EXPLORER PROP BUILDING INSTRUCTIONS & PHOTOS

Companies should be aware that tolerances in lengths of cut pipe and length of pipe inserted into joints can change the overall dimensions of product demonstration tasks. Certain non-critical dimensions may be changed to better work within the pool venue. Companies should expect tolerances in all product demonstration props, and should build their ROVs and tools accordingly. In no case should the dimensions given in this document for a product demonstration prop be used to calibrate a length measuring device.

Home Depot part numbers are given for certain construction items. However, some Home Depot stores may not carry the listed items. If the local Home Depot does not carry the part in question, MATE recommends checking other local hardware stores or online sources, such as those listed below, for the required component.

http://www.pvcfittingsonline.com/
http://pvcpipesupplies.com/pvc-fittings/schedule-40-pvc-fittings/

Task 1: Outer Space: Mission to Europa

Vent

The vent is constructed using ¾-inch PVC pipe set inside a 5-gallon bucket. A hose will carry water into the vent-pipe (opening) at the bottom of the 5-gallon bucket (vent structure). Water will exit out of a ¾-inch PVC connector that is set upright in the exact center of the 5-gallon bucket lid. A MATE temperature probe is set approximately 4 cm down inside the ¾-inch connector. To construct the vent:

1. Use a 1-inch hole saw to drill a hole in the side wall of the bucket at the bottom. Drill a second 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 other tools. The hole should be large enough to allow ¾-inch pipe to fit through it.
2. Cut a 30 cm length of ¾-inch PVC pipe. Insert the 30 cm length of pipe through the hole in the side wall of the bucket. Attach a ¾-inch 90^{o} elbow to the end of the pipe inside the bucket. Position the 90^{o} elbow so it is at the bottom center of the 5-gallon bucket. Attach a ¾-inch slip FHT PVC hose to pipe adapter fitting (Home Depot part #53360, internet #100130381, Store SKU #685707) to the end of the pipe outside the bucket.
3. Cut a 32 cm length of ¾-inch PVC pipe. Insert this 32 cm length of pipe into the other end of the ¾-inch 90^{o} elbow inside the 5-gallon bucket. The length of this pipe should stick straight up. Put the lid on the bucket. The ¾-inch PVC pipe should fit through the hole in the center of the bucket lid. Attach a ¾-inch PVC coupling to the top of the ¾-inch PVC pipe.

A temperature probe will allow the MATE Center to measure the temperature of the vent for comparison. The MATE Center temperature probe will sit 4 cm inside the ¾-inch PVC coupling. To add a temperature comparison probe:

4. Drill a hole 4 cm below the top of the ¾-inch PVC coupling. Insert the temperature probe into the hole and secure it in place.

EXPLORER product demonstration build photo #1: 5-gallon bucket with hole drilled through the side wall. 5-gallon bucket lid with hole drilled into center.

EXPLORER product demonstration build photo #2: Water bearing ¾-inch pipe.

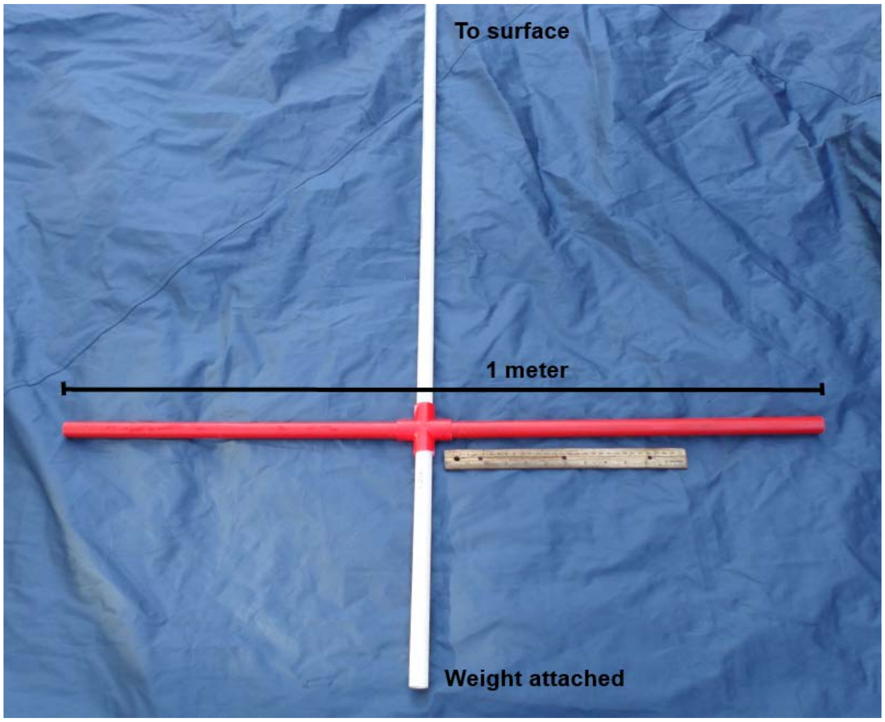
EXPLORER product demonstration build photo #3: Completed vent structure with MATE temperature probe inserted into the pipe.

Depth markers

There are two depth markers. One depth marker will denote the bottom of the ice sheet and will be painted red. The other depth marker will denote the highest point on the sea floor and will be painted yellow. To construct the depth marker denoting the bottom of the ice sheet:

1. Cut two 47 cm lengths of ½-inch PVC pipe. Insert both lengths of pipe into two opposite openings of a PVC cross. Paint the pipe and PVC cross red.
2. Cut a length of pipe between 1 and 6 meters in length. Insert this length of pipe into an opening of the PVC cross. Attach a 90^{o} elbow to the other end of the 1 to 6 meter length of PVC pipe.
3. Cut a 30 cm length of PVC pipe. Insert this pipe in the final opening of the PVC cross. Attach weights to this 10 cm length of pipe to provide ballast. The weights will hold this end of the cross down and keep the side openings with the red PVC lengths horizontal.
4. Cut a 100 cm length of ½-inch PVC pipe. Insert this pipe into the 90^{o} elbow at the top of the 1 to 6 meter length of pipe. Attach the middle opening of a PVC tee to the other end of the 100 cm length of pipe. Cut two 30 cm lengths of pipe and insert them into the side openings of the PVC tee.
5. Screw all joints together to keep the structure secure.

The 100 cm and two 30 cm lengths of pipe are located on the surface, side of the pool. Use weights to hold them in place so the structure does not move. The 1 to 6 meter length of pipe will descend into the pool. The red painted pipe should be horizontal and flush against the wall of the pool.

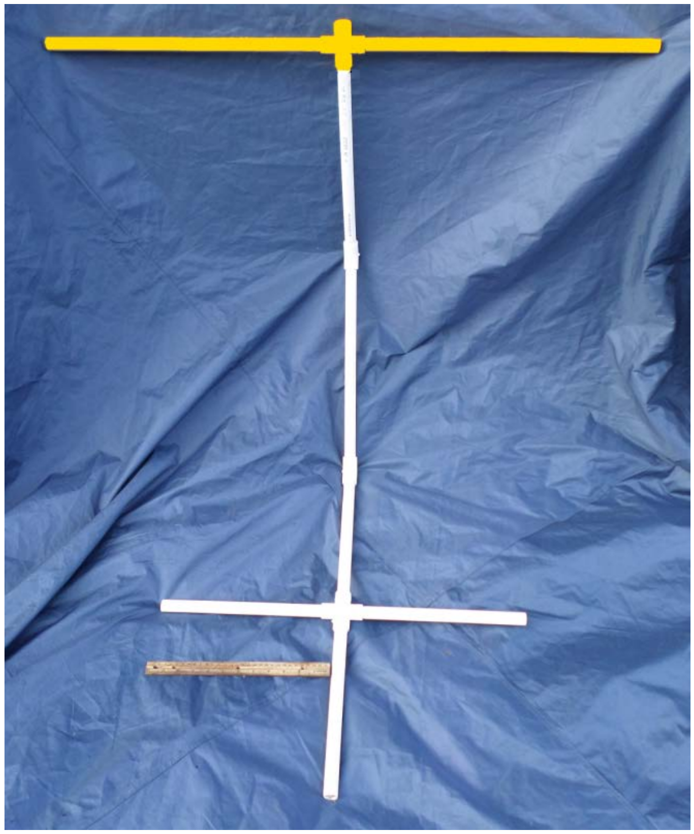


EXPLORER product demonstration build photo #4: The mark denoting the bottom of the ice sheet.

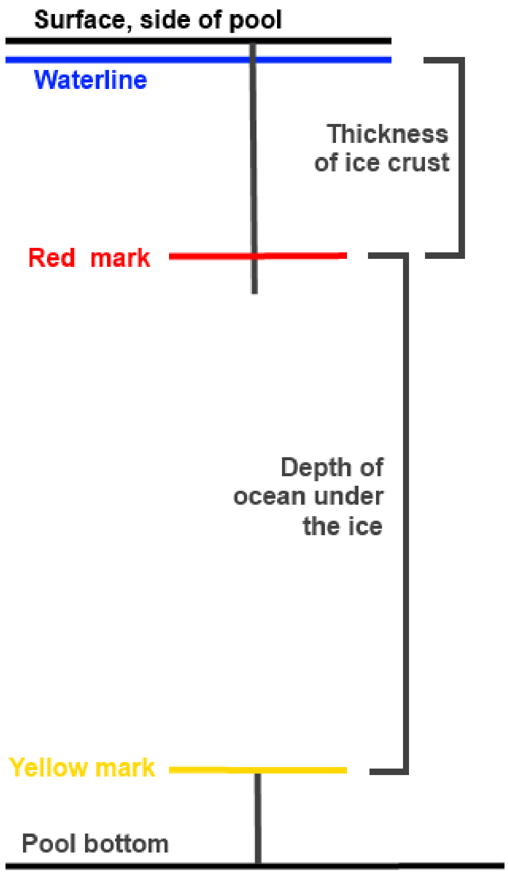
The depth marker denoting the highest point on the seafloor will rise from the pool bottom. To construct the lower depth marker:

6. Cut two 47 cm lengths of ½-inch PVC pipe. Insert both lengths of pipe into two opposite openings of a PVC cross. Paint the pipe and PVC cross yellow.
7. Cut four 30 cm lengths of ½-inch PVC pipe. Insert all four 30 cm lengths of pipe into the four openings of a different PVC cross. Attach a 45^{o} elbow to the end of one 30 cm length of pipe.
8. Cut a length of pipe between 40 cm and 60 cm. Insert the length of pipe into the 45^{o} elbow. Attach another 45^{o} elbow to the other end of this length of pipe.
9. Cut a length of pipe between 40 cm and 60 cm. This does not need to be the same length as the previously cut pipe (step 8). Insert the length of pipe into the 45^{o} elbow. Twist the two 45^{o} elbows so this length of pipe is turned upwards.
10. Attach the cross and pipes painted yellow to the other end of the upwards turned pipe.
11. Screw all the joints together to keep the structure secure.

