20 points
    - Within 0.10 meters – 20 points
    - Within 0.30 meters – 10 points
    - Within 0.50 meter – 5 points
- Collecting a water sample so that it is in possession of your ROV and no longer in the container – 20 points
- Returning the water sample to the surface side of the pool so that a member of your company can retrieve the sample – 10 points
- Returning the following volume of water sample to the surface – up to 20 points
    - >100mL – 20 points
    - 26mL to 99mL – 10 points
    - < 25mL – 0 points

  5 points will be deducted for returning a diluted sample (i.e., a sample that is lighter in color when compared to the standard).

RANGER class scoring – up to 80 points:

- Interpreting a graph to determine the correct depth at which to sample – 10 points
- Measuring the depth at the sample site – up to 20 points
    - Within 0.25 meters – 20 points
    - Within 0.50 meters – 10 points
- Collecting a water sample so that it is in possession of your ROV and no longer in the container – 20 points
- Returning the water sample to the surface side of the pool so that a member of your company can retrieve the sample – 10 points
- Returning the following volume of water sample to the surface – up to 20 points
    - >100mL – 20 points
    - 26mL to 99mL – 10 points
    - < 25mL – 0 points

5 points will be deducted for returning a diluted sample (i.e., a sample that is lighter in color when compared to the standard).

Mission notes

During the 5-minute set-up period, the mission judge will give your CEO a plot that shows Colored Dissolved Organic Matter (CDOM) concentration versus depth and ask your company to collect a water sample at a certain CDOM concentration. You will have to interpret the plot and determine the depth at which to sample. You must report to the mission station judge the depth at which you plan to sample BEFORE you descend to complete this task. The mission judge will inform you if your reported depth is correct or incorrect. If the depth that you report corresponds with the correct CDOM value, you will receive points for interpreting the plot and can proceed to measure depth and collect a water sample from that sample site. You will NOT receive points if you measure depth and/or collect a sample from an incorrect sample site.

If the depth that you report does NOT correspond with the correct CDOM value, you will NOT receive points for interpreting the plot. The mission station judge will inform you of the correct depth. You must then proceed to measure depth and collect a water sample from the correct depth in order to receive points for those portions of the task. You will NOT receive points if you measure depth and/or collect a sample from an incorrect sample site.

The water to collect at the sampling sites will be simulated by super-saline, colored water in a container with a PVC pipe extending from the top of it. You must collect your sample through this ¾-inch PVC pipe. A red stripe on the pipe will mark the location at which to measure the depth of the sample. There will be three sample containers at different depths.

You must report depth data to the mission station judge in metric units. If your depth readout is in non-metric units, or the depth readout determines pressure, you are responsible for converting to a metric measurement of depth and reporting the metric value to the mission station judge. Your depth reading should be visible to the mission station judge on your ROV's video monitor or integrated into your ROV's control system or other device. You must inform the judges when you are preparing to take a depth reading and when you are ready to have your measurement scored. The judge must see the reading taken by your vehicle.

You must retrieve a "pure" water sample from the container. Each mission station will have standard color samples to determine the purity of your sample and a graduated cylinder to determine volume. When you return your water sample to the mission station judge, the judge will pour it into the graduated cylinder to determine volume. Then the judge will compare your sample against the standard. Points will be deducted for returning a diluted sample (i.e., a sample that is lighter in color when compared to the standard).

Companies that are unsure if they sampled the container at the correct depth may elect to move to a different container and try to collect another water sample. If you sample multiple containers, it is your

responsibility to present the sample that you would like scored to the mission judge. Once you return a sample and present it to the mission judge for scoring, you are not permitted to collect another sample.

