COMPETITION MISSIONS

Diving into History: *The Role of ROVs in Exploring WWII Shipwrecks*

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)
    - International competition teams ONLY – 5 bonus points for media outreach

THINK OF YOURSELVES AS ENTREPRENEURS

From deepwater oil drilling to shipwreck 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 to media outreach), work as an integral part of a team, and apply technical knowledge and 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? Media outreach?
- 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 recently released a request for proposals. A request for proposals (RFP) is a document that an organization posts to solicit bids from potential companies for a product or service. The MATE Center's RFP focuses on the assessment of a fictional WWII shipwreck. In addition to surveying and mapping the wreck site, the RFP requires companies to develop and carry out a plan to remove hazardous material (fuel oil) that remains on board. In order to effectively respond to the RFP, companies must be prepared to design and develop specialized tools, including ROVs.

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 mission – that is, the tasks that you must accomplish – are described below.

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MISSION OVERVIEW

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

Task #1: Survey the shipwreck site (120 points)
Task #2: Remove fuel oil from the shipwreck (180 points)

Task #1 can be completed in any order. Task #2, removing fuel oil from the shipwreck, must be completed in order to receive full points. Task #2 can be attempted before task #1. See the mission task descriptions below for more details.

Your company will get up to **TWO** attempts to complete this single 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 ROV to the surface and remove the vehicle from the water for such things as buoyancy adjustments, payload changes, and trouble shooting, but the clock will only be stopped by a judge who determines it's necessary for reasons beyond your control. Otherwise, the clock will only stop after both 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 both 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 THE TWO 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!

The MATE Center would like to thank the Professional Marine Explorers Society, the OceanGate Foundation, and Global Diving & Salvage for their technical expertise and assistance with this year's mission scenario and tasks. The Center would also like to thank SUBSALVE USA for its donation of EXPLORER class lift bags. We appreciate the support of these organizations and their personnel!

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REQUEST FOR PROPROSALS (RFP)

Assessment of the *SS Gardner* and removal of hazardous material

1. Agency

The requesting organization is the Marine Advanced Technology Education (MATE) headquartered at Monterey Peninsula College in Monterey, California.

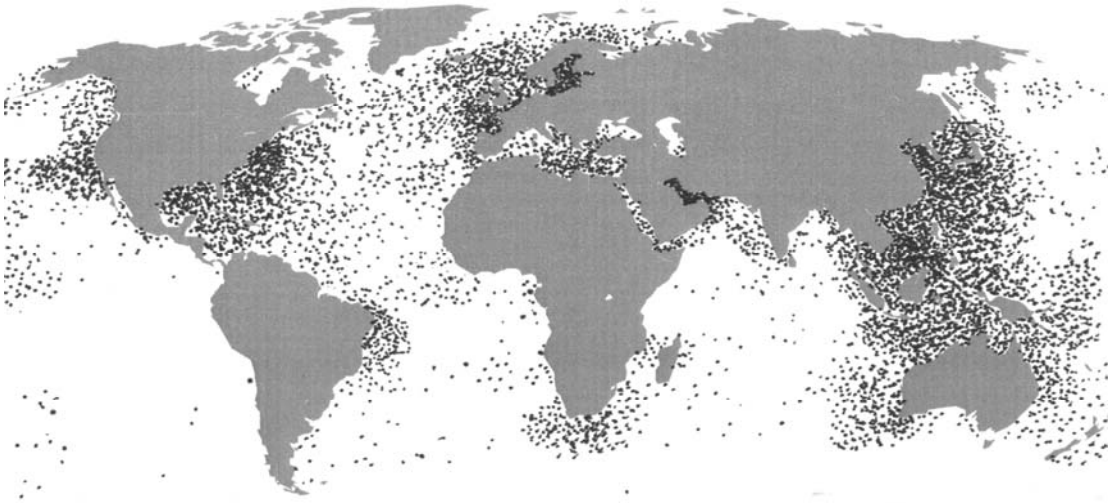
2. Objective

The MATE Center requires a remotely operated vehicle and the necessary associated systems and equipment to perform an assessment of the oil tanker *SS Gardner*. On December 25, 1942, the *SS Gardner*, loaded with a cargo of roughly 5 million gallons of bunker (fuel) oil, was hit and sunk by a German U-Boat as it traveled northward along Florida's east coast. The vessel now sits on the floor of the ocean at 84 fathoms (150 meters) approximately 30 nautical miles off of the east coast of Florida northeast of Cape Canaveral. The requirement is to complete an

assessment of the *SS Gardner* including: its current location and orientation on the seafloor; the debris field that surrounds it; the state of its hull and contents on board; and any other information necessary to develop and carry out a plan to remove any remaining oil. The assessment must be conducted no later than June 23, 2012 due to the arrival of hurricane season.

3. Background

Worldwide more than 8,500 oil-bearing ships lie at the bottom of the world's oceans and even in bodies of water like the Great Lakes. It is estimated that they contain between 0.5 and 4.3 billion gallons of oil and other hazardous cargo. More than 6,300 of them are from the World War II era.



Map of potentially polluting wreck sites

The wrecks are in various conditions. Some, like the battleship *USS Arizona* in Pearl Harbor, are leaking chronically. When the *Arizona* was hit by enemy fire it held approximately 1.5 million gallons of oil on board. Roughly a third of that amount leaked out during the bombing and caught fire; the ship burned for 2½ days. Over the last 70 years, about half of the remaining oil – 500,000 gallons – has been lost from the ship. The amount of oil that leaks each day varies and ranges from about 2 to 20 gallons per day.

The USS Arizona sinking after enemy air attacks on December 7, 1941

Other wrecks, like the *SS Jacob Luckenbach*, are leaking episodically. The *Luckenbach* was an oil tanker that collided with its sister ship and sank on July 14, 1953. This vessel, which was loaded with 457,000 gallons of fuel oil, sank in 180 feet of water approximately 17 miles west-southwest of San Francisco. It has been leaking sporadically over the years. In 2002, oil associated with several "mystery spills" was linked to the *Luckenbac*h. That summer, the U.S. Coast Guard, California Department of Fish and Game, United States Fish and Wildlife Service, National Parks Service, and National Oceanic and Atmospheric Administration (NOAA) removed much of the oil from the vessel and sealed the remaining oil inside.

The remaining wrecks can be viewed as either "having the potential to release oil in large amounts after a disturbance," relatively intact, or in a condition unknown. Unlike the *USS Arizona* whose condition is regularly monitored and the *SS Jacob Luckenbach* with its oil sealed inside, these other shipwrecks that have the potential to leak oil and those whose conditions are unknown are in need of assessment. Taking a proactive rather than a reactive approach to gathering information about these wrecks and mitigating the potential risks will not only save dollars in response costs, but will also reduce the threat of environmental and socioeconomic damages later on.

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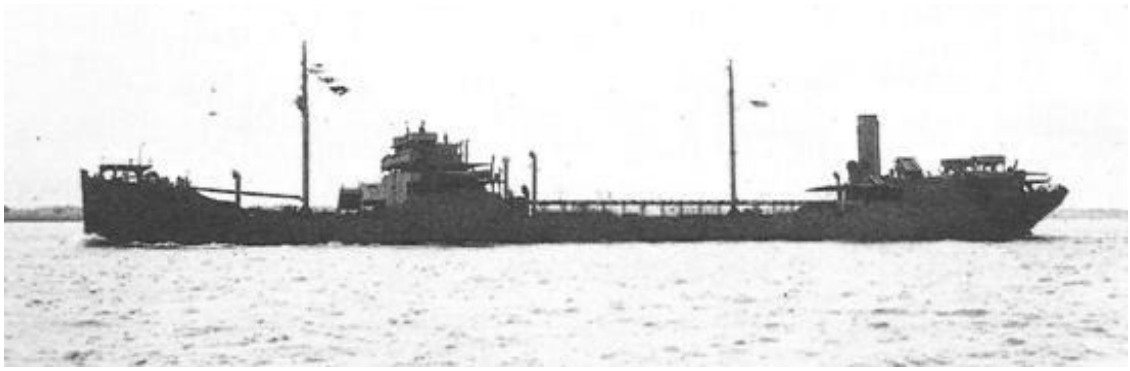
During World War II, American oil tankers made 6,500 voyages to carry 65 million tons of oil and gasoline from the U.S. and the Caribbean to the war zones and to U.S. Allies. They supplied 80% of the fuel used by bombers, tanks, jeeps, and ships during the War. Recognizing the important

role that they played in supporting war efforts, Allied oil tankers were often targeted by German U-Boats.



WWII oil tanker

Ships traveling off the coast of Cape Canaveral, Florida were especially vulnerable. Because ships needed to navigate around the cape, vessels traveling north or south along the coast would invariably pass close to one another. German U-boats took advantage of this bottleneck of ship traffic. Rather than actively hunting targets and expending their precious fuel supply to do so, U-boats patiently waited for the targets to come to them. It didn't take long. While more than 40 ships were sunk by enemy fire off of Florida, nowhere else is there a greater density of war casualties than the area between Port Canaveral and Sebastian Inlet.

The *SS Gardner* was targeted, hit, and subsequently sunk by a U-Boat as it traveled off of Cape Canaveral on Christmas Day 1942, just over one year after the attack on Pearl Harbor. Fortunately, all 43 members of the crew escaped on lifeboats, under minimal enemy fire. They were eventually picked up by an U.S. Navy destroyer and taken safely to shore in Fort Pierce, Florida.

While the survivors reported observing a slick of oil on the surface, there were no reports or records of a significant oil spill or leakage in the surrounding waters or along the coastline immediately following the disaster. To date, no sightings of oil by fisherman, beachgoers, or vessel personnel have been reported in the immediate vicinity of the wreck. Oil north of Cape Canaveral in the Gulf Steam has been reported sporadically, but its origins are unknown.

However, the effects of time and water corrosion have taken their toll on the shipwreck. A recent visual survey identified areas where the hull of the *SS Gardner* has deteriorated. While no signs of oil leakage were detected during the survey, there is growing concern that there could be a major hull breach in the near future, spilling whatever fuel oil that remains on board.

The effects of time and environmental conditions may have taken their toll on the oil and there are questions about its composition. For example, rather than a flowing liquid, it may have turned into a viscous, tar-like substance that's not easily pumped or suctioned from its tank.

As a result, the *SS Gardner* was recently identified by NOAA, the U.S. Coast Guard, and the U.S. Navy as a potential environmental and socioeconomic threat and designated as a "high risk sunken vessel." Funding was provided by these agencies to the MATE Center to develop and issue this RFP.

4. Technical Requirements

See the specific tasks (categorized as EXPLORER and RANGER) described below as well as the **Design & Building Specifications and Competition Rules** document.

5. Warranty and Technical Support

The company shall warrant the ROV and associated systems and equipment for at least the duration of the competition event. Repair or replacement of warranted items shall be at the company's expense, including the cost of shipping the ROV to and from the competition facility.

During regional contests, the company shall provide at least one day of technical support to resolve hardware, software, operational issues for regional events and at least three days for the international event.

6. Delivery

Delivery of the ROV and associated systems and equipment shall be no later than the date of the geographically closest regional contest or by June 21, 2012, which is the start date of the international competition.

7. Evaluation Criteria

- Technical report
- Engineering presentation
- Poster display
- Performance

8. References

- RFP http://searchitchannel.techtarget.com/definition/request-for-proposal
- Montebello Shipwreck http://abclocal.go.com/kgo/story?section=news/assignment_7&id=6785550
- NOAA nautical charts www.charts.noaa.gov/OnLineViewer/11460.shtml

- Dagmar Schmidt Etkin, PhD, Environmental Research Consulting. *Magnitude of the Potentially-Polluting Shipwreck Problem*. North American Marine Environmental Protection Association (NAMEPA) Environmental Intelligence in Shipping Seminar, San Francisco, California, 9 March 2010.
- National Park Service – World War II valor in the Pacific www.nps.gov/valr/faqs.htm
- Personal communication with *USS Arizona* Memorial National Park Service personnel
- California Department of Fish and Game – *SS Jacob Luckenbach* Oil Spill www.dfg.ca.gov/ospr/Science/Luckenbach.aspx
- Overview of the *Wrecks of the World II: Evaluating and Addressing Potential Underwater Threats*. Conference sponsored by the American Salvage Association (ASA) and NAMEPA and held in Washington, DC, USA, June 6 – 7, 2011.
- Tankers built in the U.S. during WWII www.usmm.org/tankers.html#anchor406074
- Shipwrecks of Florida www.electricbluefishing.com/eb_sub_menu/shipwreck_list_of_florida.htm
- Uboat.net www.uboat.net
- Project Shiphunt http://discover.store.sony.com/shiphunt/index.html

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RANGER CLASS MISSIONS

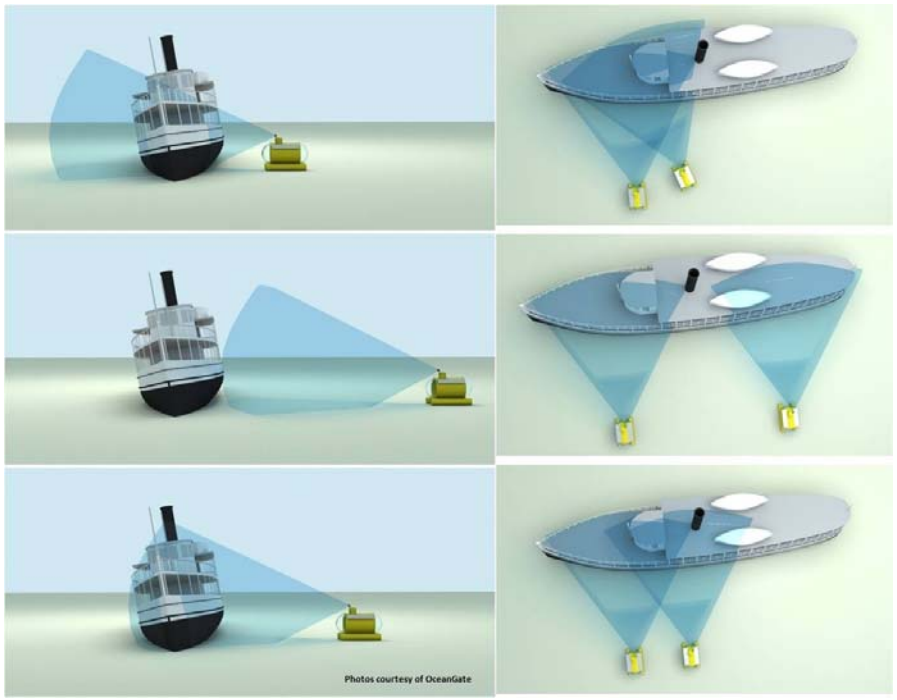
Task #1: Survey the shipwreck site

Your company is required to survey the *SS Gardner* and the wreck site. Surveying the wreck includes measuring the overall length of the ship, and determining the orientation of the ship on the seafloor. Your company must also examine the debris field alongside the wreck. The debris is overgrown with a thick layer of encrusting organisms and, from a visual standpoint, looks exactly like the encrusted rocky outcroppings found in the surrounding area. Your company must determine whether the objects in the debris field are metal, and hence part of the wreck site, or non-metal and therefore naturally occurring rocky outcroppings. Your company is then required to make a map of the wreck site based on your findings.