The yellow mark should be flush against the wall of the pool. Use weights to keep the structure from moving on the bottom.



EXPLORER product demonstration build photo #5: The mark denoting the seafloor.



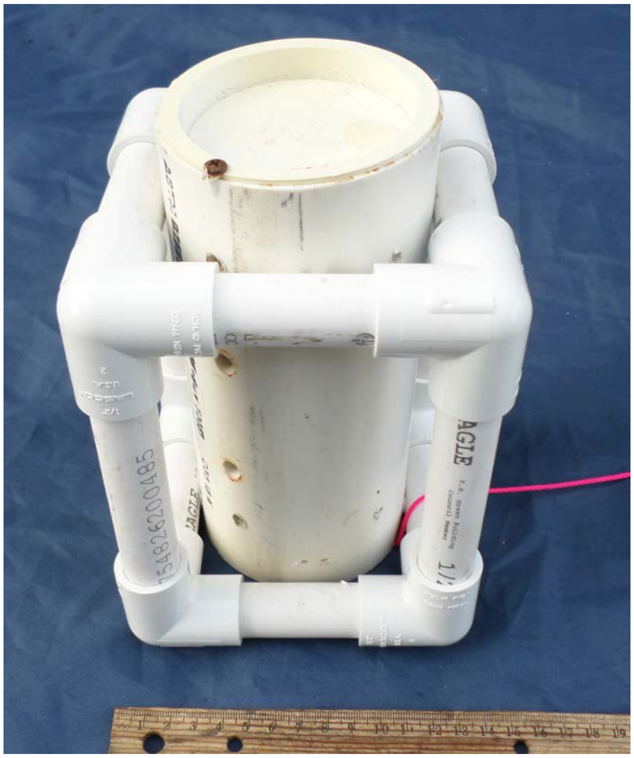
RANGER product demonstration build graphic: A depiction showing the measurements to determine the thickness of the ice sheet and the depth of the ocean under the ice.

Environmental Sample Processor and Elevator

The Environmental Sample Processor is constructed from a 3-inch PVC pipe with a ½-inch framework around it. To construct the ESP:

1. Cut four 7.5 cm lengths of PVC pipe. Use four ½-inch side outs in combination with the 7.5 cm lengths of pipe to create a square. Make sure the remaining openings on the side outs all face the same direction.
2. Cut four 12 cm lengths of pipe. Insert a 12 cm length of pipe into each open end of the four side outs.
3. Repeat step 1 to make a second square of ½-inch PVC pipe and side outs. Attach this square to the four ends of the 12 cm lengths of PVC pipe.
4. Cut a 20 cm length of 3-inch pipe. Insert this pipe between the ½-inch PVC framework. One end of the 3-inch pipe should be flush with one side (the bottom) of the PVC framework. The other end of the 3-inch pipe should stick up approximately 3 cm from top of the framework.
5. Use 2-inch screws to secure the 3-inch pipe into the framework.
6. Insert a 3-inch knock out cap (Home Depot part #39102, internet #100122751, Store SKU #508260) into the top end of the 3-inch pipe.

7. Cut an 8 meter length of 1/8-inch polypropylene rope (Home Depot part #72402, internet #205804755, Store SKU #402816). Tie the rope securely around one 12 cm length of ½-inch pipe.

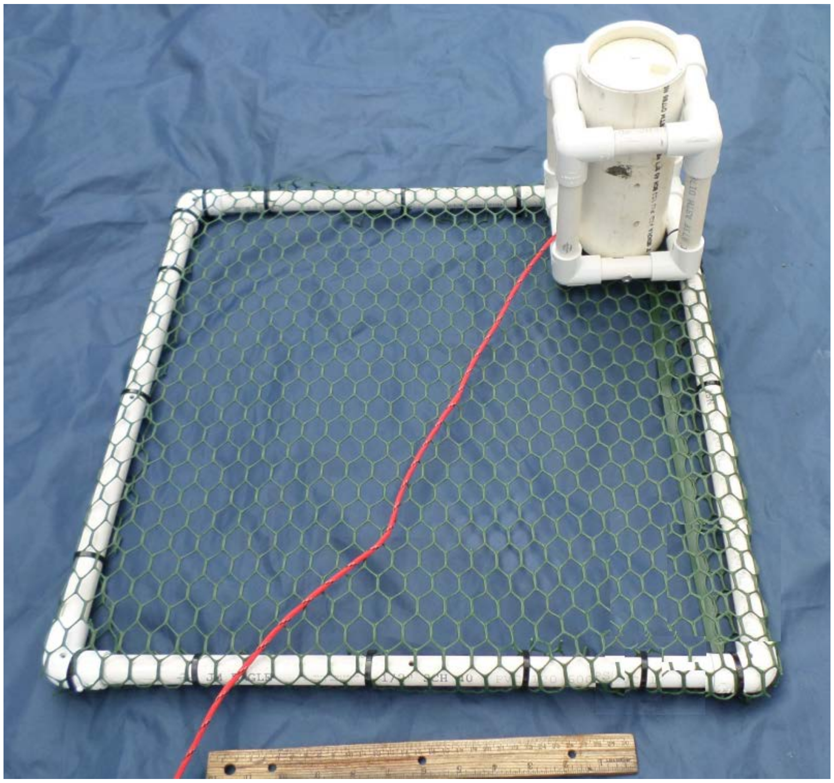


EXPLORER product demonstration build photo #6: The Environmental Sample Processor.

Design note: If you use side outs that are threaded in one opening, you will need to insert male adapters into those threaded openings. Make sure the threaded openings are open ends after creating the squares (step 1 and step 3). To compensate for the extended length, you will need to reduce the length of the 12 cm pipe. The entire length of the framework should be approximately 18 cm.

To construct the elevator:

1. Cut four 47 cm lengths of ½-inch PVC pipe. Use four ½-inch 90^{o} elbows to create a PVC square approximately 50 cm long on each side.
2. Cut a 60 cm x 60 cm square of plastic mesh (Home Depot part #090786, internet #100384027). Cover the top of the elevator with pipe, bending the sides of the mesh around the pipe and securing the mesh to the 50 cm square of pipe with zip ties. Design note: You want a smooth, top surface of the elevator so that the rope does not tangle on cut edges of the mesh. You may need to cut the corners of the mesh or snip off any excess once it is secured to the pipe of the elevator.
3. Use zip ties to secure the bottom of the ESP into one corner of the elevator.



EXPLORER product demonstration build photo #7: The elevator with the ESP attached.

Design note: Use rebar inside the ½-inch pipes of the elevator, or use dive weights, to keep the elevator stationary on the bottom of the pool.

Cable Connector

The cable connector is constructed from 1 ½-inch PVC pipe. A screw hook and a screw eye act as grab points for the cable connector. 8 meters of rope attach the cable connector to the ESP. To construct the cable connector:

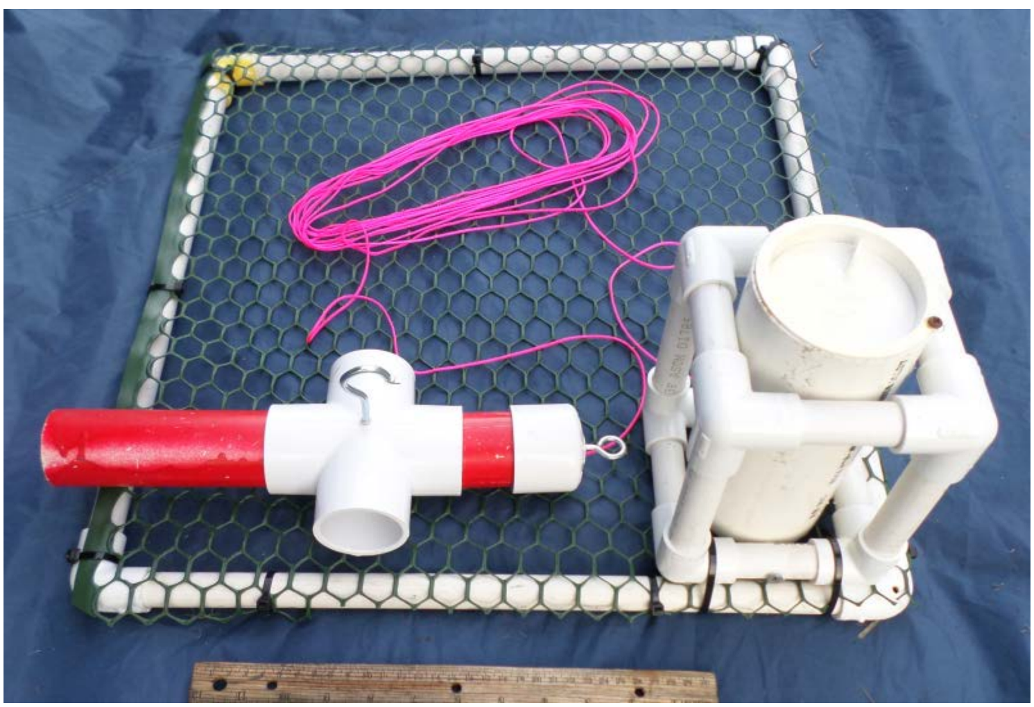
1. Cut a 16 cm length of 1 ½-inch PVC pipe. Insert it into one opening of a 1 ½-inch PVC cross.
2. Cut an 8 cm length of 1 ½-inch PVC pipe. Insert it into the opposite opening of a 1 ½-inch PVC cross. Attach a 1 ½-inch end cap to the other end of this 8 cm length of PVC pipe.
3. Drill a 3/16 hole in the center of PVC end cap. Twist a #6 screw eye (Home Depot part # 803682, internet #204273860, Store SKU #727432) into the center hole until all but 1 to 3 mm of threads are inside the plastic of the end cap. The eye should be horizontal, parallel to the side openings of the central PVC cross.
4. Drill a 1/8-inch hole half way between the center of the end cap and the bottom edge of the end cap. Insert the remaining end of the 8 meters of rope (the other end of the rope is attached to the ESP) into this hole. Tie an overhand knot in the end of the rope to secure it inside the end cap.
5. Screw a #8 screw hook (Home Depot part #803272, internet #204273853, Store SKU #727320) into the top center of the 1 ½-inch plus. Insert the screw hook until all but 1 to 3 millimeters of

thread are visible. Twist the screw hook until the top end faces the back of the cable connector, the 1 ½-inch end cap.