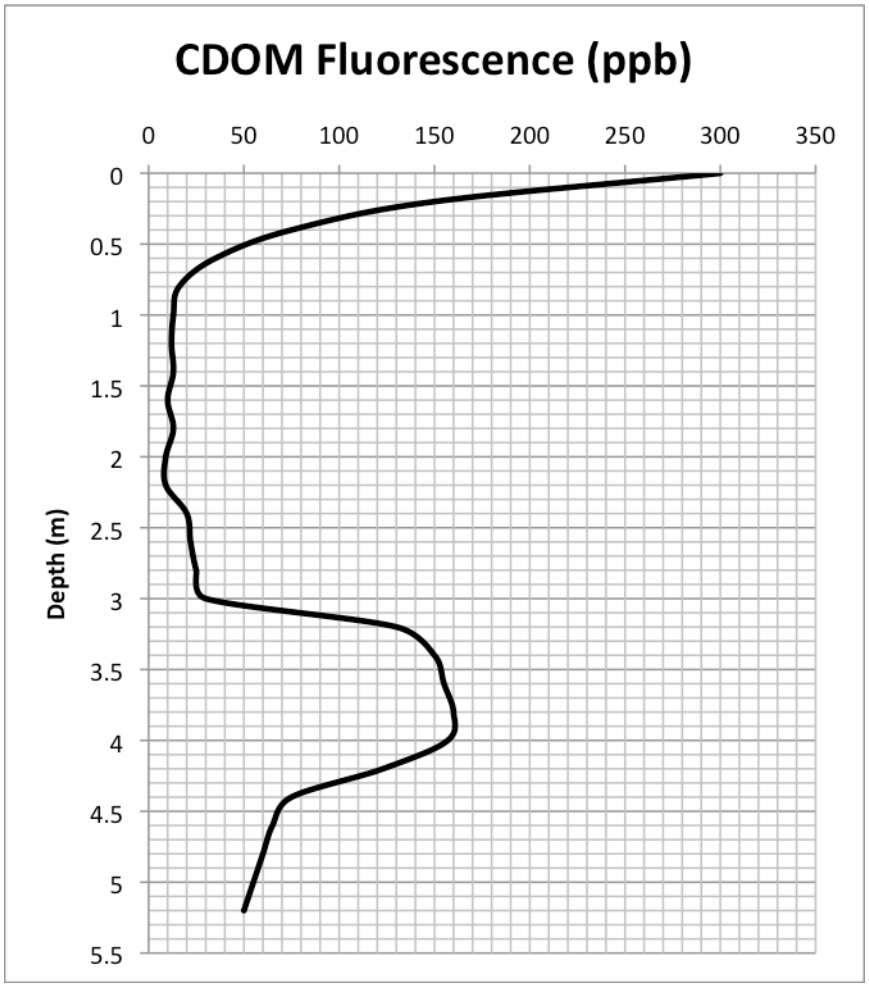
Mission prop specifications

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

Plot:

On the plot the X-axis will define CDOM concentration and the Y-axis will define depth, from 0 at the surface to the depth of the event pool.

An example plot can be seen here.



For example, a mission station judge could ask for a water sample from a depth where the CDOM concentration is 160 ppb. A proper reading of the plot shows that 160 ppb concentration occurs at two places – one very close to the surface (less than 0.2m deep – where a ship might sample) and another

within a larger region of elevated values at a depth of 3.9 meters. You would report to the mission station judge that your target sampling depth is 3.9 meters.

Water sample container:
The water sample container is a 1-liter soft water bottle within a 2-gallon bucket. The soft water bottle design allows the container to collapse under pressure when a sample is removed from it with minimal mixing of the pool water. It is placed within a 2-gallon bucket for protection and to allow for proper weight. The nozzle of the water bottle sticks through, and is secured to, the lid of the 2-gallon bucket. A ¾-inch PVC connector and 7.5cm length of ¾-inch pipe allow access to the water sample.

The soft water bottle is a *Platypus* 1.0 liter bottle. Check REI or local camping stores for availability. It can also be purchased from REI Online (Platypus SoftBottle with closure cap, 34fl ozs, Item **#797977**). Any 2-gallon bucket with lid can be used as the outer container. Check your local hardware store or paint store for 2-gallon buckets.

To construct the water sample container:

1. Use a 1-inch hole saw to drill a hole in the center of the 2-gallon bucket lid. Alternatively, you can use a smaller drill bit and widen the hole with a file or knife blade. The hole should be large enough to allow the mouth of the soft water bottle to fit through it, but not large enough so a ¾-inch PVC connector will fit through it.
2. Push the mouth of the soft water bottle completely through the hole in the bucket lid.
3. Fit a ¾-inch PVC coupling over the mouth of the soft water bottle. This should sandwich the bucket lid between the soft water bottle and the ¾-inch PVC coupling. Use super glue or 5-minute epoxy to secure the water bottle, the bucket lid, and the ¾-inch PVC coupling together.
4. Insert a 7.5cm length of ¾-inch PVC pipe into the coupling. Use red plastic tape to create the depth mark on the ¾-inch PVC pipe.

Drill 10 ¼-inch holes in the 2-gallon bucket to allow flooding. Weights can be added inside the 2-gallon bucket to hold it on the bottom. Make sure the lid is tightly secured on the 2-gallon bucket. Use straps to hold the lid on if necessary.

Water sample:
Add 125ml (1/2 cup) of salt and 4 drops of red food coloring to 1.0 liters of water. Mix well. Note that the food coloring used will be different for different depths.

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Task #4: Collect biological samples

The impact of the oil spill on organisms that live above, on, or below the water is being investigated. The effect of the spill on some of these organisms was obvious; photos of oil-soaked birds and sea turtles filled our TV and computer screens. However, the effect of the spill on organisms below the surface was less obvious. Scientists used (and are still using) submersibles and ROVs to collect samples

of these organisms and bring them back to their laboratories for analysis. Examples of these efforts are described here:
www.fau.edu/hboi/oilspill.php
www.fau.edu/hboi/oilspill_sealifeinventory.php

Your company's task is to collect samples of each of three specific benthic organisms and return the samples to the surface.