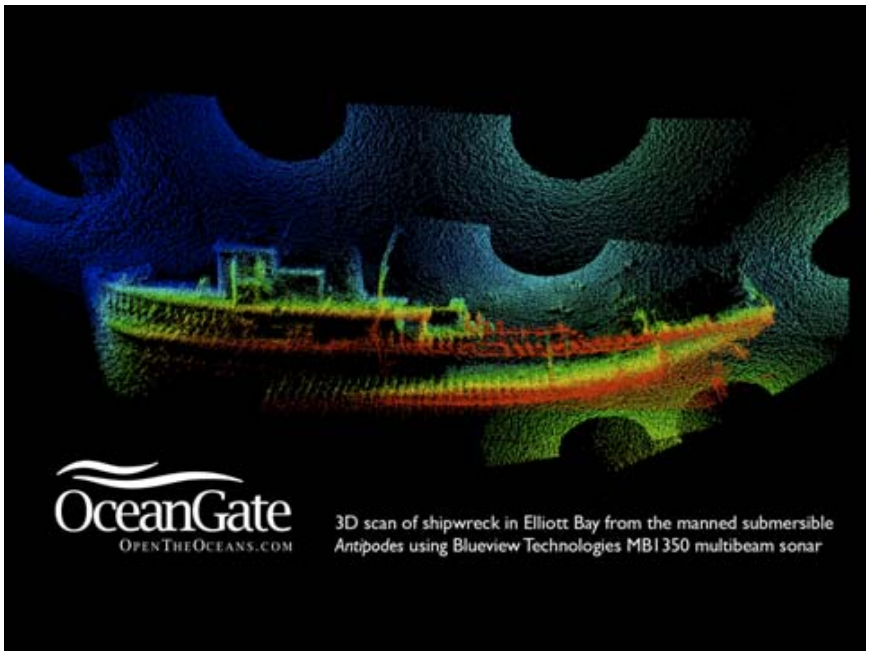
Your company must also scan the shipwreck with sonar. Today's multi-beam sonar is the best technology available for providing high quality, highly detailed images of shipwrecks and other submerged objects. By changing the angle of coverage and frequency of the sound produced by the sonar, the sonar can scan large areas with less detail, or smaller areas with extremely high detail. This,

along with your map, will help to document the wreck site and create a “snapshot” of the shipwreck at this moment in time.

Your company will simulate scanning the *SS Gardner* with a stationary multi-beam sonar. When scanning the shipwreck, distance matters. If your sonar is too far away, the beams will not reach the target. If your sonar is too close, the beams will survey a small area and miss much of the target. Spacing of the surveys is also important. Your sonar scans should be done so that there is minimal overlap of the scans. The figures below illustrate this concept.



Side view looking at the shipwreck *View looking down on shipwreck*



The result

This mission task involves:

- **Measuring the length of the wreck.**
- **Determining the orientation of the ship on the seafloor.**
- **Creating a map of the wreck site.**
- **Determining if debris piles are metal or non-metal.**
- **Scanning the shipwreck with sonar.**

RANGER class scoring – up to 120 points:

- Measuring the overall length of the wreck – up to 20 points
  - ≤ 5 cm off true length – 20 points
  - 5 cm to 30 cm off true length – 10 points
  - > 30 cm off true length – 0 points
- Determining the orientation of the ship on the seafloor – up to 20 points
  - ≤ 10^{o} off true orientation – 20 points
  - > 10^{o} to 20^{o} off true orientation – 10 points
  - > 20^{o} off true orientation – 0 points
- Creating a map of the wreck site that includes the following information – up to 25 points
  - Sketch of the shipwreck – 5 points
  - Length of the shipwreck – 5 points
  - Orientation of the shipwreck – 5 points
  - Location of debris piles – 10 points for placing all 5 debris piles in the correct grid squares

- Determining if debris piles are metal or non-metal – up to 25 points
    - Correctly identifying five objects as metal (M) or rock (R) – 5 points each (25 points total)
- Correctly "scanning" the ship at two target locations – 15 points for each target (30 points total)

Mission notes

Task #1 can be completed in any order. Companies must descend to the wreck site to create the map. Companies may alternate between task #1 and task #2.

The overall length of the shipwreck varies, but will range between 2.25 and 3.75 m. Different mission stations will have shipwrecks with different lengths.

RANGER class companies will determine the length between two designated points – one near the bow of the shipwreck and the other near the stern of the shipwreck. Each of these points will rise 16 cm above the top of the shipwreck. The point at the bow will be painted red; the point at the stern will be painted yellow. Like the shipwreck, these marks will be constructed from ½-inch PVC, with a ½-inch PVC connector at the top. The official length measurement must be taken from the center of the ½-inch PVC point on the bow to the center of the ½-inch PVC point on the stern (see **Constructing the shipwreck** within the **Mission prop specifications** below).

RANGER class companies should determine the orientation of the ship from the stern of the ship towards the bow of the ship. Both the regional competitions and the international competition will have a master compass or a designated north/south line for companies to calibrate their own compass or sensor. The orientation should be taken and reported relative to magnetic north.

A ½-inch PVC grid will be laid out on the pool bottom on one side of the shipwreck. The grid is 2.5 m long and 1.5 m wide and consists of fifteen squares, each approximately 0.5 m squared. The RANGER class mission area will have five (5) debris piles located within the grid.

During the five minute mission setup time, the mission station judge will hand your company a blank grid. Companies must create a map of the wreck site on this blank grid. In order to receive the full points for creating the map, companies will need to sketch the approximate location of the shipwreck and include the following information:

- sketch of the shipwreck
- length of the shipwreck
- orientation of the shipwreck
- location of each of the five debris piles

Companies will not be penalized if the length or orientation of the ship is incorrect on the map, but must include these measurements on the map in order receive points. RANGER class companies will not

receive full points if one (or more) of the five debris piles is not in the correct location. Companies cannot create the map by looking into the pool from the surface. Companies will not receive any points for creating a map if they do not descend to the wreck site.

Companies must determine whether these debris piles are constructed of metal or non-metal components. Any number of the five debris piles may be constructed from metal; debris piles made of metal and those made of non-metal will be visually identical. Companies will only receive points for those debris piles correctly identified.

RANGER class companies may not guess at which debris piles are metal and which are non-metal. Companies must show the mission station judge evidence that the sample is metal or non-metal. For example, companies can show the judges a sensor reading that allows them to determine whether the debris sample is metal or non-metal. This reading could be displayed on the company's video monitor.

All metal used in construction will be ferrous.

Companies should note that many pools have cement bottoms reinforced with metal rebar. Rebar in the cement could interfere with metal detectors deployed on the vehicle. To help differentiate between metal used in pool construction and the metal of the debris samples, the debris samples will be raised up off of the bottom of the pool with a brick. The center of the debris sample will be 10 cm above the bottom of the pool. Companies should take the metal rebar used in pool construction into consideration when designing their metal detector.

Companies will simulate scanning the ship with sonar by visualizing a target area. Each target area will consist of a black ring of 2-inch ABS pipe set inside a 2-inch white PVC end cap and a black mark set 25 cm to each side of the target. To effectively scan the shipwreck, an ROV must align a single camera so that the mission station judge can see on one video display the entire black ring within the end cap as well as both marks on either side of the target. The vehicle must maintain this alignment for 10 seconds. If at any time the mission station judge is unable to see the entire black ring or both colored marks, companies must realign their vehicle and start the scan again.

Targets will sit approximately 45 cm off the pool bottom.

RANGER class companies will scan two target areas. Both targets will be located on one side of the shipwreck.

Design note: Companies should consider the bottom topography of the regional and international competition venues. Do not assume that your ROV will be able to rest on a flat bottom to accomplish the scan.

Mission prop specifications

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

All PVC used in construction is DURA brand PVC. If items are unavailable or built to different specifications in your area, check online at www.duraplastics.com to purchase specific PVC pieces.

Constructing the shipwreck

The framework of the shipwreck is constructed out of ½-inch PVC. However, the exact diameter of the PVC framework is not important. Companies located outside of North America that do not have access to ½-inch PVC may substitute local PVC for ½-inch PVC pipe and connectors.

To construct the RANGER shipwreck, start construction at the stern of the ship.

1. Cut one 80 cm length, one 54 cm length, one 45 cm length, one 32 cm length, and four 38 cm lengths of ½-inch PVC pipe. Connect the 45 cm length of pipe and the 32 cm length of pipe by inserting them into the side openings of a ½-inch PVC tee.
2. Attach the middle opening of a ½-inch PVC tee to each of the ends of the 54 cm length, the 80 cm length, and the combined 45 cm and 32 cm length of pipe (six tees total). The 54 cm length of pipe is the bottom cross brace. The 80 cm length of PVC is the middle cross brace. The combined 45 cm and 32 cm length of pipe is the top cross brace. The four 38 cm lengths of PVC are the vertical braces.

See RANGER construction photo #1.

3. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the bottom cross brace (54 cm length of PVC). Attach a 90^{o} elbow to the other end of each 10 cm length of PVC pipe.
4. Cut four 3 cm lengths of ½-inch PVC pipe. Insert two of these 3 cm lengths of pipe into one side opening of each PVC tee on the middle cross brace (80 cm length of PVC).
5. Attach a side opening of a ½-inch PVC tee to the other end of each 3 cm length of PVC pipe. Insert the other two 3 cm lengths of PVC into the other side opening of the PVC tee. Attach a 90^{o} elbow to the other end of each 3 cm length of PVC pipe.
6. Cut two more 3 cm lengths of ½-inch PVC pipe. Insert these two lengths of 3 cm pipe into one side opening of each PVC tee on the top cross brace (the combined 45 cm and 32 cm length of PVC). Attach a 90o elbow to the other end of each 3 cm length of PVC pipe.

See RANGER construction photo #2.

7. Take two of the vertical braces (38 cm lengths of PVC pipe) and insert one end of a vertical brace into each of the open ends of the 90° elbow on the top cross brace. Insert the other ends of these vertical braces into the middle openings of both PVC tees on the middle cross brace (the 80 cm length of PVC pipe).
8. Take the remaining two vertical braces (38 cm lengths of PVC pipe) and insert them into the open ends of the 90° elbows on the middle cross brace. Insert the other ends of these vertical braces into the 90° elbows on the bottom cross brace (54 cm length of PVC pipe).
9. Adjust the angle of the 90° elbows on the middle cross brace and bottom cross brace so they are symmetrical. At this point, all six openings of the remaining PVC tees should be facing the same direction.

See RANGER construction photo #3.

Next, construct the center cross section of the shipwreck.

1. Cut one 80 cm length, one 54 cm length, one 44 cm length, one 23 cm length, one 10 cm length, and four 38 cm lengths of ½-inch PVC pipe.
2. Attach the side opening of a PVC tee to each end of the 10 cm length of PVC pipe. Attach the 23 cm length of pipe to the side opening of one of the PVC tees. Attach the 44 cm length of pipe to the side opening of the other PVC tee.
3. Attach the middle opening of a ½-inch PVC tee to each of the ends of the 54 cm length, the combination 23 cm, 10 cm, and 44 cm length and the 80 cm length of PVC pipe (six tees total). The 54 cm length of pipe is the bottom cross brace. The combined 23 cm, 10 cm, and 44 cm length of pipe is the middle cross brace. The 80 cm length of PVC is the top cross brace. The four 38 cm lengths of PVC are the vertical braces.

See RANGER construction photo #4.

4. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the bottom cross brace (54 cm length of PVC pipe). Attach the side opening of a PVC tee to the other end of each 10 cm length of PVC pipe.
5. Cut four 3 cm lengths of ½-inch PVC pipe. Insert all four of these 3 cm lengths of PVC pipe into the four side openings of the PVC tees attached to middle cross brace (80 cm length of PVC pipe). Attach the side opening of a PVC tee to each of the four 3 cm lengths of PVC pipe (four tees total).
6. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the top cross brace (remaining 80 cm length of PVC). Attach the side opening of a PVC tee to the other end of each 10 cm length of PVC pipe.

See RANGER construction photo #5.

7. Take the middle cross brace (combined 23 cm, 10 cm, and 44 cm lengths of PVC pipe with six PVC tees) and insert the four vertical braces (38 cm lengths of PVC pipe) into the four available middle openings of the PVC tees. The 23 cm length in the combined pipe should be positioned toward the starboard side of the ship. The vertical braces closer to the stern should be facing upwards; the vertical braces closer to the bow should be facing downwards.
8. Attach the ends of two of the vertical cross braces to the middle openings of the two tees of the bottom cross brace (54 cm length of PVC pipe). Attach the ends of the other two of the vertical cross braces to the middle openings of the two tees of the top cross brace (80 cm length of PVC pipe).
9. Adjust the angle of the 90° elbows on the middle cross brace and bottom cross brace so that they are symmetrical. The top and bottom cross braces should be set so that all the remaining openings of the PVC tees are aligned, with six side openings facing the stern of the ship and six side openings facing the bow of the ship.