EXPLORER product demonstration build photo #8: The cable connector.

Design note: The insertion tip of the cable connector will be beveled to a 45^{o} angle (not shown in photo) to allow for easier inserting into the power and communications port.

The cable connector is placed on the elevator in a corner adjacent to the ESP. The 8 meters of cable (rope) should be coiled neatly on the remaining open section of the elevator.



EXPLORER product demonstration build photo #9: The ESP, cable connector and 8 meters of coiled line on the elevator.

Power and Communications Hub

The power and communications hub is constructed from a milk crate. The door to the hub is constructed from corrugated plastic sheeting. The port on the power and communications hub is constructed from 2-inch PVC pipe.

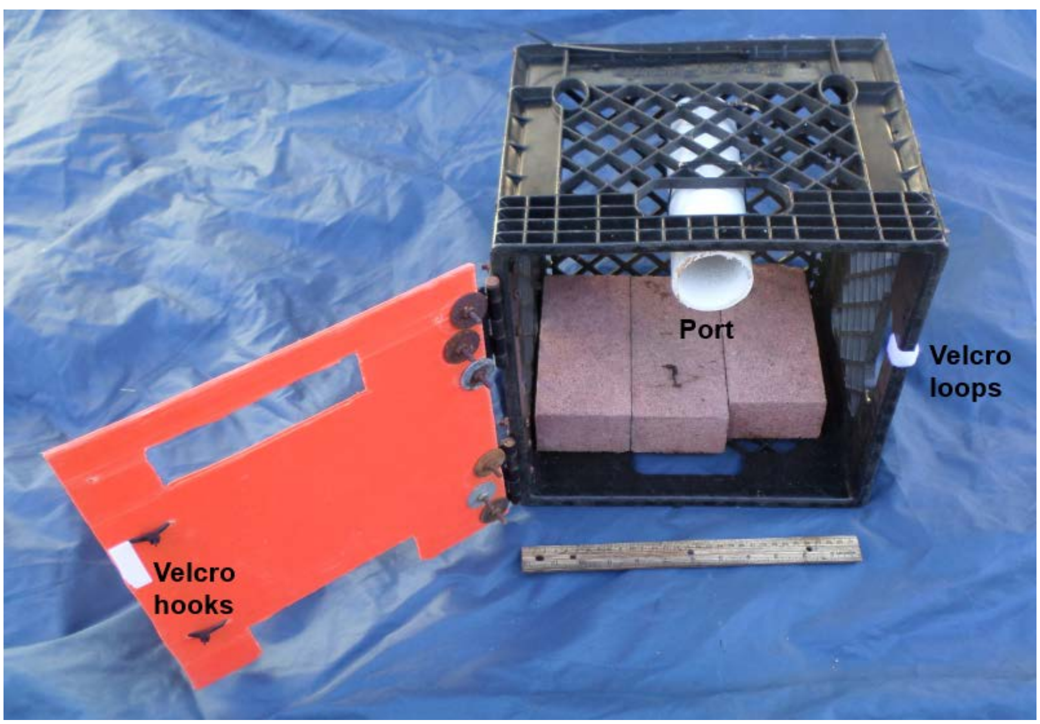
Design note: The power and communications hub is based off the cargo container from the 2014 MATE competition. Remove the locking mechanism and stand from the 2014 cargo container and cut off 2 cm from the bottom of the corrugated plastic sheet making up the door (so the door opens easily without impacting the bottom of the pool).

To construct the power and communications hub:

1. Cut a 32 cm by 30 cm sheet of corrugated plastic. Position the corrugated sheet at the top of the open side of the milk crate. Use two 3-inch brass hinges to secure the corrugated plastic sheet over the open side of the milk crate. There should be a 2 cm gap at the bottom of the open side of the milk crate, so when the door opens, it does not impact the pool bottom.
2. Position the hinges along the edge of the milk crate and drill holes into the plastic of the milk crate and into the corrugated plastic.
3. Use #10-24 1-inch long bolts instead of the screws that come with the hinges. This will eliminate the sharp points of the screws and allow for tighter connections with the plastic. Use a 10-24 nut to secure the bolts through the hinges. When attaching the bolts through the corrugated plastic, use a 1 ¼-inch x ¼-inch fender washer on the two outside bolts of each hinge. This will increase the surface area against the corrugated plastic and prevent damage.
4. Cut a 9 cm length of ½-inch PVC pipe. Attach a ½-inch 90^{o} PVC elbow to each end. Drill two 5/32-inch holes into the open end of each 90^{o} PVC elbow. This is the handle to open the corrugated plastic top of the power and communications hub.
5. Place the handle on the side of the corrugated plastic opposite the hinges, 3 cm from the edge of the plastic. The handle should be positioned so the open ends of the 90^{o} PVC elbow are flat against the corrugated plastic and the handle is located centrally between the two holes cut into the corrugate plastic.
6. Drill four holes into the corrugated plastic, each one adjacent to the holes drilled into the open end of the 90^{o} PVC elbow. Insert cable/zip ties through the holes of each 90^{o} PVC elbow, through the holes in the corrugated plastic. Tighten the ties to secure the handle to the corrugated plastic.
7. Cut a 5 cm x 1 cm length of Velcro hooks and a 5 cm x 1 cm length of Velcro loops. Attach the Velcro loops around open end of the milk crate on the opposite wall from the hinges. Attach the Velcro hooks to the inside of the door so that when the door is closed, the Velcro hooks attach to the Velcro loops.
8. Cut a 20 cm length of 2-inch PVC pipe. Insert a 2-inch knock out cap (Home Depot model #39101, Internet #100137732, Store SKU #508257) into one end of the 20 cm length of pipe. Use glue or screws to secure the knock out cap into the 2-inch pipe.

9. Use zip tie to secure the 2-inch pipe to the inside, center, top of the milk crate. The open end of the pipe should be facing the door and flush with the opening of the milk crate.

EXPLORER product demonstration build photo #10: The power and communications hub with the door closed.



EXPLORER product demonstration build photo #11: The power and communications hub with the door opened, exposing the 2-inch port.

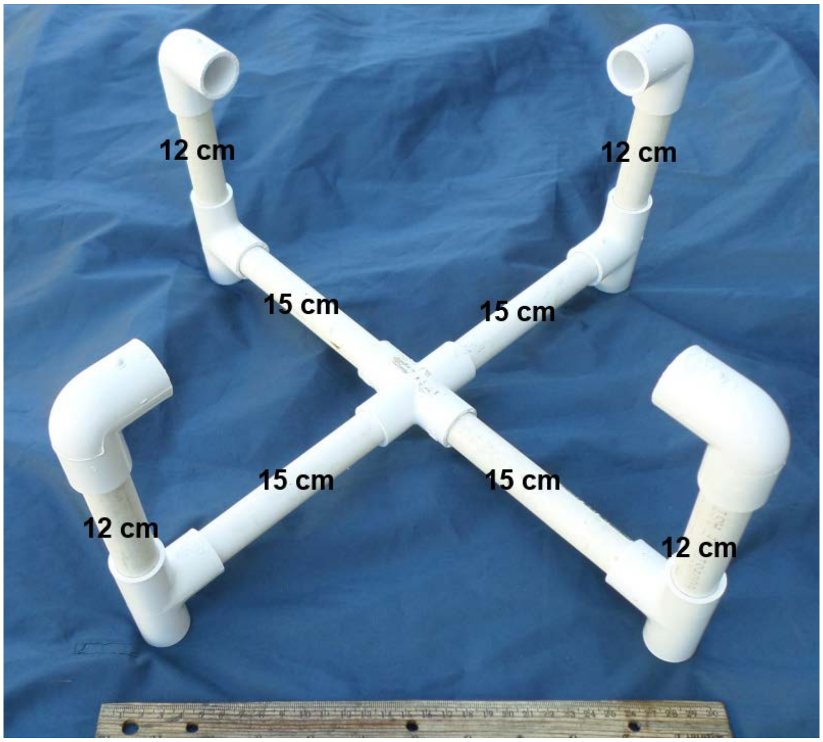
Design note: The rectangular openings on the corrugated plastic door are optional. They are remnants from the 2014 competition props.

EXPLORER product demonstration build photo #12: The cable connector successfully inserted into the port on the power and communications hub.

Waypoint

The three waypoints are constructed from ½-inch PVC pipe. To construct a waypoint:

1. Cut four 15 cm lengths of ½-inch PVC pipe. Insert the four lengths of pipe into the four openings of a ½-inch PVC cross. Attach the middle opening of a PVC tee to the other end of each 15 cm length of pipe, 4 tees total. Rotate the tees so they are perpendicular to the cross.
2. Cut four 12 cm lengths of ½-inch PVC pipe. Insert the four lengths of pipe into one side opening of the four PVC tees. All four lengths of pipe should be on the same side of the waypoint. Attach a ½-inch 90^{o} PVC elbow to the other end of each 12 cm length of pipe. Rotate the open ends of the elbow to face the PVC cross in the center.



EXPLORER product demonstration build photo #13: A waypoint.