This mission task involves:

- **Collecting one sample of each of the following organisms: sea cucumber, glass sponge, and Chaceon crab.**
- **Returning these samples to the surface.**

Scoring – up to 30 points:

- Collecting one sample of each of the following organisms: sea cucumber, glass sponge, and Chaceon crab so that the samples is in control of your ROV and no longer in contact with the seafloor – 5 points for each sample (up to 15 points total)
- Returning one sample of each of the following: sea cucumber, glass sponge, and Chaceon crab to the surface side of the pool under the control of your ROV so that a member of your company can retrieve the samples – 5 points for each sample (up to 15 points total)

Mission notes

There will be three sea cucumbers, three glass sponges, and three Chaceon crabs within the mission area. Your company must collect one of each organism and return the organisms to the surface. You may collect more than one of each type of organism, but will not receive points for doing so.

A company member may reach into the water to retrieve the samples from your ROV 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.

Sea cucumber:
EXPLORER class sea cucumbers are simulated by toy "water snakes," also called "water wigglies." The EXPLORER sea cucumbers are between 10 and 22 cm long and filled with water. Weights need to be inserted into the center of the "water snake" to make it negatively buoyant. The EXPLORER class sea cucumbers weigh less than 1.0 Newtons in water.

They can be punctured during the collection process if you are not careful. Points will not be awarded for any sea cucumber that returns to the surface with leaks in its body.

Design note: Check Target, the Dollar Tree, or Party City (as well as online) for these toys.

RANGER class sea cucumbers are constructed out of ½-inch PVC pipe. To construct the sea cucumber:

1. Cut a 12cm length of ½-inch PVC pipe.
2. Drill eight 3/32-inch holes in the pipe, four at each end. The four holes at each end should be located 90° from each other, spread evenly around the pipe.
3. Insert a ¾-inch screw into each hole, leaving 1cm to 1.5cm of the screw outside the pipe (not screwed in).

Insert foam inside the PVC pipe, between the screws, to provide buoyancy.

The RANGER class sea cucumbers weigh less than 0.5 Newtons in water.

Glass sponge:

The glass sponge is simulated using chenille stems (pipe cleaners) and basic felt. The base of the glass sponge is a ½-inch PVC end cap. To construct a glass sponge:

1. Cut a circle of felt approximately 7.5cm in diameter. Felt commonly comes in 12-inch by 9-inch sheets. These sheets will provide felt for 12 glass sponges.
2. Use a small screwdriver or drill bit to punch two small holes in the center of this circle of felt. The two holes should be between 0.5cm and 1cm apart. Push 3cm of a pipe cleaner up through one of these holes, bend the pipe cleaner back onto itself, and push it back down through the other hole. Twist the ends together to secure the felt circle onto the top of the pipe cleaner.
3. Drill a 3/32-inch hole in the bottom of a ½-inch PVC end cap. Insert 4cm of the pipe cleaner through this hole. Twist this end of the pipe cleaner into an overhand knot so that it is secured in the pipe cleaner.

A glass sponge will weigh less than 0.5 Newtons in water.

Design note: Check local craft stores for basic felt.

Chaceon crab:

The Chaceon crabs are simulated using 1 ½-inch ABS end caps for the bodies and chenille stems (pipe cleaners) for the legs and claws. If ABS end caps are unavailable, 1 ½-inch PVC end caps may be used. To construct a Chaceon crab:

1. Drill ten holes in each 1 ½-inch ABS end cap, five on each side. These holes are attachment points for 8 legs and 2 claws.
2. Twist a 30cm long pipe cleaner in half to shorten and strengthen it. Leave 2.5cm of one end of pipe cleaner untwisted and insert this end through one of the holes in the ABS end cap. Repeat until you have completed eight legs, four per side. Twist the loose ends of the legs together inside the end cap to hold them in place.
3. Twist the middle of two pipe cleaners together. At one end, leave 2.5cm untwisted. At the other end, leave 8cm untwisted.

4. Insert the end with 2.5cm of untwisted pipe cleaners through one of the holes in the ABS end cap. Repeat for the second claw, inserting the pipe cleaner through the other unused hole in the end cap. Twist the loose ends together inside the end cap to hold the claws in place.

5. Fold 4cm of the other untwisted end of the pipe cleaners back upon themselves. Shape these 4cm lengths into claws.

6. Add two small self-tapping #6 - ½-inch, round top screws to the ABS end caps to simulate the crab's eyes.

A Chaceon crab will weigh less than 1 Newton in water.

Design note: The crab design is the exact same as the crab design for the 2008 RANGER contest. Check local craft stores for pipe cleaners.