See RANGER construction photo #6.

Next, construct the bow of the shipwreck.

1. Cut two 80 cm lengths, four 38 cm lengths, and two 26 cm lengths of ½-inch PVC pipe. Connect the two 26 cm lengths of pipe by inserting both into the side openings of a PVC tee.
2. Attach a 90° elbow to the other end of each 26 cm length of pipe. Attach the middle opening of a ½-inch PVC tee to each of the ends of both 80 cm lengths of PVC pipe (four tees total). The two 26 cm lengths of pipe connected with a tee are the bottom cross brace. The two 80 cm lengths of PVC are the middle cross brace and the top cross brace. The four 38 cm lengths of PVC are the vertical braces.

See RANGER construction photo #7.

3. Cut two 3 cm lengths of ½-inch PVC pipe. Insert these two 3 cm lengths into the open end of the 90° elbows on the bottom cross brace (two 26 cm lengths of pipe). Attach the side opening of a PVC tee to the other end of each 3 cm length of PVC pipe.
4. Cut four 3 cm lengths of ½-inch PVC pipe. Insert all four of these 3 cm lengths of PVC pipe into the four side openings of the PVC tees attached to middle cross brace (80 cm length of PVC pipe). Attach the side opening of a PVC tee to two of these 3 cm lengths of pipe. Attach a 90° elbow to the other two of the 3 cm lengths of PVC pipe.
5. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the top cross brace (remaining 80 cm length of PVC). Attach the side opening of a PVC tee to the other end of each 10 cm length of PVC pipe.

See RANGER construction photo #8.

6. Insert a vertical brace (38 cm length of pipe) into each of the two middle openings of these PVC tees. Insert the other ends of these two vertical braces into the openings on the two 90° elbows on the middle cross brace. Insert the other two vertical braces (38 cm lengths of pipe) into the middle openings of the PVC tees on the middle cross brace. Insert the other ends of these two vertical braces into the middle openings of the PVC tees on the bottom cross brace.
7. Adjust the angle of the 90° elbows on the middle cross brace and bottom cross brace so that they are symmetrical.

See RANGER construction photo #9.

8. Cut one 104 cm length, one 57 cm length, one 51 cm length, one 3 cm length, and two 25 cm lengths of ½-inch PVC pipe. Connect the 51 cm length of pipe and the 3 cm length of pipe by inserting them into the side openings of a ½-inch PVC tee.
9. Insert the two 25 cm lengths of PVC pipe into the side openings of the PVC tees on the top cross brace. Attach a 45° elbow to the other end of each 25 cm length of pipe.
10. Insert the 57 cm length of PVC pipe into the open end of the 45° elbow on the port side of the shipwreck. Insert the combined 51 cm and 3 cm length of pipe into the open end of the 45° elbow on the starboard side of the shipwreck, with the PVC tee close to the bow. Attach a single ½-inch PVC sideout to the ends of the 57 cm pipe and the 3 cm pipe, inserting the ends of the pipe into the two slip ends of the PVC sideout. Insert a ½-inch male adapter into the threaded opening of the ½-inch sideout.
11. Cut a 3 cm length of ½-inch pipe and insert it into open end of the male adapter. Attach a 45° elbow to the other end of this 3 cm length of pipe. Insert the 104 cm length of PVC pipe into the open end of the 45° elbow. Insert the other end of the 104 cm pipe into the middle opening of the tee in the center of the bottom cross piece. The bow of your shipwreck is now complete.

See RANGER construction photos #10.

Design note: Depending on your construction and assembly, you may need to slightly adjust the lengths of PVC on the shipwreck for the wreck to fit together properly.

To complete the shipwreck, add lengths of pipe to connect the bow to the center area, and the center area to the stern. The overall length of the wreck will be variable and must be measured by RANGER class companies.

1. Cut six equal lengths of PVC pipe to connect side openings of the tees in the bow to those in the center of the shipwreck.
2. Cut six equal lengths of PVC pipe to connect the side openings of the tees in the center of the ship to those in the stern of the shipwreck.

The overall length of the shipwreck should be between 2.25 m and 3.75 m.

3. Cut two 12 cm lengths of ½-inch PVC.
4. Attach a ½-inch PVC coupling to one end of each 12 cm length of pipe. Wrap approximately 3 cm of the other end of the pipe with tape.
5. Spray one length of pipe and connector with red spray paint. Spray the other length of pipe with yellow spray paint.
6. Once the paint has dried, remove the tape and insert the yellow colored pipe into the middle opening of the PVC tee on the top stern cross brace. Remove the tape and insert the red colored pipe into the middle opening of the tee located at the very bow of the ship.

Design note: RANGER class companies will measure the overall length of the shipwreck between the yellow and red colored markers.

Add a cradle to the middle of the ship.

1. Remove both lengths of PVC pipe that run from the middle cross brace at the center of the shipwreck to the middle cross brace at the stern of the shipwreck. Cut 4 cm from each of the PVC pipes removed from the shipwreck.
2. Cut an additional 20 cm from one of the removed pipes and insert both the 20 cm length of pipe and the remaining length of pipe into the side openings of A PVC tee. This overall length should match the length of the remaining lengths of pipe running between the middle and stern of the shipwreck.
3. Repeat this procedure on the other removed length of pipe.
4. Reinsert these lengths into the shipwreck, running between the middle cross brace at the center of the shipwreck to the middle cross brace at the stern of the shipwreck. The 20 cm length of pipe should be at the center of the shipwreck.
5. Cut one 44 cm length, one 23 cm length, and one 10 cm length of ½-inch PVC pipe.
6. Attach the side opening of a PVC tee to each end of the 10 cm length of PVC pipe. Attach the 23 cm length of pipe to the side opening of one of the PVC tees. Attach the 44 cm length of pipe to the side opening of the other PVC tee.
7. Insert this combined length of pipe into the middle openings of the PVC tees just behind the middle cross brace in the center of the shipwreck. The 23 cm length of PVC pipe should go into the tee on the starboard side of the shipwreck.

This creates a second middle cross brace approximately 31 cm behind the original middle cross brace at the center of the shipwreck.

8. Cut three 10 cm lengths of ½-inch PVC pipe. Connect them with a pair of 45^{o} PVC elbows. Turn the PVC tees that are on both middle cross braces, approximately 26 cm from the starboard side of the shipwreck, so they face towards each other and down at a 45^{o} angle.

9. Insert the ends of this combined length into the middle openings of the PVC tees 26 cm from the starboard side of the shipwreck.
10. Cut one 26 cm length of ½-inch PVC. Insert it into the middle opening of the two PVC tees remaining on the middle cross braces. A 5-gallon bucket should fit tightly inside this cradle.

See RANGER construction photo #11 and #12.
See RANGER construction photos #13 and #14.

Plastic sheeting is added to one side of the shipwreck to provide a working area. Plastic sheeting is comprised of 1/8-inch black ABS sheets and corrugated plastic sheets.

To construct the working areas of the shipwreck:

1. Place one 61 cm x 46 cm (24inch x 18inch) of 1/8-inch black ABS sheeting along one side of the shipwreck. Position one 61 cm edge of the sheet along the top of the frame, near the center section of the shipwreck. The 61 cm edge should reach from 15 cm behind the center top cross brace towards the bow of the ship. The rough side of the ABS sheet should be facing outwards.
2. Use screws to fasten the corners of the ABS sheet into the PVC framework of the shipwreck.
3. Attach two 5 cm x 5 cm squares of Velcro hooks to ABS sheet. These 5 cm x 5 cm squares should be located approximately 15 cm to 20 cm apart from each other, half way up the ABS sheet.
4. Place a 61 cm x 46 cm (24 inch x 18 inch) of corrugated plastic sheeting along the same side of the shipwreck. The first corrugated plastic sheet should be adjacent to the black ABS sheet but located closer to the bow.
5. Use screws to fasten the corners of the corrugated plastic sheet into the PVC framework of the shipwreck.
6. Place a 61 cm x 46 cm (24inch x 18inch) of corrugated plastic sheeting along the same side of the shipwreck. This corrugated plastic sheet should be closer to the stern of the shipwreck. Leave a 15 cm gap between the 46 cm edge of the black ABS sheet and the 46 cm edge of the stern corrugated plastic sheet.
7. Use screws to fasten the corners of the corrugated plastic sheet into the PVC framework of the shipwreck.

Design note: Check sign-making/printing stores for black plastic ABS sheeting and corrugated plastic. Alternatively, Plexiglas, Lexan, or other flat plastic sheeting may be substituted. The working area of the shipwreck (black ABS sheet) should be able to withstand impacts from and ROV.

Design note: At the regional and international competitions, different colors of corrugated plastic will be used to differentiate the shipwrecks.

Metal/Non-metal debris:

The base of the debris samples is a red brick (Home Depot online part #M2501PPSM011, Home Depot SKU #393126). The brick is 19 cm x 9 cm by 5.5 cm (8-inch x 4-inch x 2 ½-inch). The metal/non-metal sample is attached with cable ties to the 19 cm x 9 cm face of the brick.

To construct the metal sample:

1. Purchase a ¾-inch x 5-inch galvanized steel pipe nipple that is threaded on both ends (Home Depot part #564-050HN, Home Depot SKU# 182664). Attach a ¾-inch 90° elbow to each end of the galvanized pipe, completely covering the threads on either end.
2. Spray paint the entire debris sample, but not the brick, multiple times to completely disguise the metal galvanized pipe.
3. Drill a pair of holes in the side of each 90° elbow that does not contain the galvanized pipe. Use cable ties through these holes to secure the sample to the brick.

To construct the non-metal sample:

1. Cut an 11.5 cm length of ¾-inch PVC pipe. Attach a ¾-inch 90° elbow to each end of the PVC pipe.
2. Spray paint the entire debris sample, but not the brick, multiple times to completely disguise the PVC pipe.
3. Drill a pair of holes in the side of each 90° elbow that does not contain the ¾-inch pipe. Use cable ties through these holes to secure the sample to the brick.

Design note: Use a black primer spray paint to give a heavy base coat to the debris samples. Finish with a heavy coat of red paint. When the samples are painted, the metal sample and the non-metal sample should be visually identical.

See RANGER construction photo #15.

Grid:

The RANGER class grid is constructed of ½-inch PVC. The grid is 2.5 m long and 1.5 m wide and consists of 0.5 m x 0.5 m squares.

To construct the RANGER class grid:

1. Cut sixteen 46 cm lengths of ½-inch PVC pipe.
2. Using the side openings of four ½-inch PVC tees, connect five of these 46 cm lengths of PVC in a line. Repeat this process, connecting five more lengths of pipe with four more PVC tees.
3. Using the side openings of two ½-inch PVC tees, connect three 46 cm lengths of PVC in a line. Repeat this process, connecting three more lengths of pipe with two more PVC tees.

These combined lengths form the outer edge of the grid. The longer lengths should be 2.5 m long. The shorter lengths should be 1.5 m long.

See RANGER construction photo #16.

4. Attach four ½-inch PVC 90° elbows to the end lengths of PVC on both 2.5 m edges of the grid.
5. Attach the ends of the combined PVC lengths together to form a rectangle approximately 2.5 m long by 2 m wide. All the middle openings of the PVC tees should face inwards.
6. Use two lengths of 2.46 m PVC pipe to connect the tees facing each other on the 1.5 m sides of the rectangle. Use four lengths of 1.96 m PVC pipe to connect the tees facing each other on the 2.5 m sides of the rectangle.

The five debris piles will be placed randomly within the fifteen 0.5 m x 0.5 m squares created by the grid.

See RANGER construction photo #17.

Targets:
RANGER class targets are constructed from a white, 2-inch PVC end cap with a ring of black, 2-inch ABS set inside the end cap.

1. Cut a 1 cm length of 2-inch black ABS pipe. Use a saw or heavy wire cutters to cut a 1 to 2 mm section from ABS ring.
2. Insert this ABS ring into the end cap, as close to the bottom as possible.

See RANGER construction photo #18.

Design note: If ABS is unavailable in your area, cut a 1 cm length of 2-inch PVC and paint it black before inserting it inside the 2-inch PVC end cap.

3. Use screws to fasten the target onto the shipwreck 45 cm from the bottom. Drill a 1/8-inch hole in the center of the PVC end cap and a 1/8-inch hole though the corrugated plastic into a length of PVC 45 cm off the bottom. Use a ¾-inch screw to attach the 2-inch end cap to the PVC pipe.

25 cm to each side of the target will be a black mark. These marks will be 1 cm wide and 4 cm tall and located on the colored corrugated plastic sheet.

4. Use a black Sharpie or permanent marker to draw the 1 cm x 4 cm mark on the corrugated plastic, 25 cm to each side of the center of the target.

See RANGER construction photo #19.

Task #2: Removing fuel oil from the shipwreck

Your company must clear the worksite of debris before attempting to determine if fuel oil remains on board. Clearing the worksite involves removing one of the *SS Gardner*'s masts that had fallen onto an area of the hull above the fuel tanks. Once the mast is removed from the worksite, your company must then clear the hull of encrusting organisms in order to provide a clean, unobstructed working surface. However, one of the organisms is an endangered species of coral. These corals cannot be decimated but rather must be transplanted to a new location.

Examples of coral

Once the hull is clear, your company must confirm the presence of oil within the underlying fuel tank. To accomplish this, your company will use two simulated sensors – an ultrasonic thickness gauge and a neutron backscatter device. The ultrasonic thickness gauge works by measuring the amount of time it takes for sound waves to travel through the hull and back. It then calculates the thickness based on the speed of the sound through the hull. The readings are instantaneous.

The thickness of the hull is used to calibrate the neutron backscatter device. To assist with calibration, the MATE Center constructed a test or calibration tank and placed in on the bottom near the shipwreck. This tank is filled with oil and water. Based on historical records of the *SS Gardner*, the MATE Center calculated a range of potential thicknesses and constructed the tank so that each wall is a different thickness. The readings from the ultrasonic thickness gauge will determine which wall of the tank should be used to calibrate the neutron backscatter device.