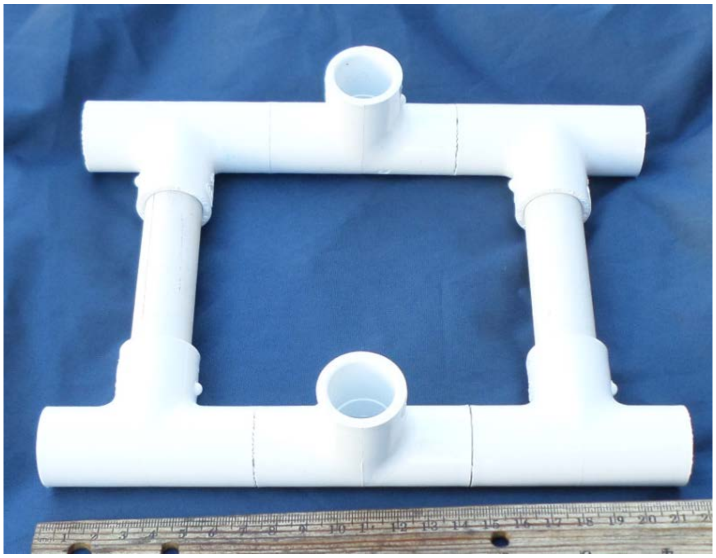
Use dive weights to secure the waypoints to the bottom of the pool.

Task 2: Inner Space: Mission-critical equipment recovery

Cube Sats

The Cube Sats are constructed from ½-inch PVC pipe and corrugated plastic sheeting. All eight Cube Sats are identical in construction, but each will have a different serial number. To construct a Cube Sat:

1. Cut two 3 cm lengths of ½-inch PVC pipe. Insert these two lengths into the two side openings of a ½-inch PVC tee. Attach the side opening of another PVC tee to the end of each 3 cm length of pipe. This will give you three ½-inch tees in a row.
2. Cut two 10 cm lengths of ½-inch PVC pipe. Insert the lengths of 10 cm pipe into the middle opening of the two PVC tees on the ends of the row.
3. Repeat step 1 to create a second set of three PVC tees in a row.
4. Attach the middle openings of the two PVC tees on the ends of the row to the other ends of the 10 cm lengths of pipe. This should create a ½-inch PVC rectangle approximately 21 cm by 17 cm. Set the rectangle flat on the ground and rotate the middle opening of the two middle tees so the opening faces up.
5. Repeat steps 1 through 4 to create the other end of the Cube Sat.



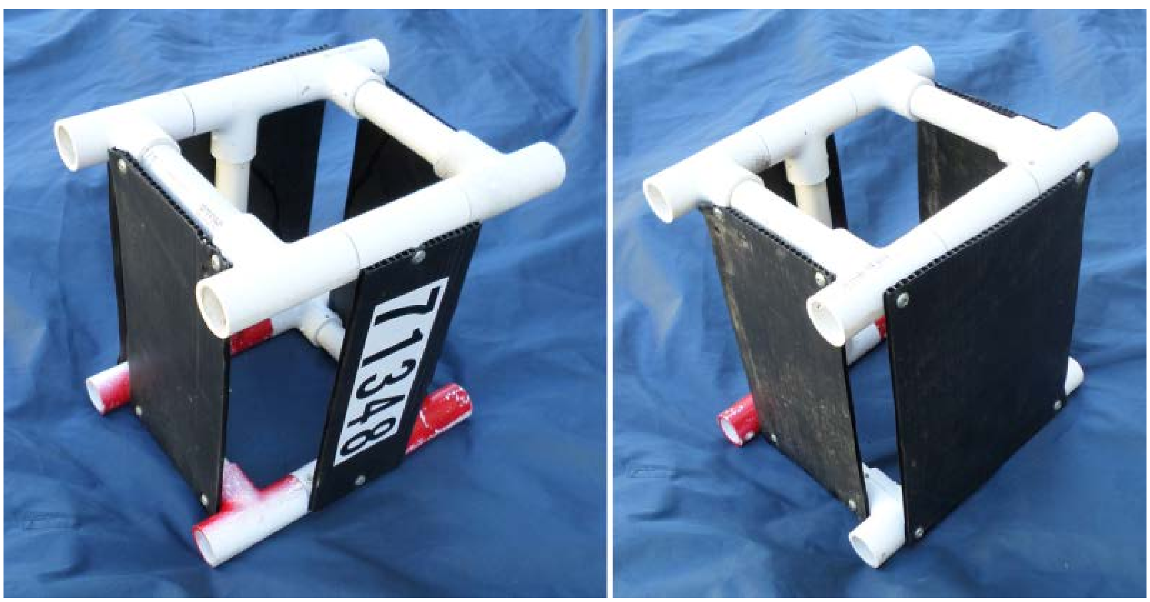
EXPLORER product demonstration build photo #14: One end of a Cube Sat.

6. Cut two 16 cm lengths of ½-inch PVC pipe. Insert these lengths of pipe into the middle openings of the two PVC tees on one end of the Cube Sat. Attach the middle openings of the PVC tees of the other end of the Cube Sat to the 16 cm lengths of pipe. This should create a rectangular prism 21 cm x 17 cm x 23 cm.

EXPLORER product demonstration build photo #15: The framework of a Cube Sat.

7. Cut four rectangles from corrugated plastic sheeting. One rectangle should be 20 cm x 8 cm. One rectangle should be 21 cm x 16 cm. The remaining two rectangles should be 21 cm x 11 cm.
8. Attach the 21 cm x 16 cm rectangle of corrugated plastic sheeting onto one side of the Cube Sat with the 16 cm length of PVC pipe running down the center. Use screws to secure all four corners of the plastic rectangle to the Cube Sat framework.
9. Attach the 20 cm x 8 cm rectangle of corrugated plastic sheeting onto the opposite side of the Cube Sat. This side will also have the 16 cm length of PVC pipe running down the center. Use screws to secure the rectangle at both ends.
10. Attach the two 21 cm x 11 cm rectangles of corrugated plastic sheeting onto the two opposite open sides of the Cube Sat. Secure the plastic sheets to the PVC framework with screws.
11. Using 2-inch, black on white lettering (Home Depot part #842282, Internet #100186676, Store SKU #836196), attach the serial number to the outside of the 20 cm x 8 cm rectangle of corrugated plastic sheeting.

Repeat these steps to create eight Cube Sats, each with a distinct serial number. Serial numbers at the international competition will be five digits long and may include numbers and letters. Serial numbers at regionals may be different. The serial number does not matter, as long as each CubeSat has a different set of numbers.



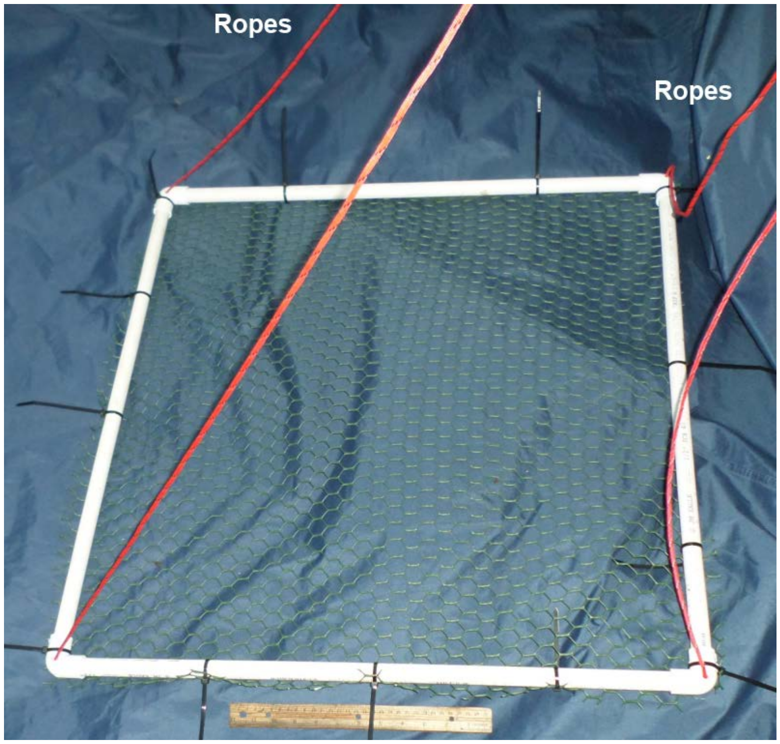
EXPLORER product demonstration build photo #16: A finished Cube Sat, serial #71348, from two angles.

Lift Basket

The lift basket is constructed from ½-inch PVC pipe and plastic mesh. To construct the lift basket:

1. Cut four 72 cm lengths of ½-inch PVC pipe. Use four ½-inch 90^{o} elbows to create a square that is 75 cm per side.
2. Cut a 77 cm x 77 cm square of plastic mesh (Home Depot part #090786, internet #100384027). Use zip ties to attach the square of plastic mesh to the 75 cm PVC square.

3. Cut four 2 meter lengths of 1/8-inch polypropylene rope (Home Depot part #72402, internet #205804755, Store SKU #402816). Drill a 3/16-inch hole into each 90^o elbow at the corners of the PVC square. Insert a 2 meter length of rope into each hole. Tie an overhand knot to secure the rope inside the elbow.
4. Bring the four loose ends of the ropes together and tie a knot to secure them. Attach a small float to keep the ropes suspended above the lift basket.



EXPLORER product demonstration build photo #17: The lift basket for the four mission-critical Cube Sats. Ropes at each corner come together at a float above the lift basket.

Use rebar inside the PVC pipes or dive weights to secure the lift basket to the bottom of the pool.

Task 3: Inner Space: Forensic Fingerprinting

Oil mat

The oil mats are constructed from a 5-gallon bucket lid painted black or brown. Six oil samples will sit on top of the 5-gallon bucket lid. To construct the oil mat, paint the top side of one 5-gallon bucket lid black. Paint the top side of another 5-gallon bucket lid brown.

Oil samples

The oil samples are constructed from 1-inch PVC pipe and end caps. The oil samples are painted black or brown; black oil samples will be located on the black oil mat, brown oil samples will be located on the brown oil mats. There will be six oil samples located on each oil mat. To construct an oil sample:

1. Cut a 14 cm long length of 1-inch PVC pipe. Attach a 1-inch PVC end cap to each end of the pipe. Drill a 3/16-inch hole in the middle of each end cap to allow water to enter and drain the PVC pipe.

Construct twelve oil samples total. Paint six oil samples black, paint six oil samples brown. Place the six appropriately colored oil samples on each 5-gallon bucket lid.

EXPLORER product demonstration build photo #18: An oil sample.

EXPLORER product demonstration build photo #19: Black oil mat with six oil samples.

Design note: The end caps should not be tightly secured onto the ends of the 1-inch pipe. The end caps should be easy to pull off the pipe by hand.

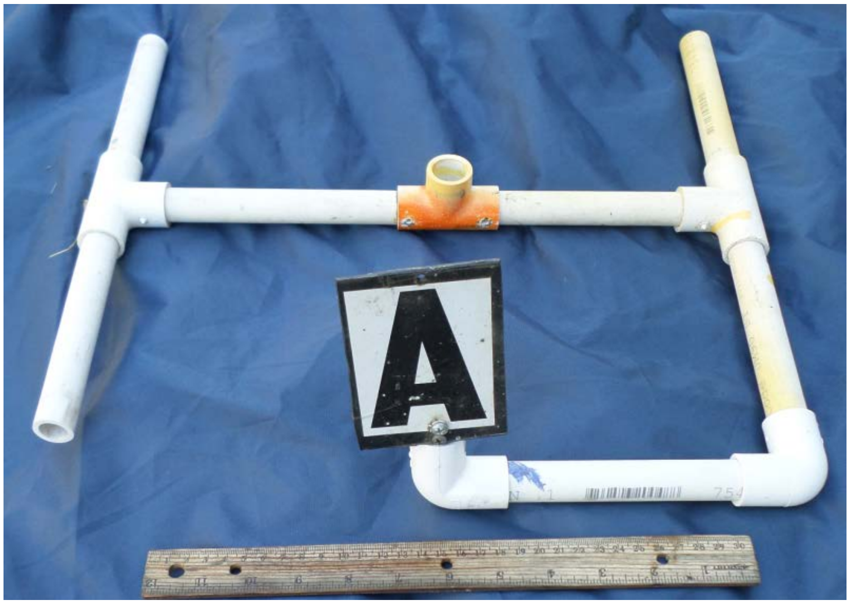
A gas chromatograph will be rolled up inside each oil sample. The gas chromatograph will be printed on a laminated sheet approximately 22 cm by 14 cm. Examples of gas chromatographs can be seen in the **EXPLORER Oil Fingerprint Handbook**.

Task 4: Inner Space: Deepwater coral study

***Paramurice* Coral Base**

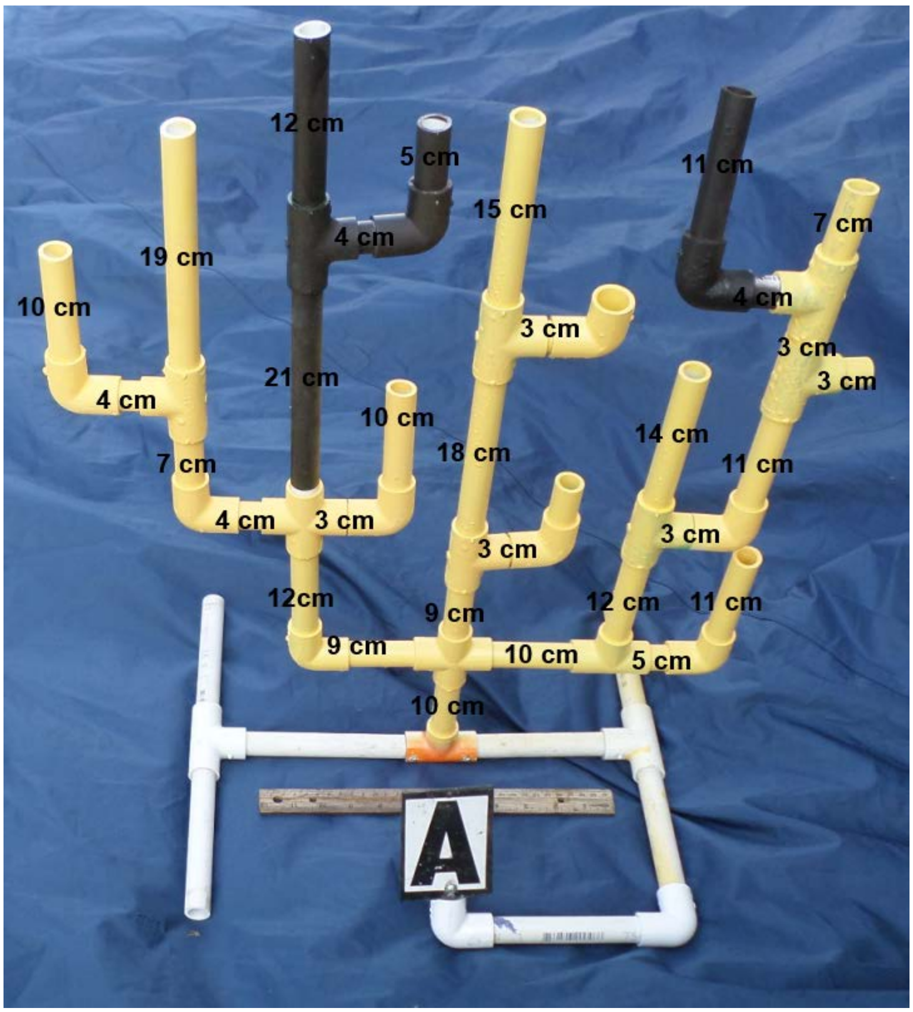
The base of the *Paramurice biscaya* coral colony is constructed from ½-inch PVC pipe. This base holds the coral colony upright, but is not included in the colony growth or colony decrease in size. To build the coral colony base:

1. Cut two 18 cm lengths of ½-inch PVC pipe. Insert these two lengths into the side openings of a PVC tee. Attach the middle opening of a tee to the other end of each 18 cm length of pipe, two tees total.
2. Cut four 15 cm lengths of ½-inch PVC pipe. Insert the four lengths of pipe into the side openings of the two PVC tees. Attach a single PVC 90° elbow to the end of one 15 cm lengths of pipe (it does not matter which length of pipe). Twist the middle tee so the middle opening is facing upwards.
3. Cut an 18 cm length of ½-inch PVC pipe. Insert it into the open end of the 90° elbow. Attach another ½-inch PVC 90° elbow to the end of the 18 cm length of pipe. Cut a 6 cm length of pipe and insert it into the open end of the 90° elbow.
4. Cut a 10 cm by 7 cm rectangle of flat plastic sheeting. Attach a 3-inch letter A or B (Home Depot model #847015, Internet #202982489, Store SKU#881277) to the rectangle of black plastic. Secure the rectangle to the 6 cm length of pipe so the letter is right side up and the letter facing outwards.



EXPLORER product demonstration build photo #20: The base of the coral colony.

Paramurice Coral
The *Paraurice biscaya* coral colony extends straight up into the water column from the base. The colony is constructed out of ½-inch PVC pipe. Each coral colony built should be unique in length of pipe and location of elbows, tees and crosses. The overall colony should be less than 100 cm tall and less than 75 cm wide. The coral colony should also be flat (built in two dimensions). Branches should not extend forward or backwards from the flat coral colony. The following build instructions are for the *Paramurice biscaya* coral colony shown in the photo below. Vary coral in size and shape to differentiate between the colonies at different product demonstration stations.



EXPLORER product demonstration build photo #21: Dimensions of pipe for building this coral.

These build instructions should be varied to build your own unique coral. To build this coral colony:

1. Cut a 10 cm length of ½-inch PVC pipe. Attach a PVC cross to one end of the 10 cm length of pipe. Cut a 9 cm length of ½-inch PVC pipe. Insert the 9 cm length of PVC pipe into the opening of the PVC cross opposite the 10 cm length of pipe. Attach the side opening of a PVC tee to the other end of the 9 cm length of pipe. Twist the PVC tee so the middle opening faces to the right.

2. Cut an 18 cm length and a 3 cm length of ½-inch PVC pipe. Insert the 18 cm length of pipe into the other side opening of the PVC tee. Insert the 3 cm length of pipe into the middle opening of the PVC tee. Attach a ½-inch 90^o elbow to the other end of the 3 cm length of pipe. Cut a 5 cm length of pipe and insert it into the other opening of the 90^o elbow.
3. Attach the side opening of ½-inch PVC tee to the end of the 18 cm length of pipe. Cut a 15 cm length of ½-inch PVC pipe and insert it into the other side opening of a PVC tee. Cut a 3 cm length of pipe and insert it into the middle opening of the PVC tee. Attach a ½-inch 90^o elbow to the other end of the 3 cm length of pipe.

This completes the central branch of the coral colony. The following steps are for the right side branch of the coral colony.

4. Cut a 12 cm length, a 10 cm length, and a 5 cm length of ½-inch PVC pipe. Insert the 12 cm length of pipe into the middle opening of a tee. Insert the 10 cm length and 5 cm length into the side openings of the same PVC tee. Insert the other end of the 10 cm length of pipe into the right-side opening of the PVC cross (step 1 above). Twist the tee so the 12 cm length is facing upwards (the same direction as the center branch of the coral colony).
5. Attach a ½-inch 90^o elbow to the other end of the 5 cm length of pipe. Cut an 11 cm length of pipe and insert it into the other opening of the 90^o elbow.
6. Attach the side opening of a PVC tee to the other end of the 12 cm length of pipe. Cut a 14 cm length of pipe and a 3 cm length of pipe. Insert the 14 cm length of pipe into the other side opening of the PVC tee. Insert the 3 cm length of pipe into the middle opening of the PVC tee. Attach a 90^o elbow to the other end of the 3 cm length of pipe. Twist the tee so the middle opening with the elbow is facing to the right.
7. Cut an 11 cm length of PVC pipe. Insert this 11 cm length of pipe into the open end of the 90^o elbow. Attach the side opening of a PVC tee to the other end of the 11 cm length of pipe. Twist the tee so the middle opening is facing right.
8. Cut two 3 cm lengths of ½-inch PVC pipe. Insert one length into the remaining side opening of the tee. Insert the other length into the middle opening of the PVC tee. Attach a PVC tee to the 3 cm length of pipe that was inserted into the remaining side opening. Twist the tee so the middle opening faces left.
9. Cut a 7 cm length and a 4 cm length of PVC pipe. Insert the 7 cm length of pipe into the remaining side opening of the tee. Insert the 3 cm length of pipe into the middle opening of the PVC tee. Attach a 90^o elbow to the other end of the 4 cm length of pipe.
10. Cut an 11 cm length of PVC pipe and insert it into the open end of the 90^o elbow.