Once calibrated, your company must place the neutron backscatter device on the hull to test for the presence of oil. The device works by emitting high energy neutrons. When a fast neutron collides with a hydrogen atom it releases energy and becomes a slow or thermal neutron. The thermal neutrons are scattered in all directions. Some of these thermal neutrons are scattered back towards and counted by the device. The more hydrogen atoms present in a substance the more thermal neutrons are created and can be detected. Therefore, high readings indicate the presence of oil.

After you complete this task, you can assume that there is oil on board.

Your company must then penetrate the hull to collect a sample of the fuel oil. The sample must be returned to the surface so that it can be tested to determine the quality and condition of the oil.

References

- Coral photos http://na.oceana.org/en/category/blog-free-tags/deep-sea-coral and www.esablawg.com/esalaw/ESBlawg.nsf/d6plinks/KRII-7B66S7
- Ultrasonic thickness gauge http://ultrasonicthicknessgauge.org/
- Neutron backscatter device www.scanningtech.com/Neutron_Backscatter.html

This mission task involves:

- **Transporting and attaching a lift bag to a fallen mast.**
- **Inflating the lift bag to remove the fallen mast from the worksite.**
- **Removing endangered encrusting coral from the ship's hull.**
- **Transplanting the coral.**
- **Using two simulated sensors, determine if fuel oil remains inside the fuel tank.**
- **Removing a sample of fuel oil from within the tank by drilling a hole into the hull.**
- **Resealing the hole.**
- **Returning the sample to the surface.**

RANGER class scoring – up to 180 points:

- Transporting and attaching a lift bag to the U-bolt on a fallen mast – 10 points
- Inflating the lift bag so the mast ascends to the surface – 20 points
- Removing endangered corals from the hull– 5 points each (10 points total)
- Transplanting the corals to an unoccupied square within the grid – 10 point each (20 points total)
- Using two simulated sensors, determine if fuel oil remains inside the fuel tank – up to 30 points
    - Placing the ultrasonic thickness gauge sensor on the hull – 10 points
    - "Calibrating" the neutron backscatter device by placing it on the calibration tank – 10 points
    - Placing the neutron backscatter device on the hull – 10 points
- Simulating drilling a hole into the fuel tank by penetrating a layer of petroleum jelly and removing a sample of fuel oil from within the fuel tank so that it is in possession of your ROV and no longer in the container – 30 points
- Resealing the drill hole with a simulated magnetic patch – 20 points
- Returning a volume of sample to the surface side of the pool so that a member of your company can retrieve the sample – up to 40 points
    - > 100ml – 40 points

- 50 – 99 ml – 20 points
- 25 – 49 ml – 10 points
- < 25 ml – 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

Task #2 must be completed in order. Companies may alternate between task #1 and task #2, but task #2 must be completed in order. Companies may skip any part of task #2, but will not receive points if they complete that part at a later time. Companies may choose to return the volume of liquid to the surface before resealing the drill hole or may reseal the drill hole before returning the sample to the surface. All tasks must be completed in order to receive a time bonus.

The fallen mast will be located against the hull of the shipwreck. RANGER class companies must attach a lift bag to the U-bolt on the mast. One lift bag will be provided to RANGER class companies at the mission station during the five minute set-up period. A manual pump and 40 feet of air line tubing will also be provided to the companies during set up. RANGER class companies **MAY NOT** use air compressors or compressed air tanks to fill the lift bags. The lift bags MUST be filled from the manual pump provided by the competition officials.

Note: RANGER class companies do not have to pass the fluid power quiz to use the manual air pump.

The lift bag will be constructed from 3-inch ABS pipe with 1/8-inch rope holding a hook at the bottom. The hook will have a diameter of 1.7 cm. Only one lift bag will be provided to RANGER class companies. If the bag is dropped, companies must retrieve it with their vehicle.

Lift bags must be completely empty of air before the ROV descends. Companies may evacuate air and fill their lift bag with water during the 5-minute set up period.

Details of the air line tubing and the manual air pump are detailed in the mission prop specifications below.

The mast is constructed from ¾-inch PVC. Weights inside the bottom-most ¾-inch PVC pipes will provide ballast. A U-bolt will be the attachment point for the lift bag.

Companies will receive points when the 3-inch ABS lift bag breaks the surface. If the lift bag is still rising as the mission time ends, companies will not receive points for completing this task.

After removing the mast from the worksite, RANGER class companies must remove encrusting corals from the hull of the shipwreck. These endangered corals must be transplanted into an open grid square.

An open grid square is considered a grid square that does not have a debris sample within it. Two corals will be growing on the black ABS sheeting attached to the side of the shipwreck. Both corals will be held onto the side of the hull by Velcro. Both corals must be removed from the hull and placed in an open grid square in order to receive full points for this step and to be eligible for a time bonus. Corals may be placed in the same grid square or different grid squares as needed. Corals do not need to be placed upright within the grid square in order to receive full points. To successfully transplant a coral, no portion of the coral should be touching any part of the PVC grid.

Corals will require less than 1 Newton to detach from the hull of the shipwreck. Corals will weigh less than 1 Newton in water.

After removing both corals from the hull of the ship, companies must gauge the thickness of the hull, use the thickness to calibrate their neutron backscatter device against a calibration tank, and determine if oil remains in the fuel tank using the calibrated neutron backscatter device. Both the ultrasonic thickness gauge sensor and the neutron backscatter device will be simulated.

RANGER class companies must create their own simulated sensors. Both simulated sensors may be combined into one unit. Guidelines for creating the sensor are that it must be able to touch the vertical hull of the ship and calibration tank. The sensor must be at least 12 cm long and at least 2 cm in diameter or at least 2 cm x 2 cm square. The sensor should be labeled and identified to the mission station judge during the 5-minute mission set up time.

Once both corals are removed from the hull of the ship, companies must maneuver their vehicle so that the ultrasonic thickness gauge is touching the working surface of the hull of the shipwreck. The working surface of the hull is defined as the 61 cm x 46 cm black ABS sheet. The mission station judge must be able to see through an ROV camera that the ultrasonic thickness gauge sensor is touching this area of the hull for a continuous five seconds. If the sensor comes off of the hull during those five seconds, companies must reposition their vehicle and restart the five second time period. Companies should inform the mission station judge that they are attempting this task and ask the mission station judge to count off the five seconds.

Companies must then pilot their vehicle to the calibration tank to calibrate their neutron backscatter device. The calibration tank is a standard milk crate, approximately 32 cm long, 32 cm wide, and 28 cm tall. The calibration tank will be positioned on the pool bottom within one meter of the working area on the hull of the shipwreck. Companies must maneuver their vehicle so that the neutron backscatter device is touching the wall of the milk crate. The mission station judge must be able to see through an ROV camera that the neutron backscatter device is touching the calibration tank for a continuous five seconds. If the sensor comes off of the calibration tank during those five seconds, companies must reposition their vehicle and restart the five second time period. Companies should inform the mission station judge that they are attempting this task and ask the mission station judge to count off the five seconds.

Once the neutron backscatter device is calibrated, companies can return to the working area of the hull. Companies must maneuver their vehicle so that the neutron backscatter device is touching the working area of the hull of the shipwreck. The mission station judge must be able to see through an ROV camera that the neutron backscatter device is touching the hull for a continuous five seconds. If the sensor comes off of the hull during those five seconds, companies must reposition their vehicle and restart the five second time period. Companies should inform the mission station judge that they are attempting this task and ask the mission station judge to count off the five seconds.

RANGER class companies are also tasked with removing a sample of fuel oil, which is simulated by green saltwater, from inside a tank.

RANGER class companies will simulate drilling through the hull by penetrating a layer of petroleum jelly. The petroleum jelly will be located at the end of a 1 ½-inch to 1-inch PVC reducer bushing. The layer will be approximately 1 cm to 2 cm thick, will be 3.3 cm in diameter and located 1 cm to 3 cm deep into the reducer bushing. Companies must design a device to puncture through the petroleum jelly seal in this reducer bushing.

No sharp objects are permitted on the vehicle to puncture through the petroleum jelly. Hypodermic needles, knives, razor blades, etc. are not allowed.

The reducer bushing will be set into a 1 ½-inch PVC coupling that is attached to the top of a 5-gallon bucket lid. The bucket lid is attached to a 5-gallon bucket which rests on its side near the center-stern of the shipwreck.

The outside edge of the 1 ½-inch to 1-inch reducer bushing will be covered with Velcro loops.

Design note: Velcro loops are the soft, “wool” side of Velcro.

Any petroleum jelly removed by the vehicle may be left in the pool or returned to the surface with the ROV.

Once the layer of petroleum jelly is penetrated, RANGER class companies must retrieve a sample of fuel oil from within the tank and return it to the surface. The fuel oil is simulated by green saltwater comprised of water, salt, and green food coloring.

The sample of fuel oil must be returned to the surface so that it may be retrieved by a member of your company and handed to the mission station judge. To receive points for returning a sample to the surface, the ROV must be within the grasp of a member of your company before the 15-minute mission time period has ended. Companies that have a fuel oil sample on board, but are still in the pool when the mission time ends, will receive points for collecting the sample, but will not receive points for

returning the sample to the surface. If companies have completed all other mission tasks and have the fuel oil sample on board, their mission time will end when a member of their company grasps the vehicle at the surface, side of the pool. In this case, companies may retrieve the sample from their vehicle and hand it to the mission station judge after the mission time has ended. Once the clock has stopped, if a company member drops the sample, or the company feels the sample size is insufficient or too diluted, they may not return to the water to retrieve a second sample. If the sample size is not >100 ml, companies will be unable to receive a time bonus.

Companies that return their fuel oil sample before completing other mission tasks may ask the mission station judge to measure the volume of the sample or compare it to the standard to determine if it is too dilute. Time will not stop while the judge is making the measurements. Companies may elect to retrieve an additional sample if they feel that the sample size is insufficient or the sample is too dilute.

Once your company is satisfied with the fuel oil sample, you must use a magnetic patch to reseal the drill hole. Magnetic patches will be simulated by Velcro. RANGER class companies must place a Velcro patch over the simulated drill hole.

Note: Once the Velcro patch is placed over the drill hole, companies may not attempt to remove it to obtain a sample of liquid.

The Velcro patch will have a diameter of 7.3 cm. The patch must completely cover the entire 5.3 cm diameter of the reducer bushing to successfully reseal the drill hole.

RANGER class companies will be provided with two patches at the mission control shack. If one patch is dropped, the vehicle can attempt to retrieve it from the bottom of the pool, or may return to the surface for the second patch. If a second patch is dropped, companies will have to retrieve one of the patches from the bottom of the pool to complete this step of the mission.

Mission prop specifications

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

Mast:

The RANGER class mast is constructed from ¾-inch PVC. The mast is 65 cm tall and 45 cm wide. A 3 ½-inch U-bolt will be the attachment point for the lift bag. Six lengths of rope hang from the mast. Weights in the bottom of the mast will provide ballast.

To construct the mast:

1. Cut one 40 cm length, four 20 cm lengths, and one 15 cm length of ¾-inch PVC pipe.
2. Take the 15 cm 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 10 cm 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 8.6 cm (3.5-inches) 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 stick 8.5 cm out from the mast. Use 3/8-inch lock nuts to secure the U-bolt in place.

Design note: The 15 cm length of PVC pipe with the U-bolt is recycled from the 2011 RANGER class missions. It was used in 2011 as the connection point for lifting the riser pipe off the oil well.

3. Insert two of the 20 cm lengths of pipe into opposite openings of a ¾-inch PVC cross. Insert the 40 cm length of pipe into another opening of the cross. Insert the 15 cm length of pipe with the U-bolt into the final opening of the PVC cross.
4. Attach a ¾-inch end cap to the other end of the 15 cm length of pipe.
5. Drill holes into the ¾-inch end cap to allow air to escape from the mast.
6. Attach the middle opening of a ¾-inch PVC tee to the other end of the 40 cm length of PVC pipe.
7. Insert the other two 20 cm lengths of pipe into the side openings of the ¾-inch PVC tee. Align these two lengths to match the 20 cm lengths of pipe above.

The RANGER class mast will weigh less than 11.5 Newtons (2.5 pounds) in water. Add weights into the bottom PVC pipe of the mast to achieve the proper weight.

1. Drill three 3/16-inch holes in each of the 20 cm lengths of 1 ½-inch PVC pipe (six holes total).
2. Cut six lengths of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**140-287**, ACE Hardware part #75851). The lengths of rope should vary from 20 cm to 50 cm long. Insert one end of each length of rope into the holes drilled through the pipe and tie and overhand knot to secure them in place.

See RANGER construction photo #20.

Lift bag:

The lift bag is constructed from 3-inch ABS pipe with a 3-inch knockout cap (Home Depot part# 39102, SKU#508260, Home Depot online# 39102) at one end. A hook is attached by 1/8-inch rope to the other end of the 3-inch ABS pipe.

To construct the RANGER class lift bag:

1. Cut a 32 cm length of 3-inch ABS pipe.
2. Use 5-minute epoxy (or other glue) to secure and waterproof a 3-inch knockout cap to one end of the 32 cm length of ABS pipe. Use enough epoxy or glue so that air will not leak out the end.
3. Drill four 3/16-inch holes spaced evenly around the other end of the 32 cm length of ABS pipe.

4. Cut four 20 cm lengths of 1/8-inch braided rope. Insert the ends of the 20 cm lengths of rope into the four holes drilled, one rope per hole. Rope should be inserted from the outside of the pipe to the inside of the pipe. Tie an overhand knot to secure the rope inside the ABS pipe.
5. Cut 7.5 cm from a 6-inch J-hook (ACE Hardware part #57933). Keep the hook portion of the J-hook.
6. Use plastic/electrical tape and/or epoxy to secure the four loose ends of rope to the J-hook. Secure approximately 2 cm to 3 cm of rope to the top 3 cm of the J-hook.