This completes the right branch of the coral colony. The following steps are for the left side branch of the coral colony.

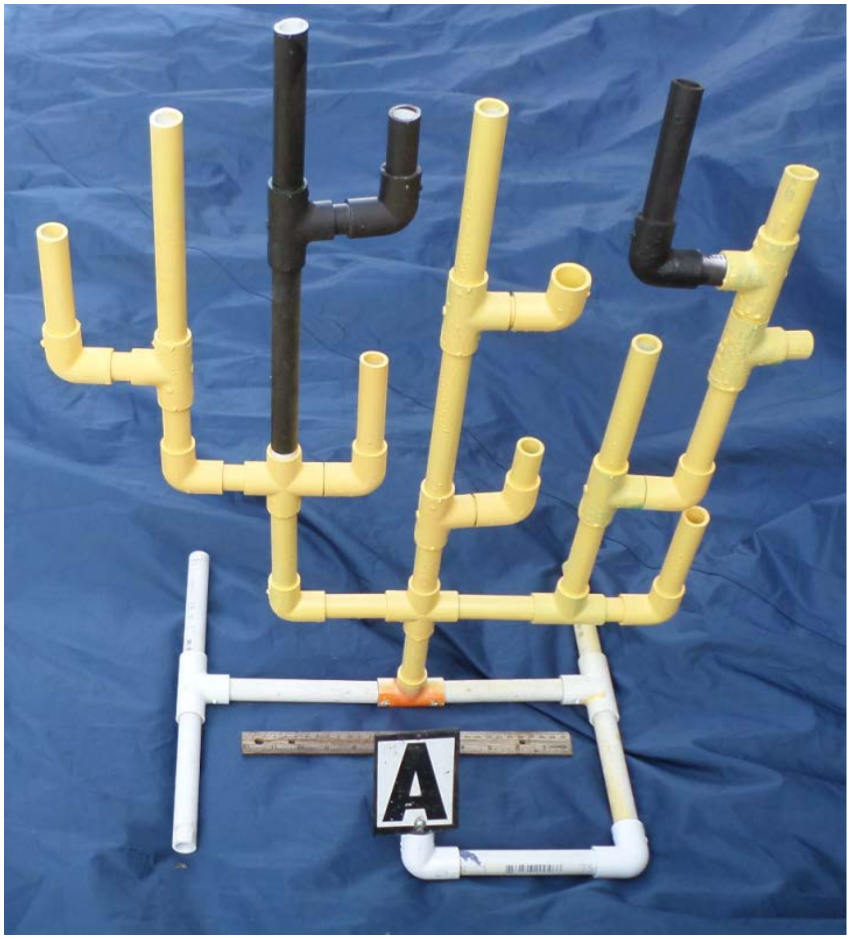
11. Cut a 12 cm length and a 9 cm length of ½-inch PVC pipe. Insert the two lengths of pipe into the openings of a 90^o elbow. Insert the other end of the 9 cm length of pipe into the left side opening of the PVC cross near the base. Attach one opening of a different ½-inch PVC cross to the other end of the 12 cm length of pipe.

12. Cut a 3 cm length of pipe and insert it into the right side opening of the PVC cross. Attach a 90° elbow to the other end of this 3 cm length of pipe. Cut a 10 cm length of pipe and insert it into the remaining opening of the 90° elbow.
13. Cut a 4 cm length of pipe and insert it into the left side opening of the PVC cross. Attach a 90° elbow to the other end of this 4 cm length of pipe. Cut a 7 cm length of pipe and insert it into the remaining opening of the 90° elbow. Attach the side opening of a PVC tee to the other end of this 7 cm length of pipe. Twist the PVC tee so the middle opening faces left.
14. Cut a 19 cm length, a 10 cm length and a 4 cm length of PVC pipe. Insert the 19 cm length of pipe into the other side opening of the PVC tee. Insert the 4 cm length of pipe into the middle opening of the PVC tee. Attach a 90° elbow to the other end of the 4 cm length of PVC pipe. Insert the 10 cm length of pipe into the other opening of the 90° elbow.
15. Cut a 21 cm length of ½-inch PVC pipe and insert it into the remaining top opening of the PVC cross. Attach the side opening of a PVC tee to the other end of the 21 cm length of pipe.
16. Cut a 12 cm length, a 5 cm length, and a 4 cm length of ½-inch PVC pipe. Insert the 12 cm length of pipe into other side opening of the PVC tee. Insert the 4 cm length of pipe into the middle opening of a PVC tee. Attach a 90° elbow to the other end of the 4 cm length of pipe. Insert the 5 cm length of pipe into the other opening of the 90° elbow.

The coral build is complete, but the coral still needs to be painted. The living coral should be painted yellow. A few "dead"' branches should be painted black. Choose some exterior coral branches (those on the outside or top of the coral colony). Remove them and paint them black. Paint the remaining coral colony yellow. When the paint has dried, return the black coral branches to the colony (re-insert the branches into the build).

Design note: You may want to avoid painting the inside opening of the connector where a branch has been removed. Likewise you may want to avoid painting 1 cm of the removed pipe that will fit into the connector. The paint will add significant diameter to the pipe and make it hard to re-insert the removed pieces.

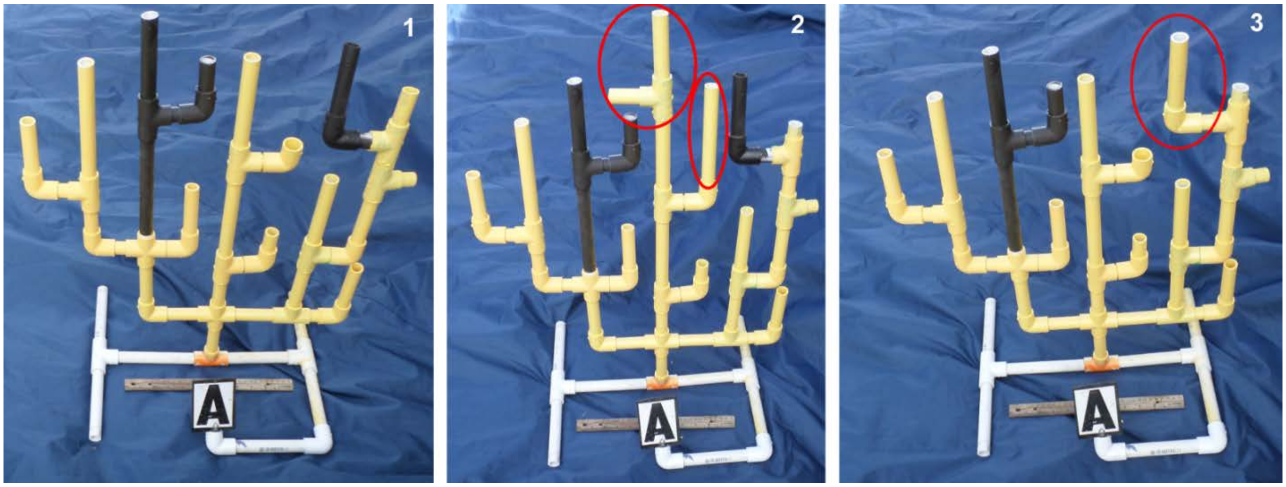
Once the coral colony has been reassembled with both living and dead branches, insert the coral colony into the colony base and take a photo of it. This photo represents the coral colony in the photo taken 6 months previously.



EXPLORER product demonstration build photo #22: The photo of the coral colony from 12 months before.

The coral colony can be updated to show growth or decrease in size, or it can be left as is to represent a stable colony. Growth is represented as new branches on the colony or a previously black branch that has turned yellow. To build an updated growing colony:

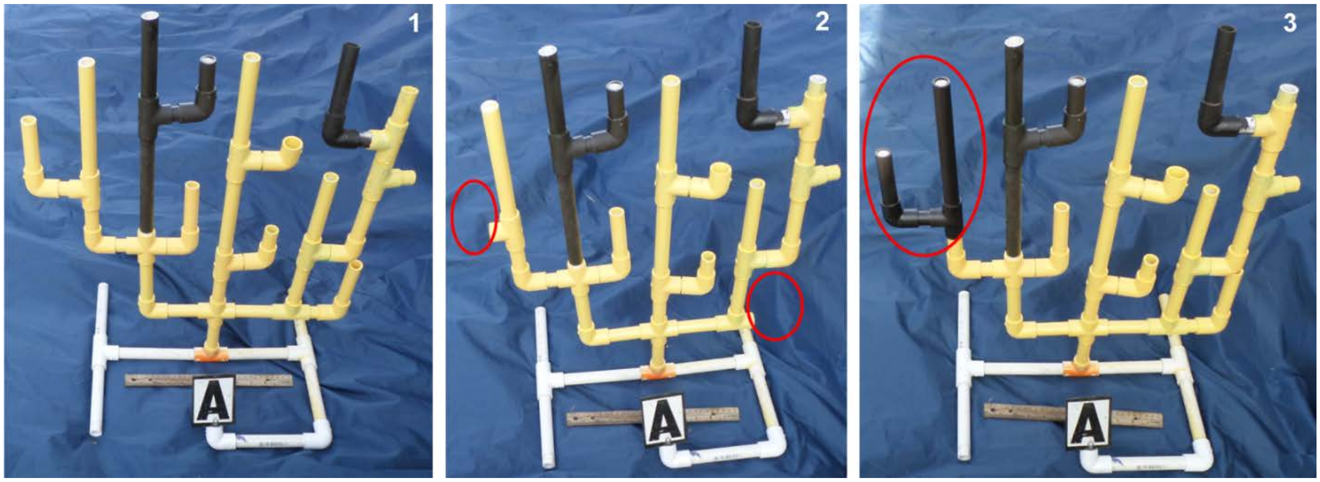
17. Add additional yellow branches to the coral colony. For example, cut a 10 cm length and a 6 cm length of ½-inch PVC pipe. Insert the 10 cm length into the side opening of a ½-inch tee. Insert the 6 cm length into the middle opening of the tee. Paint the pipe yellow and attach the remaining side opening of the tee to the 15 cm length of pipe at the top of the center branch of the coral colony. Cut a 16 cm length of pipe and paint it yellow. Insert the 16 cm length of yellow pipe into the opening on the 90^{o} elbow near the top of the central branch. OR
18. Remove a black branch of coral colony and paint it yellow, or alternatively build a copy of that branch of coral and paint it yellow. For example, remove the black 4 cm, 90^{o} elbow and 11 cm length of pipe at the top right of the coral colony. Cut an 11 cm length and 4 cm length of ½-inch PVC pipe and insert them into the openings of a 90^{o} elbow. Paint the branch yellow and insert it into the middle opening of the tee where the black branch was removed.



EXPLORER product demonstration build photo #23: A comparison of photos showing coral growth. 1) Photo of the coral from 12 months before. 2) Coral colony shows growth of new branches compared to the photo taken 12 months before. 3) Coral colony shows regrowth of previously dead branch in the photo taken 12 months before.

The updated coral colony can also show a decrease in the size of the colony. A decrease in size is represented as branches missing from the colony or a previously yellow branch that has dies (turned black). To build an updated growing that has decreased in size:

19. Remove yellow branches from the coral colony. For example, remove the branch constructed from a 10 cm length and 4 cm length of PVC pipe connected by an elbow from the top left of the coral colony. Also remove the branch constructed from an 11 cm length and 5 cm length of pipe on the bottom right of the coral colony. OR
20. Remove a yellow branch from the coral colony and paint it black, or alternatively build a copy of that branch of coral and paint it black. For example, remove the tee, 90^{o} elbow, 19 cm length, 10 cm length and 4 cm length of yellow pipe from the top left of the coral colony. Cut a 19 cm length, a 10 cm length and a 4 cm length of pipe. Insert the 19 cm length into the side opening of the tee and the 4 cm length into the middle opening of the tee. Attach the 90^{o} elbow to the 4 cm pipe and insert the 10 cm length into the other opening. Paint the branch black and attach it to the other end of the 7 cm length of pipe where the yellow branch was removed.



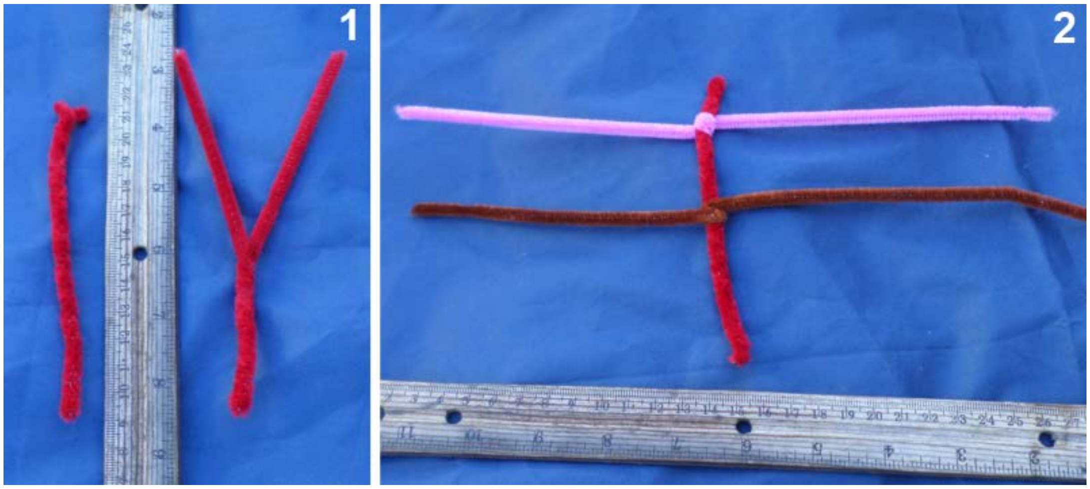
EXPLORER product demonstration build photo #24: A comparison of photos showing a decrease in size of the coral colony. 1) Photo of the coral from 12 months before. 2) Coral colony shows loss of living branches in two locations compared to the photo take 12 months before. 3) Coral colony shows death of previously living branch in the photo taken 12 months before.

21. Once the updated coral colony is assembled, use screws to secure the PVC pipe into the tees, elbows and crosses.

***Madrepora* Coral**

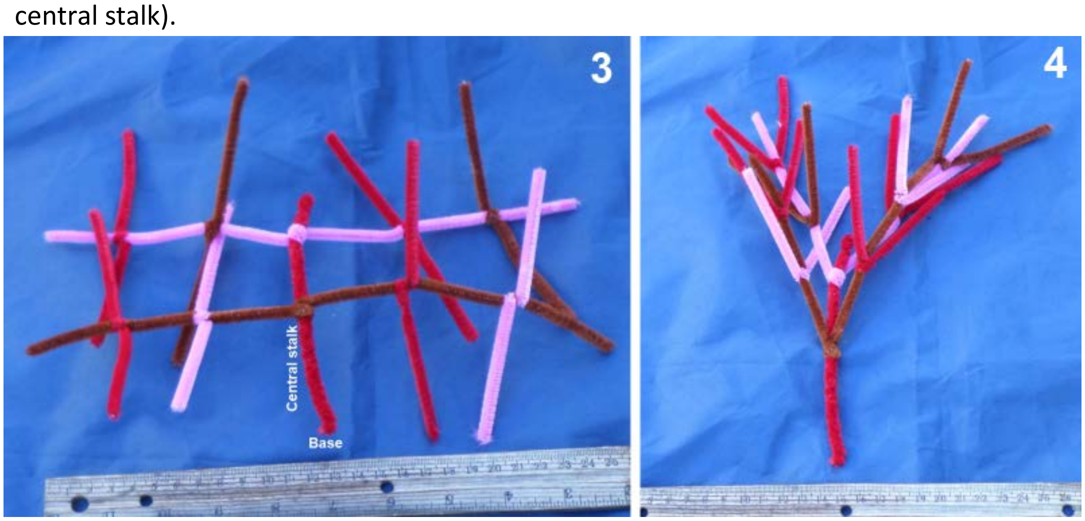
The scleractinian coral colony *Madrepora prolifera* is constructed from brown, red and pink chenille pipe cleaners. Colors may vary in different coral colonies. The base of the coral colony is a ½-inch PVC tee. To construct the *Madrepora* coral:

1. Fold a red chenille pipe cleaner in half and twist it tightly together. This double strength pipe cleaner is the central stalk of the coral colony.
2. Take a brown pipe cleaner and wrap it three times around the red central stalk pipe cleaner, about half way between the two ends. Take a pink pipe cleaner and wrap it three times around the red central stalk pipe cleaner, about halfway between the brown pipe cleaner and one end.



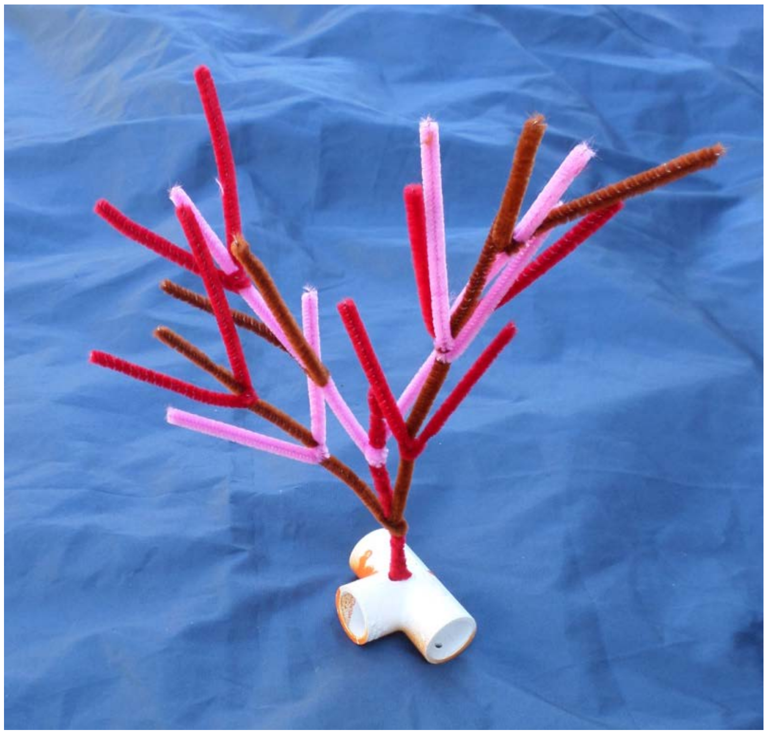
EXPLORER product demonstration build photo #25: 1) The central stalk of the coral. Completed central stalk on left of ruler, half twisted central stalk on the right of the ruler. 2) Additional brown and pink chenille pipe cleaners added to the central stalk of the coral colony.

3. Cut a red pipe cleaner in half (two 15 cm lengths). Cut a pink pipe cleaner in half (two 15 cm lengths). Wrap a red pipe cleaner three times around one side of the brown pipe cleaner, about 5 cm from the central stalk. Wrap a pink pipe cleaner three times around the same side of the brown pipe cleaner, about 10 cm from the central stalk. Use the other 15 cm red and pink pipe cleaners on the brown pipe cleaner on the other side of the central stalk.
4. Cut a red pipe cleaner in half (two 15 cm lengths). Cut a brown pipe cleaner in half (two 15 cm lengths). Wrap these around the pink pipe cleaner that is wrapped around the central stalk, using the same method as step 3.
5. Twist all the pipe cleaners so the branches bend in one direction. Design note: The easiest way to do this is to grab the base with one hand, form a circle with your thumb and index finger of your other hand and run it up the central stalk two or three times. The base of the stalk is the side of the central stalk that does not have the second pipe cleaner (the longer side of the central stalk).



EXPLORER product demonstration build photo #26: 3) Eight additional side branches added to the coral. Note the central stalk and base of the coral. 4) Coral colony with all branches positioned.

6. Drill two 3/16-inch holes into the center side of a ½-inch PVC tee. The holes should be 0.5 cm apart. Push the base of the center stalk into one hole and bend it out the other. Twist the ends of the base together to form a tight, strong base. The tight, strong base should be able to hold the coral colony upright in air.