See RANGER construction photo #21.

Design note: Companies that cannot find ABS in their area should check online sources.

Air pump:
RANGER class companies will be provided with a manual (hand-powered or foot-powered) pump at the mission station. The pump is connected to 40 feet of 3/16 (inner diameter) of air line tubing. The bottom end of the air line tubing is attached with a pair of cable ties to the outside of a 10 cm length of PVC pipe.

Companies may provide their own air line tubing. Companies that choose to use their own air line are responsible for providing a connector that will fit 3/16-inch air line tubing and are responsible for making the connection to the manual pump. Companies are allowed to connect their air line tubing during the five minute set-up period.

Design note: If 3/16-inch air line tubing is not available in your local hardware stores, check online sources for "3/16 inch air line" tubing.

Coral:
The coral is simulated using chenille stems (pipe cleaners) set into a ½-inch PVC end cap base.

To construct a coral:
1. Cut three 30 cm long, pink pipe cleaners into six 15 cm lengths. Cut four 30 cm long, white pipe cleaners into eight 15 cm lengths.
2. Drill an 1/8-inch hole 0.5 cm off center in the bottom of a ½-inch PVC end cap. Insert 4 cm of a white pipe cleaner through this hole. Twist the end of the pipe cleaner into an overhand knot so that it is secured in the end cap.
3. Drill a pair of 3/16-inch holes on opposite sides of the wall of the ½-inch PVC end cap. Insert a small cable tie through both holes on the side of the end cap, over the top of the end cap, and over the white pipe cleaner coming out the top of the end cap. Pull the cable tie to secure the pipe cleaner tightly against the surface of the end cap.
4. Take a 15 cm length of pink pipe cleaner and twist the middle of it twice around the white pipe cleaner, about 1 cm up from the end cap. 7 cm should extend from each end of the twist.

5. Take two 15 cm lengths of white pipe cleaner and twist the middle of each around either length of the pink pipe cleaner, about 1 cm up from the base.
6. Repeat until all 15 cm lengths of pipe cleaner are used.
7. Bend the ends of all pipe cleaners upwards, away from the end cap.
8. Cut a 3 mm by 4 cm length of Velcro loops. Attach the Velcro strip to the base of the end cap, placing one end approximately 1.5 cm inside the end cap, and the other end outside the end cap.

See RANGER construction photo #22.

Ultrasonic thickness gauge sensor and neutron backscatter devices:
RANGER class companies are tasked with building their own simulated ultrasonic thickness gauge sensor and neutron backscatter device. Both simulated sensors may be combined into one unit; in other words, one device can serve as both sensors. The sensor must be able to touch a flat, vertical surface. The sensor must be at least 12 cm long. The sensor must be at least 2 cm in diameter or at least 2 cm x 2 cm square.

RANGER class companies may attach the sensors to their vehicle by any method they choose.

Calibration tank:
The calibration tank will be simulated by a milk crate.

1. Use cable ties to attach a 34 cm x 34 cm length of colored corrugated plastic to the top of a milk crate.
2. Turn the milk crate on its side and add sufficient weight to secure it to the bottom of the pool.

The neutron backscatter device must be held to the 34 cm x 34 cm sheet of corrugated plastic surface for five seconds.

Design note: Check sign-making/printing stores for colored corrugated plastic sheeting. Alternatively use 1/8-inch black ABS sheeting, Plexiglas or Lexan.

Fuel tank:
The fuel tank is a 1-liter soft water bottle within a 5-gallon bucket. The soft water bottle design allows the container to collapse under pressure when a sample is removed with minimal mixing of the pool water. It is placed within a 5-gallon bucket for protection and weight. The nozzle of the water bottle extends from, and is secured to, the lid of the 5-gallon bucket. The water sample is accessed through a 1 ½-inch to ¾-inch reducer bushing.

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, 34flozs, Item #797977). Any 5-gallon bucket with lid can be used as the outer container.

To construct the fuel tank container:

1. Use a 1-inch hole saw to drill a hole in the center of the 5-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 ¾-inch PVC pipe to fit through it, but not large enough so a ¾-inch PVC coupling will fit through it.
2. Attach a ¾-inch PVC coupling over the mouth of the soft water bottle. Secure with a small screw or glue. Insert a 4.5 cm length of ¾-inch PVC pipe into the coupling.
3. Push the end of the 4.5 cm length of PVC through the hole in the 5-gallon bucket lid. Attach a 1 ½-inch to ¾-inch reducer bushing (Home Depot Part #437-210HC, Home Depot SKU #896-981, DURA online part #437-210) to the 4.5 cm length of pipe.
4. Attach a 1 ½-inch coupling to the reducer bushing. Insert a 1 ½-inch to 1-inch reducer bushing (Home Depot part # 437-211HC, Home Depot SKU #294-284, DURA part #437-211) into the other end of the coupling.
5. Add a layer of petroleum jelly (Vaseline) to the 1 ½-inch to 1-inch reducer bushing. The petroleum jelly should completely fill the entire diameter of the bushing and should be 1.5 cm to 2 cm thick.

Design note: Check pharmacies/drug stores for petroleum jelly.

6. Drill multiple ¼-inch holes in the 5-gallon bucket to allow flooding. Weights can be added inside the 5-gallon bucket to hold it on the bottom. Make sure the lid is tightly secured on the 5-gallon bucket. Use straps to hold the lid on if necessary.
7. Set the 5-gallon bucket into the cradle located behind the center of the shipwreck. The bucket lid should be facing the starboard side of the shipwreck. The 1 ½-inch coupling and reducer bushing should extend beyond the side of the shipwreck.

See RANGER construction photo #23.
See RANGER construction photo #24.

<u>Fuel oil</u>:
Add 125ml (1/2 cup) of salt and 4 drops of green food coloring per 1.0 liters of water. Mix well. Fill the 1 liter soft water bottle and all PVC pipes with the dense colored liquid.

<u>Patch</u>:
The contact surface of the patch is constructed from a 3-inch knockout cap (Home Depot part# 39102, SKU#508260, Home Depot online# 39102) covered with Velcro hooks.

To construct the patch:

1. Use heavy wire cutters or dykes to cut the pull tab from the 3-inch knockout cap.
2. Place the top of a ½-inch PVC end cap onto the center of the bottom side (non pull tab side) of a 3-inch knockout cap.
3. Use two #6 ½-inch sheet metal screws to secure the end cap onto the 3-inch knockout cap. The heads of the screws should be on the top side flat, 7.3 cm side of the knockout cap (the side the pull tab was removed from).
4. Cut an 8 cm length of ½-inch PVC and insert it into the end cap.
5. Drill a pair of 3/16-inch holes in the 8 cm length of pipe approximately 0.5 cm from the end.
6. Cut a 20 cm length of 1/8-inch braided nylon and polypropylene rope. Insert one end of the rope through a drill hole from the outside to the inside of the pipe. Tie an overhand knot to secure the rope inside the pipe. Insert the other end of the rope through the other drill hole, from the outside to the inside of the pipe. Tie an overhand knot to secure the rope inside the pipe.
7. Cover the entire top of the 3-inch knockout cap, including the heads of the sheet metal screws, with Velcro hooks.

See RANGER construction photo #25.

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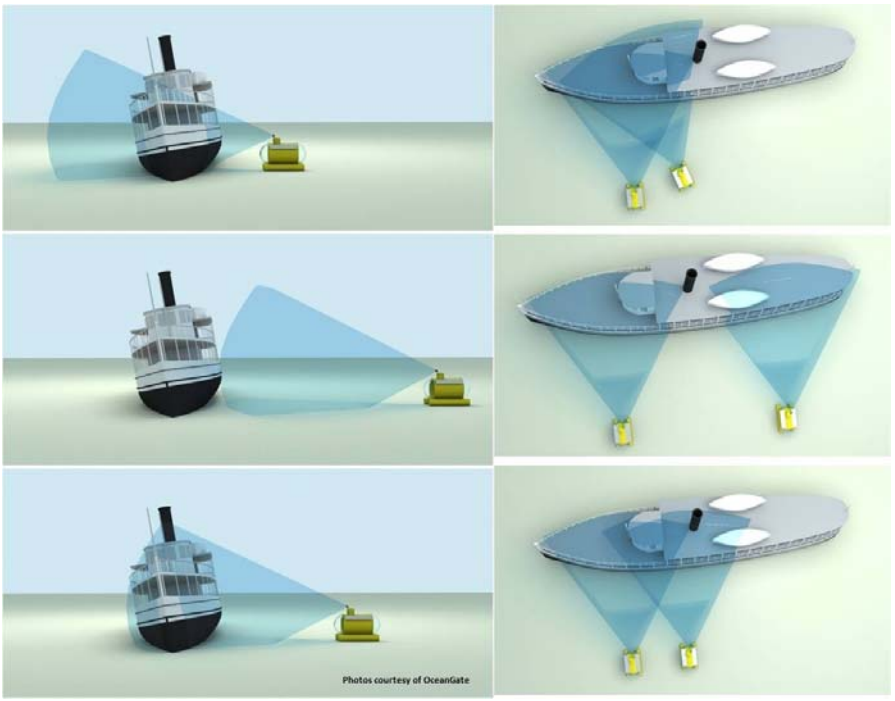
EXPLORER CLASS MISSIONS

Task #1: Survey the wreck site

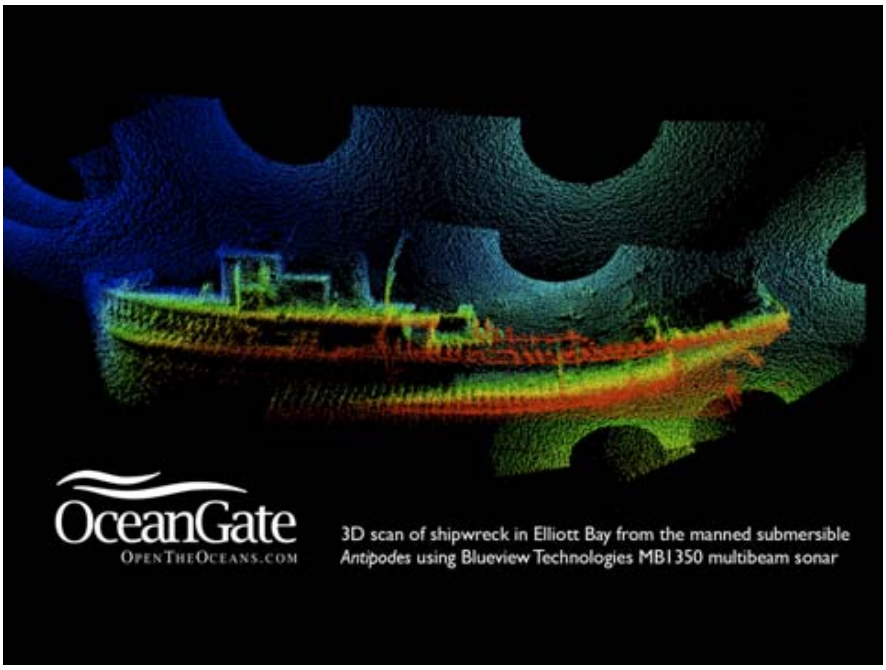
Your company is required to survey the *SS Gardner* and the wreck site. Surveying the wreck includes measuring the overall length of the ship, and determining the orientation of the ship on the seafloor. Your company must also examine the debris field alongside the wreck. The debris is overgrown with a thick layer of encrusting organisms and, from a visual standpoint, looks exactly like the encrusted rocky outcroppings found in the surrounding area. Your company must determine whether the objects in the debris field are metal, and hence part of the wreck site, or non-metal and therefore naturally occurring rocky outcroppings. Your company is then required to make a map of the wreck site based on your findings.

Your company must also scan the shipwreck with sonar. Today's multi-beam sonar is the best technology available for providing high quality, highly detailed images of shipwrecks and other submerged objects. By changing the angle of coverage and frequency of the sound produced by the sonar, the sonar can scan large areas with less detail, or smaller areas with extremely high detail. This, along with your map, will help to document the wreck site and create a "snapshot" of the shipwreck at this moment in time.

Your company will simulate scanning the *SS Gardner* with a stationary multi-beam sonar. When scanning the shipwreck, distance matters. If your sonar is too far away, the beams will not reach the target. If your sonar is too close, the beams will survey a small area and miss much of the target. Spacing of the surveys is also important. Your sonar scans should be done so that there is minimal overlap of the scans. The figures below illustrate this concept.



Side view looking at the shipwreck *View looking down on shipwreck*



The result

This mission task involves:

- **Measuring the length of the wreck.**
- **Determining the orientation of the ship on the seafloor.**
- **Creating a map of the wreck site.**

- **Determining if debris piles are metal or non-metal.**
- **Scanning the shipwreck with sonar.**

EXPLORER class scoring – up to 120 points:

- Measuring the length of the wreck – up to 20 points
  - ≤ 5 cm off true length – 20 points
  - 5 cm to 20 cm off true length – 10 points
  - > 20 cm off true length – 0 points
- Determining the orientation of the ship on the seafloor – up to 20 points
  - ≤ 10^{o}off true orientation – 20 points
  - > 10^{o} to 20^{o}off true orientation – 10 points
  - > 20^{o}off true orientation – 0 points
- Creating a map of the wreck site that includes the following information – up to 10 points
  - Sketch of the shipwreck, length of shipwreck, orientation of shipwreck – 5 points
  - Location of debris piles – 5 points for placing all eight debris piles in the correct grid squares
- Determining if debris piles are metal or non-metal – up to 40 points
  - Correctly identifying eight objects as metal (M) or rock (R) – 5 points each (40 points total)
- Correctly "scanning" the ship at three target locations – 10 points for each target (30 points total)

Mission notes

Task #1 can be completed in any order. Companies must descend to the wreck site to create the map. Companies may alternate between task #1 and task #2.

The overall length of the shipwreck varies, but will range between 2.25 m and 4 m. Different mission stations will have shipwrecks with different lengths.