EXPLORER product demonstration build photo #27: Completed scleractinian coral colony with base.

Optional design 1: Cut a few more 15 cm lengths of various colored pipe cleaners. Add them into the coral colony to fill it out.

Optional design 2: Attach small bits of pink or red flotation to the top ends of a few coral branches. This flotation will help hold the coral upright in the water.

Task 5: Inner Space: Rigs to Reefs

Wellhead

The wellhead is constructed from 2-inch PVC pipe and couplings set into a cement base. To construct the cement base, fill a 40 cm oil pan with cement. Before the cement dries, set a 2-inch PVC coupling into the cement and let the cement dry.

1. Cut a 40 cm to 75 cm length of 2-inch PVC pipe. Insert this length of 2-inch pipe into the 2-inch coupling in the dried cement. Attach another 2-inch coupling to the top end of the pipe.

2. Insert a 2-inch to 1 ¼-inch reducer bushing (Home Depot model #PVC021071350HD, Internet # 203811555, Store SKU # 744836) into the other end of the 2-inch coupling. Cut an 8.5 cm length of 1 ¼-inch PVC pipe. Insert the length of pipe into the reducer bushing.

Design note: The Home Depot part number for the 2-inch to 1 ¼-inch reducer bushing has changed since the preview product demonstration was released in September. The part numbers given above are correct. Also note that the photograph of the bushing on the Home Depot website is not the correct picture for the 2-inch to 1 ¼-inch bushing. The desired component should reduce the size of the pipe from a 2-inch coupling to 1 ¼-inch PVC pipe.

3. Cut a length of 5 cm wide industrial strength Velcro hooks. The length of this Velcro should stretch all the way around the 1 ¼-inch pipe. Adhere the Velcro 1 cm below the top of the 8.5 cm pipe in the top of the wellhead.

EXPLORER product demonstration build photo #28: The wellhead.

Flange

The flange is constructed from an ABS 3-inch to 2-inch reducer bushing (Home Depot model #C58012FHD32, Internet #100343802, store SKU # 188301). Holes are drilled through the walls of the flange. Bolts inserted through these holes will secure the flange to the end of the pipeline. To construct the flange:

Design note: There are two 3-inch to 2-inch ABS reducer bushing designs available in Hardware stores, one with a round top and beveled edge, or one with an octagonal cap and angled edge. The part number given refers to both designs. Either reducer bushing design can be used to complete the product demonstration task. EXPLORER class companies should expect to find either reducer bushing design at the international competition.

1. Drill six 5/8-inch holes through the side wall of the flange at 60^{o} angles around the 360^{o} circumference. These holes should go all the way through the wall, from the outside to the middle of the reducer bushing.
2. Cut six 1 cm x 5 cm lengths of Velcro hooks. Attach these six rectangles of Velcro to the top of the flange, centering each rectangle between two of the six holes drilled into the flange.

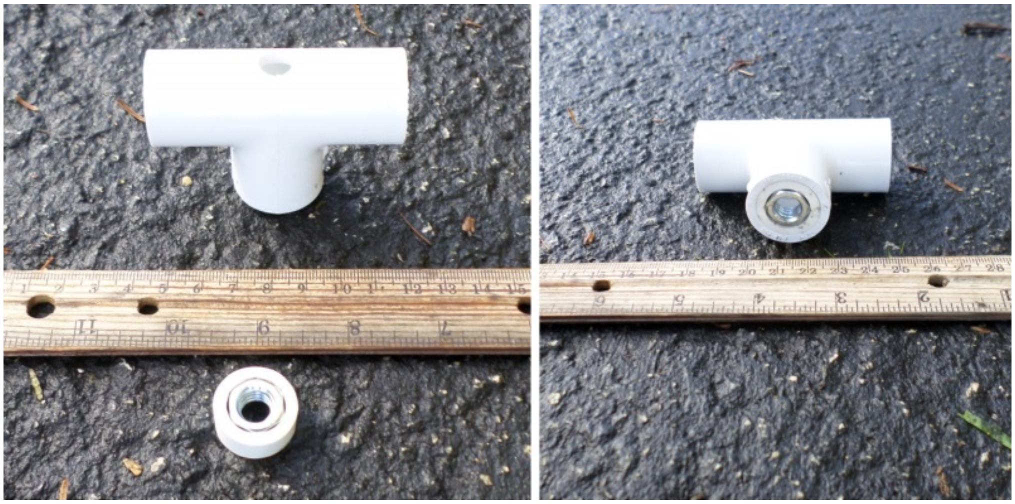
EXPLORER product demonstration build photo #29: Flange with Velcro strips attached.

Bolts

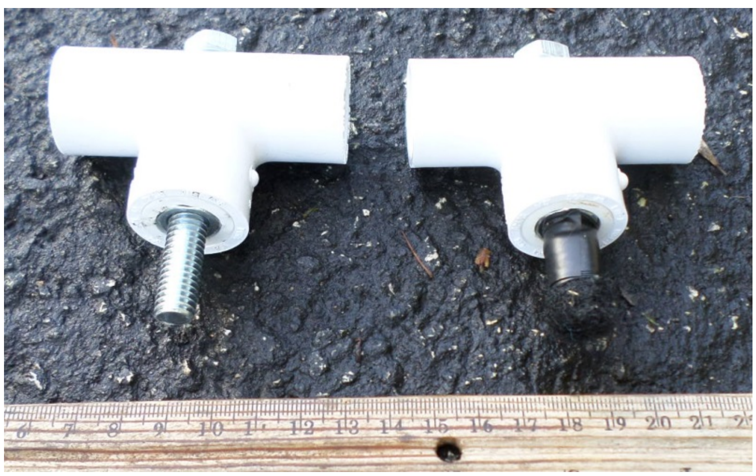
The bolts are constructed from 3-inch long 3/8-inch x 16 thread bolts through a ½-inch PVC tee, which serves as a holder for the bolts. Velcro loops around the end of the bolt will secure the bolt to the Velcro hooks on the end of the wellhead pipe. To construct a bolt:

1. Drill a 3/8-inch hole through the center of the middle opening of a PVC tee.
2. Cut a 1 cm long length of ½-inch PVC pipe. Use a hammer to force a 3/8-inch nut inside the 1 cm length of PVC pipe. Insert the 1 cm length of pipe into the middle opening of the PVC tee.
3. Push a 3-inch long 3/8-inch bolt through the hole in the tee and screw it into the nut inserted into the middle opening of the tee. The bolt should extend approximately 2.5 cm beyond the middle opening of the tee.
4. Cut a 5 cm x 1 cm rectangle of Velcro loops. Attach the middle of the Velcro loop rectangle to the end of the 3/8-inch bolt. Secure the 2 cm Velcro on either side of the middle of the

rectangle to the sides of the bolts. Wrap plastic tape tightly around the ends of the Velcro loop rectangle to secure it to the end of the bolt.



EXPLORER product demonstration build photo #30: PVC base of the bolt with 3/8-inch nut inserted.



EXPLORER product demonstration build photo #31: Completed bolt without Velcro. Completed bolt with Velcro.

Wellhead cap

The wellhead cap is constructed from an ABS 3-inch to 2-inch reducer bushing (Home Depot model #C58012FHD32, Internet #100343802, store SKU # 188301). It has four ½-inch PVC end caps screwed into the top side to serve as ports for the bolts. To construct the wellhead cap:

1. Cut a 2 cm length of 2-inch PVC pipe. Insert the 2 cm length of pipe into the 2 cm opening on the reducer bushing.
2. Insert a 2-inch knockout cap (Home Depot model #39101, Internet #100137732, Store SKU #508257) into the 2-inch pipe.

3. Use a screw to secure a ½-inch PVC end cap to the outside of the top edge of the 3-inch to 2-inch ABS reducer bushing. The screw should go straight down into the side wall of the bushing. Repeat this three more times (four end caps total) at equal distances around the bushing.
4. Cut four 1.8 cm x 1.8 cm squares of Velcro hooks. Adhere the sticky side of the Velcro to the inside bottom surface of the four end caps, over the screw heads holding them in place.
5. Cut four 5 cm x 3 cm lengths of Velcro loops. Attach them around the bottom, angled end of the 3-inch to 2-inch reducer bushing.

EXPLORER product demonstration build photo #32: Wellhead cap with four ports for bolts.

Elevator

The elevator is constructed of a 90 cm x 15 cm rectangle of corrugated plastic sheeting and ½-inch PVC framework. Flanges and wellhead caps will rest upright on the plastic sheeting. ½-inch end caps will hold the bolts upright above the plastic sheeting. To construct the Rigs to Reefs elevator:

1. Cut a 90 cm by 15 cm rectangle of corrugated plastic sheeting.
2. Cut two 87 cm lengths and two 9 cm lengths of ½-inch PVC pipe. Use four tees combine the PVC pipes into a rectangle 90 cm by 15 cm. Screw the corrugated plastic sheeting on top of the PVC pipe rectangle.
3. Screw three end caps into the corrugated plastic sheeting, 5 cm from one short edge. Two of the end caps should be 3 cm from each long end, the third end cap should be in the center, 7.5 cm from each long end. Cut three 2 cm long lengths of ½-inch PVC pipe and insert them into each end cap.
4. Repeat this process, screwing 3 end caps into the corrugated plastic sheeting, 14 cm from the same short edge (9 cm from the other end caps).

5. Repeat this process again, screwing 3 end caps into the corrugated plastic sheeting 23 cm from the same short edge (9 cm from the previous end caps).
6. Cut nine 1 cm lengths of ½-inch PVC pipe. Insert a 1 cm length of pipe into each end cap, making the edge of the 1 cm length flush with the end of the end cap.

EXPLORER product demonstration build photo #33: The elevator holding flanges, wellhead caps, and bolts.

The elevator will have a total of 9 bolts available to EXPLORER class companies. Each elevator will have 2 flanges and 2 wellhead caps available for EXPLORER class companies.

7. Attach weights to the underside of the elevator to keep it from moving on the pool floor.

Design note: The weights may increase the distance between the pool bottom and top of the elevator. Companies should not rely on a set height for the elevator.