EXPLORER class companies will determine the length of the shipwreck from the front tip of the bow to the stern most edge of the stern top cross brace (see **Constructing the shipwreck** within the **Mission prop specifications** below).

EXPLORER class companies should determine the orientation of the ship from the stern of the ship towards the bow of the ship. The international competition will have a master compass or a designated north/south line for companies to calibrate their own compass or sensor. The orientation should be taken and reported relative to magnetic north.

A ½-inch PVC grid will be laid out on the pool bottom on one side of the shipwreck. The grid will be 2.5 m long and 1.5 m wide and consist of fifteen squares, each approximately 0.5 m squared. The EXPLORER class mission area will have eight (8) debris piles located within the grid.

During the five minute mission setup time, the mission station judge will hand your company a blank grid. Companies must create a map of the wreck site on this blank grid. In order to receive the full points for creating the map, companies will need to sketch the approximate location of the shipwreck and include the following information:

- sketch of the shipwreck
- length of the shipwreck
- orientation of the shipwreck
- location of each of the eight debris piles

Companies will not be penalized if the length or orientation of the ship is incorrect on the map, but must include these measurements on the map in order receive points. EXPLORER class companies will not receive full points if one (or more) of the eight debris piles is not in the correct location. Companies cannot create the map by looking into the pool from the surface. Companies will not receive any points for creating a map if they do not descend to the wreck site.

Companies must determine whether these debris piles are constructed of metal or non-metal components. Any number of the eight debris piles may be constructed from metal; debris piles made of metal and those made of non-metal will be visually identical. Companies will only receive points for those debris piles correctly identified.

EXPLORER class companies may not guess at which debris piles are metal and which are non-metal. Companies must show the mission station judge evidence that the sample is metal or non-metal. For example, companies can show the judges a sensor reading that allows them to determine whether the debris sample is metal or non-metal. This reading could be displayed on the company's video monitor.

All metal used in construction will be ferrous.

Companies should note that many pools have cement bottoms reinforced with metal rebar. Rebar in the cement could interfere with metal detectors deployed on the vehicle. To help differentiate between metal used in pool construction and the metal of the debris samples, the debris samples will be raised up off the bottom of the pool with a brick. The center of the debris sample will be 10 cm above the bottom of the pool. Companies should take the metal rebar used in pool construction into consideration when designing their metal detector.

Companies will simulate scanning the ship with sonar by visualizing a target area. Each target area will consist of a black ring of 1 ½-inch ABS pipe set inside a 1 ½-inch white PVC end cap and a black mark set

25 cm to each side of the target. To effectively scan the shipwreck, an ROV must align a single camera so that the mission station judge can see on one video display the entire black ring within the end cap, as well as both marks on either side of the target. The vehicle must maintain this alignment for 10 seconds. If at any time the mission station judge is unable to see the entire black ring or both colored marks, companies must realign their vehicle and start the scan again.

Targets will sit approximately 45 cm off the pool bottom.

EXPLORER class companies will scan three target areas. Two will be located on one side of the shipwreck; one will be on the stern of the shipwreck. In addition, EXPLORER class companies are required to shine a high intensity light (**lasers are not allowed**) into the target area for a full 10 seconds. The back of the target area will be covered with reflective tape to help judges determine that this task is completed correctly.

Design note: High intensity lights may not use batteries as their power source. Companies must power these lights directly from tether power.

Design note: Companies should consider the bottom topography of the regional and international competition venues. Do not assume that your ROV will be able to rest on a flat bottom to accomplish the scan.

Mission prop specifications

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

All PVC used in construction is DURA brand PVC. If items are unavailable or built to different specifications in your area, check online at www.duraplastics.com to purchase specific PVC pieces.

Constructing the shipwreck:
The framework of the shipwreck is constructed out of ½-inch PVC. However, the exact diameter of the PVC framework is not important. Companies located outside of North America that do not have access to ½-inch PVC may substitute local PVC for ½-inch PVC pipe and connectors.

To construct the EXPLORER shipwreck, start construction at the stern of the ship.

1. Cut two 80 cm lengths, one 54 cm length, and four 38 cm lengths of ½-inch PVC pipe.
2. Attach the middle opening of a ½-inch PVC tee to each of the ends of the 54 cm length and both 80 cm lengths of PVC pipe (six tees total). The 54 cm length of pipe is the bottom cross brace. The two 80 cm lengths of PVC are the middle cross brace and the top cross brace. The four 38 cm lengths of PVC are the vertical braces.

See EXPLORER construction photo #1.

3. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the bottom cross brace (54 cm length of PVC). Attach a 90° elbow to the other end of each 10 cm length of PVC pipe.
4. Cut four 3 cm lengths of ½-inch PVC pipe. Insert two of these 3 cm lengths of pipe into one side opening of each PVC tee on the middle cross brace (80 cm length of PVC).
5. Attach a side opening of a ½-inch PVC tee to the other end of each 3 cm length of PVC pipe. Insert the other two 3 cm lengths of PVC into the other side opening of the PVC tee. Attach a 90° elbow to the other end of each 3 cm length of PVC pipe.
6. Cut two more 3 cm lengths of ½-inch PVC pipe. Insert these two lengths of 3 cm pipe into one side opening of each PVC tee on the top cross brace (the remaining 80 cm length of PVC).
7. Attach a 90° elbow to the other end of each 3 cm length of PVC pipe.

See EXPLORER construction photo #2.

8. Take two of the vertical braces (38 cm lengths of PVC pipe) and insert one end of a vertical brace into each of the open ends of the 90° elbow. Insert the other ends of these vertical braces into the middle openings of both PVC tees on the middle cross brace (the other 80 cm length of PVC pipe).
9. Take the remaining two vertical braces (38 cm lengths of PVC pipe) and insert them into the open ends of the 90° elbows on the middle cross brace. Insert the other ends of these vertical braces into the 90° elbows on the bottom cross brace (54 cm length of PVC pipe).
10. Adjust the angle of the 90° elbows on the middle cross brace and bottom cross brace so they are symmetrical. At this point, all six openings of the remaining PVC tees should be facing the same direction.

See EXPLORER construction photo #3.

Next, construct the center cross section of the shipwreck.

1. Cut two 80 cm lengths, one 54 cm length, and four 38 cm lengths of ½-inch PVC pipe.
2. Attach the middle opening of a ½-inch PVC tee to each of the ends of the 54 cm length and both 80 cm lengths of PVC pipe (six tees total). The 54 cm length of pipe is the bottom cross brace. The two 80 cm lengths of PVC are the middle cross brace and the top cross brace. The four 38 cm lengths of PVC are the vertical braces.

See EXPLORER construction photo #4.

3. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the bottom cross brace (54 cm length of PVC pipe). Attach the side opening of a PVC tee to the other end of each 10 cm length of PVC pipe.
4. Cut four 3 cm lengths of ½-inch PVC pipe. Insert all four of these 3 cm lengths of PVC pipe into the four side openings of the PVC tees attached to middle cross brace (80 cm length of PVC pipe). Attach the side opening of a PVC tee to each of the four 3 cm lengths of PVC pipe (four tees total).
5. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the top cross brace (remaining 80 cm length of PVC). Attach the side opening of a PVC tee to the other end of each 10 cm length of PVC pipe.

See EXPLORER construction photo #5.

6. Take the middle cross brace (80 cm length of PVC pipe with six PVC tees) and insert the four vertical braces (38 cm lengths of PVC pipe) into the four available middle openings of the PVC tees. The vertical braces closer to the stern should be facing upwards; the vertical braces closer to the bow should be facing downwards.
7. Attach the ends of two of the vertical cross braces to the middle openings of the two tees of the bottom cross brace (54 cm length of PVC pipe). Attach the ends of the other two of the vertical cross braces to the middle openings of the two tees of the top cross brace (54 cm length of PVC pipe).
8. Adjust the angle of the 90° elbows on the middle cross brace and bottom cross brace so that they are symmetrical. The top and bottom cross braces should be set so that all the remaining openings of the PVC tees are aligned, with six side openings facing the stern of the ship and six side openings facing the bow of the ship.

See EXPLORER construction photo #6.

Next, construct the bow of the shipwreck.

1. Cut two 80 cm lengths, four 38 cm lengths and two 26 cm lengths of ½-inch PVC pipe. Connect the two 26 cm lengths of pipe by inserting both into the side openings of a PVC tee.
2. Attach a 90° elbow to the other end of each 26 cm length of pipe. Attach the middle opening of a ½-inch PVC tee to each of the ends of both 80 cm lengths of PVC pipe (four tees total). The two 26 cm lengths of pipe connected with a tee are the bottom cross brace. The two 80 cm lengths of PVC are the middle cross brace and the top cross brace. The four 38 cm lengths of PVC are the vertical braces.

See EXPLORER construction photo #7.

3. Cut two 3 cm lengths of ½-inch PVC pipe. Insert these two 3 cm lengths into the open end of the 90° elbows on the bottom cross brace (two 26 cm lengths of pipe). Attach the side opening of a PVC tee to the other end of each 3 cm length of PVC pipe.
4. Cut four 3 cm lengths of ½-inch PVC pipe. Insert all four of these 3 cm lengths of PVC pipe into the four side openings of the PVC tees attached to middle cross brace (80 cm length of PVC pipe). Attach the side opening of a PVC tee to two of these 3 cm lengths of pipe. Attach a 90° elbow to the other two of the 3 cm lengths of PVC pipe.
5. Cut two 10 cm lengths of ½-inch PVC pipe. Insert these 10 cm lengths into one side opening of each PVC tee on the top cross brace (remaining 80 cm length of PVC). Attach the side opening of a PVC tee to the other end of each 10 cm length of PVC pipe.

See EXPLORER construction photo #8.

6. Insert a vertical brace (38 cm length of pipe) into each of the two middle openings of these PVC tees. Insert the other ends of these two vertical braces into the openings on the two 90° elbows on the middle cross brace. Insert the other two vertical braces (38 cm lengths of pipe) into the middle openings of the PVC tees on the middle cross brace. Insert the other ends of these two vertical braces into the middle openings of the PVC tees on the bottom cross brace.
7. Adjust the angle of the 90° elbows on the middle cross brace and bottom cross brace so that they are symmetrical.

See EXPLORER construction photo #9.

8. Cut one 104 cm length, two 57 cm lengths, and two 25 cm lengths of ½-inch PVC pipe.
9. Insert the two 25 cm lengths of PVC pipe into the side openings of the PVC tees on the top cross brace. Attach a 45° elbow to the other end of each 25 cm length of pipe.
10. Insert the two 57 cm lengths of PVC pipe into the open ends of the 45° elbows. Attach a single ½-inch PVC sideout to both ends of the 57 cm pipes, inserting the ends of the pipe into the two slip ends of the PVC sideout. Insert a ½-inch male adapter into the threaded opening of the ½-inch sideout.
11. Cut a 3 cm length of ½-inch pipe and insert it into open end of the male adapter. Attach a 45° elbow to the other end of this 3 cm length of pipe. Insert the 104 cm length of PVC pipe into the open end of the 45° elbow. Insert the other end of the 104 cm pipe into the middle opening of the tee in the center of the bottom cross piece. The bow of your shipwreck is now complete.

See EXPLORER construction photo #10.

Design note: Depending on your construction and assembly, you may need to slightly adjust the lengths of PVC on the shipwreck for the wreck to fit together properly.

To complete the shipwreck, add lengths of pipe to connect the bow to the center area and the center area to the stern. The overall length of the wreck will be variable and must be measured by EXPLORER class companies.

1. Cut six equal lengths of PVC pipe to connect side openings of the tees in the bow to those in the center of the shipwreck.
2. Cut six equal lengths of PVC pipe to connect the side openings of the tees in the center of the ship to those in the stern of the shipwreck.

The overall length of the shipwreck should be between 2.25 m and 4m.

See EXPLORER construction photo #11 and #12.

Plastic sheets are added to one side of the shipwreck to provide a working area. Plastic sheeting is comprised of 1/8-inch black ABS sheets and corrugated plastic sheets.

To construct the working areas of the shipwreck:

8. Place one 61 cm x 46 cm (24inch x 18inch) of 1/8-inch black ABS sheeting along one side of the shipwreck. Position one 61 cm edge of the sheet along the top of the frame, near the center section of the shipwreck. The 61 cm edge should reach from 15 cm behind the center top cross brace towards the bow of the ship. The rough side of the ABS sheet should be facing outwards.
9. Use screws to fasten the corners of the ABS sheet into the PVC framework of the shipwreck.
10. Attach two 5 cm x 5 cm squares of Velcro hooks to ABS sheet. These 5 cm x 5 cm squares should be located approximately 15 cm to 20 cm apart from each other, half way up the ABS sheet.
11. Place a 61 cm x 46 cm (24inch x 18inch) of corrugated plastic sheeting along the same side of the shipwreck. The first corrugated plastic sheet should be adjacent to the black ABS sheet but located closer to the bow.
12. Use screws to fasten the corners of the corrugated plastic sheet into the PVC framework of the shipwreck.
13. Place a 61 cm x 46 cm (24inch x 18inch) of corrugated plastic sheeting along the same side of the shipwreck. This corrugated plastic sheet should be closer to the stern of the shipwreck. Leave a 15 cm gap between the 46 cm edge of the black ABS sheet and the 46 cm edge of the stern corrugated plastic sheet.
14. Use screws to fasten the corners of the corrugated plastic sheet into the PVC framework of the shipwreck.

Design note: Check sign-making/printing stores for black plastic ABS sheeting and corrugated plastic. Alternatively, Plexiglas, Lexan, or other flat plastic sheeting may be substituted. The working area of the shipwreck (black ABS sheet) should be able to withstand impacts from an ROV.

Design note: At the international competition, different colors of corrugated plastic will be used to differentiate the shipwrecks.

Metal/Non-metal debris:
The base of the debris samples is a red brick (Home Depot online part #M2501PPSM011, Home Depot SKU #393126). The brick is 19 cm x 9 cm by 5.5 cm (8-inch x 4-inch x 2 ½-inch). The metal/non-metal sample is attached with cable ties to the 19 cm x 9 cm face of the brick.

To construct the metal sample:

4. Purchase a ¾-inch x 5-inch galvanized steel pipe nipple that is threaded on both ends (Home Depot part #564-050HN, Home Depot SKU# 182664). Attach a ¾-inch 90° elbow to each end of the galvanized pipe, completely covering the threads on either end.
5. Spray paint the entire debris sample, but not the brick, multiple times to completely disguise the metal galvanized pipe.
6. Drill a pair of holes in the side of each 90° elbow that does not contain the galvanized pipe. Use cable ties through these holes to secure the sample to the brick.

To construct the non-metal sample:

4. Cut an 11.5 cm length of ¾-inch PVC pipe. Attach a ¾-inch 90° elbow to each end of the PVC pipe.
5. Spray paint the entire debris sample, but not the brick, multiple times to completely disguise the PVC pipe.
6. Drill a pair of holes in the side of each 90° elbow that does not contain the ¾-inch pipe. Use cable ties through these holes to secure the sample to the brick.

Design note: Use a black primer spray paint to give a heavy base coat to the debris samples. Finish with a heavy coat of red paint. When the samples are painted, the metal sample and the non-metal sample must be visually identical.

See EXPLORER construction photo #13.

Grid:
The EXPLORER class grid is constructed of ½-inch PVC. The grid is 2.5 m long and 1.5m wide and consists of 0.5 m x 0.5 m squares.

To construct the EXPLORER class grid:

7. Cut sixteen 46 cm lengths of ½-inch PVC pipe.
8. Using the side openings of four ½-inch PVC tees, connect five of these 46 cm lengths of PVC in a line. Repeat this process, connecting five more lengths of pipe with four more PVC tees.

9. Using the side openings of two ½-inch PVC tees, connect three 46 cm lengths of PVC in a line. Repeat this process, connecting three more lengths of pipe with two more PVC tees.

These combined lengths form the outer edge of the grid. The longer lengths should be 2.5m long. The shorter lengths should be 1.5 m long.

See EXPLORER construction photo #14.

10. Attach two ½-inch PVC 90° elbows to the end lengths of PVC on one of the 2.5 m edges of the grid. Attach the side opening of a PVC tee to the end lengths of PVC on the other 2.5 m edge of the grid.
11. Attach the ends of the combined PVC lengths together to form a rectangle approximately 2.5 m long by 2 m wide. All the middle openings of the PVC tees should face inwards.
12. Use two lengths of 2.46 m PVC pipe to connect the tees facing each other on the 2 m sides of the rectangle. Use four lengths of 1.96 m PVC pipe to connect the tees facing each other on the 2.5 m sides of the rectangle.
13. Cut two 1.5 m lengths of PVC pipe. Insert these lengths of pipe into the side openings of the tees at two of the corners of the PVC grid. This 2.5 m edge will be closest to the shipwreck.

The eight debris piles will be placed randomly within the fifteen 0.5 m x 0.5 m squares created by the grid.

See EXPLORER construction photo #15.

Targets:
EXPLORER class targets are constructed from a white, 1 ½-inch PVC end cap with a ring of black, 1 ½-inch ABS set inside the end cap. The back inside surface of the 1 ½-inch end cap will be covered with 1-inch wide, yellow reflective tape (REI online part# 634417, also available at bike shops).

5. Cut a 1 cm length of 1 ½-inch black ABS pipe. Use a saw or heavy wire cutters to cut a 1 mm to 2 mm section from ABS ring.
6. Cut a 4 cm length and two 0.5 cm lengths of 1-inch reflective tape. Attach these lengths of reflective tape to the back, inside surface of the 1 ½-inch PVC end cap.
7. Insert this ABS ring into the end cap, as close to the bottom as possible.

See EXPLORER construction photo #16.

Design note: If ABS is unavailable in your area, cut a 1 cm length of 1 ½-inch PVC and paint it black before inserting it inside the 1 ½-inch PVC end cap.

8. Use screws to fasten the target onto the shipwreck 45 cm from the bottom. Drill a 1/8-inch hole in the center of the PVC end cap and a 1/8-inch hole though the corrugated plastic into a length of PVC 45 cm off the bottom. Use a ¾-inch screw to attach the 1 ½-inch end cap to the PVC pipe.

25 cm to each side of the target will be a black mark. These marks will be 1 cm wide and 4 cm tall and located on the colored corrugated plastic sheet. The marks on the stern of the ship will be black marks on the stern middle cross brace, which is built of ½-inch PVC. The marks will be located 25 cm on either side of the target.

9. Use a black Sharpie or permanent marker to draw the 1 cm x 4 cm mark on the corrugated plastic, 25 cm to each side of the center of the target. Use a black sharpie or permanent marker to draw the mark 25 cm to each side of the target on the stern middle cross bar.

See EXPLORER construction photo #17.

Task #2: Removing fuel oil from the shipwreck

Your company must clear the worksite of debris before attempting to determine if fuel oil remains on board. Clearing the worksite involves removing one of the *SS Gardner*'s masts that had fallen onto an area of the hull above the fuel tanks. Once the mast is removed from the worksite, your company must then clear the hull of encrusting organisms in order to provide a clean, unobstructed working surface. However, one of the organisms is an endangered species of coral. These corals cannot be decimated but rather must be transplanted to a new location.

Examples of coral

Once the hull is clear, your company must confirm the presence of oil within the underlying fuel tank. To accomplish this, your company will use two simulated sensors – an ultrasonic thickness gauge and a neutron backscatter device. The ultrasonic thickness gauge works by measuring the amount of time it

takes for sound waves to travel through the hull and back. It then calculates the thickness based on the speed of the sound through the hull. The readings are instantaneous.

The thickness of the hull is used to calibrate the neutron backscatter device. To assist with calibration, the MATE Center constructed a test or calibration tank and placed in on the bottom near the shipwreck. This tank is filled with oil and water. Based on historical records of the *SS Gardner*, the MATE Center calculated a range of potential thicknesses and constructed the tank so that each wall is a different thickness. The readings from the ultrasonic thickness gauge will determine which wall of the tank should be used to calibrate the neutron backscatter device.

Once calibrated, your company must place the neutron backscatter device on the hull to test for the presence of oil. The device works by emitting high energy neutrons. When a fast neutron collides with a hydrogen atom it releases energy and becomes a slow or thermal neutron. The thermal neutrons are scattered in all directions. Some of these thermal neutrons are scattered back towards and counted by the device. The more hydrogen atoms present in a substance the more thermal neutrons are created and can be detected. Therefore, high readings indicate the presence of oil.

After you complete this task, you can assume that there is oil on board. You can also assume that, because of the deteriorated condition of the hull, you have made the decision to remove the oil. However, it is more complicated than that. Removing the oil is likely to collapse the hull, which could potentially result in damage to the endangered corals and the wreck itself. The survivors and their families are very passionate about the shipwreck. It is your responsibility to keep the wreck site as intact as possible while mitigating the threat of an oil leak.

Your only option is to replace the oil with the surrounding seawater. Your company must penetrate the hull to access the fuel tank, remove the oil, and replace it as you are removing it with seawater. As you are accomplishing this, oil must NOT leak into the environment.

References

- Coral photos http://na.oceana.org/en/category/blog-free-tags/deep-sea-coral and www.esablawg.com/esalaw/ESBlawg.nsf/d6plinks/KRII-7B66S7
- Ultrasonic thickness gauge http://ultrasonicthicknessgauge.org/
- Neutron backscatter device www.scanningtech.com/Neutron_Backscatter.html

This mission task involves:

- **Transporting and attaching a lift bag to a fallen mast.**
- **Inflating the lift bag and removing the fallen mast from the worksite.**
- **Removing endangered encrusting coral from the ship's hull.**

- **Transplanting the coral.**
- **Using two simulated sensors, determine if fuel oil remains inside the fuel tank.**
- **Simulating drilling two holes into the hull and underlying fuel tank by penetrating a layer of petroleum jelly.**
- **Removing fuel oil from within the tank and replacing it with simulated seawater.**
- **Resealing the drill holes with a simulated magnetic patch.**

EXPLORER class scoring – up to 180 points:

- Transporting and attaching a lift bag to the U-bolt on a fallen mast – 10 points
- Inflating the lift bag so that the mast is lifted off the bottom of the pool – 10 points
- Moving the fallen mast so that it does not drag along the bottom of the pool and placing it in a designated area – 10 points
- Removing endangered corals from the hull – 5 points each (10 points total)
- Transplanting the corals to an unoccupied square within the grid – 5 points each (10 points total)
- Using two simulated sensors, determine if fuel oil remains inside the fuel tank – up to 30 points
    - Placing the ultrasonic thickness gauge sensor on the hull – 10 points
    - "Calibrating" the neutron backscatter device by placing it on the calibration tank – 10 points
    - Placing the neutron backscatter device on the hull – 10 points
- Simulating drilling holes into the fuel tank by penetrating layers of petroleum jelly and replacing the fuel oil in the tank with seawater– up to 80 points
    - Seawater begins to flow into the fuel tank – 20 points
    - All of the fuel oil is removed from the fuel tank – 40 points
    - The fuel oil is captured so that it does not leak into the pool – 20 points
- Resealing the drill holes by placing a simulated magnetic patch over each hole – 10 points each (20 points total)

Mission notes

Task #2 must be completed in order. Companies may alternate between task #1 and task #2, but task #2 must be completed in order. Companies may skip any part of task #2, but will not receive points if they complete that part at a later time. All tasks must be completed to receive a time bonus.

The fallen mast will be located against the hull of the shipwreck. EXPLORER class companies must attach a lift bag to a U-bolt on the mast and move the fallen mast to a designated area.

Note: The MATE Center, with support from SUBSALVE USA (www.subsalve.com), will provide a professional SUBSALVE 25 pound lift bag to any EXPLORER class company that requests one. Alternatively, companies are free to engineer or purchase their own lift bag to lift and move the mast to the designated area.

The mast is constructed from1 ½-inch PVC. Cement inside the 1 ½-inch PVC pipe will provide ballast. A U-bolt will be the attachment point for the lift bag.

Once the lift bag is attached, EXPLORER class companies must move the mast and place it in a designated area. The designated area is located on either side of the 2.5 m x 1.5 m grid. When transporting the mast to the designated area, EXPLORER class companies must lift the mast so that it does not drag along the bottom, but do not have to bring the mast all the way to the surface. To successfully move the fallen mast into the designated area, no part of the mast may be touching the grid or shipwreck.

If any part of the mast drifts out of the designated area after being successfully placed, the mission task will be considered incomplete and companies will lose the 10 points that they had been awarded. Companies may attempt to return the mast to the designated area, without penalty, to regain these 10 points. Companies that successfully return the mast to the designated area may still receive a time bonus.

Lift bags must be empty of air before the ROV descends. Companies may evacuate air and fill their lift bag with water during the 5-minute set up period.

The EXPLORER class mast will weigh between 50 and 75 Newtons (between 11 and 16.5 pounds) in water.

After removing the mast from the worksite, EXPLORER class companies must remove encrusting corals from the hull of the shipwreck. These endangered corals must be transplanted into an open grid square. An open grid square is considered a grid square that does not have a debris sample within it. Two corals will be growing on the black ABS sheeting attached to the side of the shipwreck. Both corals will be held onto the side of the hull by Velcro. Both corals must be removed from the hull and placed in an open grid square in order to receive full points for this step and to be eligible for a time bonus. Corals may be placed in the same grid square or different grid squares as needed. Corals do not need to be placed upright within the grid square in order to receive full points. To successfully transplant a coral, no portion of the coral should be touching any part of the PVC grid.

Corals will require less than 1 Newton to detach from the hull of the shipwreck. Corals will weigh less than 1 Newton in water.

After removing both corals from the hull of the ship, companies must gauge the thickness of the hull, use the thickness to calibrate their neutron backscatter device against a calibration tank, and determine if oil remains in the fuel tank using the calibrated neutron backscatter device. Both the ultrasonic thickness gauge sensor and the neutron backscatter device will be simulated.

EXPLORER class companies must create their own simulated sensors. Both simulated sensors may be combined into one unit. Guidelines for creating the sensor are that it must be able to touch the vertical hull of the ship and calibration tank. The sensor must be at least 12 cm long and at least 2 cm in diameter or at least 2 cm x 2 cm square. The sensor should be labeled and identified to the mission station judge during the 5-minute mission set up time.

Once both corals are removed from the hull of the ship, companies must maneuver their vehicle so that the ultrasonic thickness gauge is touching the working surface of the hull of the shipwreck. The working surface of the hull is defined as the 61 cm x 46 cm black ABS sheet. The mission station judge must be able to see through an ROV camera that the ultrasonic thickness gauge sensor is touching this area of the hull for a continuous five seconds. If the sensor comes off of the hull during those five seconds, companies must reposition their vehicle and restart the five second time period. Companies should inform the mission station judge that they are attempting this task and ask the mission station judge to count off the five seconds.

Companies must then pilot their vehicle to the calibration tank to calibrate their neutron backscatter device. The calibration tank is a standard milk crate, approximately 32 cm long, 32 cm wide, and 28 cm tall. The calibration tank will be positioned on the pool bottom within one meter of the working area on the hull of the shipwreck. Companies must maneuver their vehicle so that the neutron backscatter device is touching the wall of the milk crate. The mission station judge must be able to see through an ROV camera that the neutron backscatter device is touching the calibration tank for a continuous five seconds. If the sensor comes off of the calibration tank during those five seconds, companies must reposition their vehicle and restart the five second time period. Companies should inform the mission station judge that they are attempting this task and ask the mission station judge to count off the five seconds.

Once the neutron backscatter device is calibrated, companies can return to the working area of the hull. Companies must maneuver their vehicle so that the neutron backscatter device is touching the working area of the hull of the shipwreck. The mission station judge must be able to see through an ROV camera that the neutron backscatter device is touching the hull for a continuous five seconds. If the sensor comes off of the hull during those five seconds, companies must reposition their vehicle and restart the five second time period. Companies should inform the mission station judge that they are attempting this task and ask the mission station judge to count off the five seconds.

EXPLORER class companies are also tasked with removing, replacing, and collecting the oil from the fuel tank. To prevent the degraded hull from collapsing, EXPLORER class companies must replace the fuel oil with seawater.

The fuel oil will be simulated by pool water colored green and will be located inside a clear tank. The MATE Center will provide simulated seawater to any EXPLORER class companies that wish to use it. The seawater will be simulated by clear saltwater. Companies may provide their own replacement liquid

provided that the liquid contains only water and salt. No other substances may be pumped into the fuel tank or pool.

Companies must access two locations, an inflow port and an outflow port, to effectively remove and replace the simulated fuel oil. Both the inflow port and outflow port are constructed from a 1-inch to ¾-inch PVC reducer bushing. These ports have an outer diameter of 4.2 cm and in inner diameter of 2.6 cm. A lip at the bottom of the bushing has an inner diameter of 2.1 cm. The top edge of both the inflow port and the outflow port will be covered with Velcro loops.

Companies must simulate drilling through the hull by penetrating a layer of petroleum jelly located inside the inflow port and outflow port. The petroleum jelly will be located at the end of each 1-inch to ¾-inch reducer bushing. The layer will be approximately 1 cm to 2 cm thick, will be 2.6 cm in diameter and located 1 cm to 3 cm deep into the reducer bushing. Companies must design a device to penetrate through the petroleum jelly seal on both reducer bushings.

No sharp objects are permitted on the vehicle to puncture through the petroleum jelly. Hypodermic needles, knives, razor blades, etc. are not allowed.

The top edge of both 1-inch to ¾-inch reducer bushings will be covered with Velcro loops.

Design note: Velcro loops are the soft, “wool” side of Velcro.

Any petroleum jelly removed by the vehicle may be left in the pool or returned to the surface with the ROV.

Seawater must be added to the tank through the inflow port. Fuel oil must not leak into the pool, but must be collected from the outflow port.

Companies will receive 20 points once the seawater enters the fuel tank through the inflow port. To receive these points, the mission station judge must be able to see, on a company video display, seawater moving into the fuel tank. Companies will receive an additional 40 points once all of the oil has been removed from the fuel tank. The mission station judge must be able to see, on a company video display, that the entire fuel tank is clear of oil. The judge will inform the pilot when all of the oil has been successfully removed from the fuel tank.

Companies must capture all of the oil that is removed from the fuel tank. Companies may contain the oil onboard their ROV or pump it to the surface. If any of the oil leaks into the pool, companies will not receive points for capturing the oil and will not be able to receive a time bonus.

Once your company is satisfied that you have removed the oil, you must use a magnetic patch to seal both drill holes. Magnetic patches will be simulated by Velcro. EXPLORER class companies must place a Velcro patch over each simulated drill hole.

The Velcro patch will have a diameter of 7.3 cm. The patch must completely cover the entire 4.2 cm diameter of the inflow port and the outflow port.

EXPLORER class companies will be provided with three patches at the mission control shack to patch both openings. If one patch is dropped, EXPLORER class companies may retrieve it from the bottom of the pool, or may return to the surface for another patch. If a second patch is dropped, companies will have to retrieve one of the patches from the bottom of the pool to complete this step of the mission.

EXPLORER companies that do not remove sufficient fuel oil may still receive points for patching the hull. However, once the Velcro patch is placed over the drill holes, companies may not attempt to remove them in order to attempt to remove additional fuel oil. Companies that do not remove all the oil from the fuel tank (and therefore do not receive full points for this task) cannot receive a time bonus.

Mission prop specifications

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

Mast:

The EXPLORER mast is constructed from 1 ½-inch PVC pipe. The mast is 99 cm tall and 71 cm wide. A 2 ½-inch U-bolt will be the attachment point for the lift bag. Six lengths of rope hang from the mast. Cement weights in the bottom of the mast will provide ballast.

To construct the mast:

3. Cut a 70 cm length, two 30 cm lengths, two 20 cm lengths, and a 15 cm length of 1 ½-inch PVC pipe.
4. Take the 15 cm length of 1 ½-inch PVC pipe and drill a pair of 7/16-inch holes. These holes must be spaced approximately 7.5 cm 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 ½-inch U-bolt. The EXPLORER class U-bolt is 8.1 cm wide (ACE Hardware part# **5230214**:3/8-inch x 2 ½-inch x 3 5/8-inch U-bolt). The U-bolt will stick out 7.5 cm from the mast. Use lock nuts to secure the U-bolt in place.

Design note: The 15 cm length of PVC pipe with the U-bolt is recycled from the 2011 EXPLORER class missions. It was used in 2011 as the connection point for lifting the riser pipe off the oil well.

5. Insert the two 20 cm lengths of 1 ½-inch PVC pipe into opposite openings on a 1 ½-inch PVC cross. Insert the 70 cm length of pipe into a third opening of the PVC cross. Insert the 15 cm

length of pipe with U-bolt into the fourth opening of the PVC cross. Adjust the angle of the U-bolt so it is set at a 90° angle from the mast.

6. Attach a 1 ½-inch end cap to the other end of the 15 cm length pipe with the U-bolt. Drill holes into the end cap to allow air to escape from the mast.
7. Attach the middle opening of a 1 ½-inch PVC tee to the other end of the 70 cm length of 1 ½-inch PVC pipe.
8. Attach a 1 ½-inch end cap to one end of each 30 cm length of 1 ½-inch PVC pipe.
9. Fill both 30 cm lengths of PVC pipe with cement. When the cement is dry, insert these 30 cm lengths into the side openings of the 1 ½-inch PVC tee.
10. Add additional cement into the 70 cm length of pipe (companies will have to remove the 70 cm length of pipe from the cross) to achieve the desired weight in water.

The EXPLORER class mast will weigh between 50 and 75 Newtons (between 11 and 16.5 pounds) in water.

11. Drill three 3/16-inch holes in each of the 20 cm lengths of 1 ½-inch PVC pipe (six holes total).
12. Cut six lengths of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**140-287**, ACE Hardware part #**75851**). The lengths of rope should vary from 25 cm to 75 cm long. Insert one end of each length of rope into the holes drilled through the pipe and tie and overhand knot to secure them in place.

See EXPLORER construction photo #18.

Coral:

The coral is simulated using chenille stems (pipe cleaners) set into a ½-inch PVC end cap base.

To construct a coral:

9. Cut three 30 cm long, pink pipe cleaners into six 15 cm lengths. Cut four 30 cm long, white pipe cleaners into eight 15 cm lengths.
10. Drill an 1/8-inch hole 0.5 cm off center in the bottom of a ½-inch PVC end cap. Insert 4 cm of a white pipe cleaner through this hole. Twist the end of the pipe cleaner into an overhand knot so that it is secured in the end cap.
11. Drill a pair of 3/16-inch holes on opposite sides of the wall of the ½-inch PVC end cap. Insert a small cable tie through both holes on the side of the end cap, over the top of the end cap and over the white pipe cleaner coming out the top of the end cap. Pull the cable tie to secure the pipe cleaner tightly against the surface of the end cap.
12. Take a 15 cm length of pink pipe cleaner and twist the middle of it twice around the white pipe cleaner, about 1 cm up from the end cap. 7 cm should extend from each end of the twist.
13. Take two 15 cm lengths of white pipe cleaner and twist the middle of each around either length of the pink pipe cleaner, about 1 cm up from the base.
14. Repeat until all 15 cm lengths of pipe cleaner are used.

15. Bend the ends of all pipe cleaners upwards, away from the end cap.
16. Cut a 3 mm by 4 cm length of Velcro loops. Attach the Velcro strip to the base of the end cap, placing one end approximately 1.5 cm inside the end cap, and the other end outside the end cap.

See EXPLORER construction photo #19.

Coral will be placed onto the working surface (black ABS sheeting) of the shipwreck.

1. Cut two 5 cm x 5 cm lengths of Velcro hooks. Attach the two squares of Velcro to the center of the black ABS sheeting using the adhesive on the back of the Velcro hooks. The two squares should be located approximately 15 cm to 20 cm apart, halfway down the ABS sheet.

Ultrasonic thickness gauge sensor and neutron backscatter devices:
EXPLORER class companies are tasked with building their own simulated ultrasonic thickness gauge sensor and neutron backscatter device. Both simulated sensors may be combined into one unit; in other words, once device can serve as both sensors. The sensor must be able to touch a flat, vertical surface. The sensor must be at least 12 cm long. The sensor must be at least 2 cm in diameter or at least 2 cm x 2 cm square.

EXPLORER class companies may attach the sensors to their vehicle by any method they choose.

Calibration tank:
The calibration tank will be simulated by a milk crate.

3. Use cable ties to attach a 34 cm x 34 cm length of colored corrugated plastic to the top of a milk crate.
4. Turn the milk crate on its side and add sufficient weight to secure it to the bottom of the pool.

The neutron backscatter device must be held to the 34 cm x 34 cm sheet of corrugated plastic surface for five seconds.

Design note: Check sign-making/printing stores for colored corrugated plastic sheeting. Alternatively, use 1/8-inch black ABS sheeting, Plexiglas or Lexan.

Fuel Tank:
The fuel tank is simulated by two clear Lexan sheets around a rectangle of ½-inch PVC.

To construct the tank:

1. Cut two Lexan sheets 20 cm x 12.5 cm. Smooth or snip the corners off for safety.
2. Cut two 15 cm lengths and two 7 cm lengths of ½-inch PVC pipe.

3. Attach two ½-inch 90° elbows to both sides of a 7 cm length of pipe. Adjust the angle of the elbows so both opening face the same direction.
4. Drill five ¼-inch holes into the inside edge pipe and 90° elbows.
5. Insert both 15 cm lengths of ½-inch PVC pipe into the openings of the two 90° elbows. Attach the side opening of a PVC tee to the other end of each 15 cm length of pipe. Face the two middle openings of the PVC tee towards each other.
6. Take the remaining 7 cm length of PVC pipe and tape over one end. Use 5-minute or other epoxy to form a 1 cm long plug in the taped end of this 7 cm length of pipe. Once the epoxy has dried, remove the tape.
7. Drill three ¼-inch holes into the 7 cm length of pipe. Insert the pipe between the two PVC tees in the tank framework. Rotate pipe so that the drill holes are along the inside edge of the framework.

See EXPLORER construction photo #20.

The dimensions of the PVC framework rectangle should be approximately 21.5 cm x 13.5 cm. The Lexan sheets fit over both sides of this framework and are waterproofed with caulking or silicone.

1. Cover one edge of the framework completely with a thick ring of caulking or silicone. Press one 20 cm x 12.5 cm sheet of Lexan into the caulking or silicone.
2. Secure the Lexan to the PVC framework with four sheet metal screws.
3. Cover the other edge of the framework completely with a thick ring of caulking or silicone. Press the other 20 cm x 12.5 cm sheet of Lexan into the caulking or silicone.
4. Secure the Lexan to the PVC framework with four sheet metal screws.

Design note: Properly placing the 8 screws (4 per side) will allow you to secure the four lengths of PVC pipe into the elbows and tees.

Allow the caulking or silicone to dry overnight. Test to insure the tank is watertight. Add additional caulking or silicone as necessary to make the tank watertight.

To construct the inflow port and outflow port:

1. Cut a 10 cm length of ½-inch PVC pipe.
2. Attach a 1-inch to ½-inch reducer bushing (Home Depot part# 438-130HC, DuraPlastics Online #C437-130) to one end of the 10cm length of pipe.
3. Attach a 1-inch coupling to the reducer bushing. Insert a 1-inch to ¾-inch reducer bushing (Home Depot part #437-131HC, Home Depot Online part# C437-101, Home Depot SKU# 188042, DuraPlastics Online #C437-131) into the other side of the 1-inch PVC coupling.
4. Spray paint the 1-inch coupling of the inflow port green. Spray paint the 1-inch coupling of the outflow port silver.

5. Cut Velcro strips and cover the entire top surface of the 1-inch to ¾-inch reducer bushing with Velcro wool.
6. Use PVC glue to secure the reducer bushings and couplings together.

See EXPLORER construction photo #21.
See EXPLORER construction photo #22.

7. Add a layer of petroleum jelly (Vaseline) to the 1-inch to ¾-inch reducer bushing. The petroleum jelly should completely fill the entire diameter of the bushing and should be 1.5 cm to 2 cm thick.

The fuel tanks will hold less than 1.5 liters of green colored water.

Design note: Check pharmacies/drug stores for petroleum jelly.

Fuel oil and seawater:
For the fuel oil, add 8 drops of green food coloring per 1.0 liters of water. The simulated seawater provided by the MATE Center will have 125ml (1/2 cup) of salt per liter of water.

Patch:
The contact surface of the patch is constructed from a 3-inch knockout cap (Home Depot part# 39102, SKU#508260, Home Depot online# 39102) covered with Velcro hooks.

To construct the patch:

8. Use heavy wire cutters or dykes to cut the pull tab from the 3-inch knockout cap.
9. Place the top of a ½-inch PVC end cap onto the center of the bottom side (non pull tab side) of a 3-inch knockout cap.
10. Use two #6 ½-inch sheet metal screws to secure the end cap onto the 3-inch knockout cap. The heads of the screws should be on the top side flat, 7.3 cm side of the knockout cap (the side the pull tab was removed from).
11. Cut an 8 cm length of ½-inch PVC and insert it into the end cap.
12. Drill a pair of 3/16-inch holes in the 8 cm length of pipe approximately 0.5 cm from the end.
13. Cut a 20 cm length of 1/8-inch braided nylon and polypropylene rope. Insert one end of the rope through a drill hole from the outside to the inside of the pipe. Tie an overhand knot to secure the rope inside the pipe. Insert the other end of the rope through the other drill hole, from the outside to the inside of the pipe. Tie an overhand knot to secure the rope inside the pipe.
14. Cover the entire top of the 3-inch knockout cap, including the heads of the sheet metal screws, with Velcro hooks.

See EXPLORER construction photo #23.