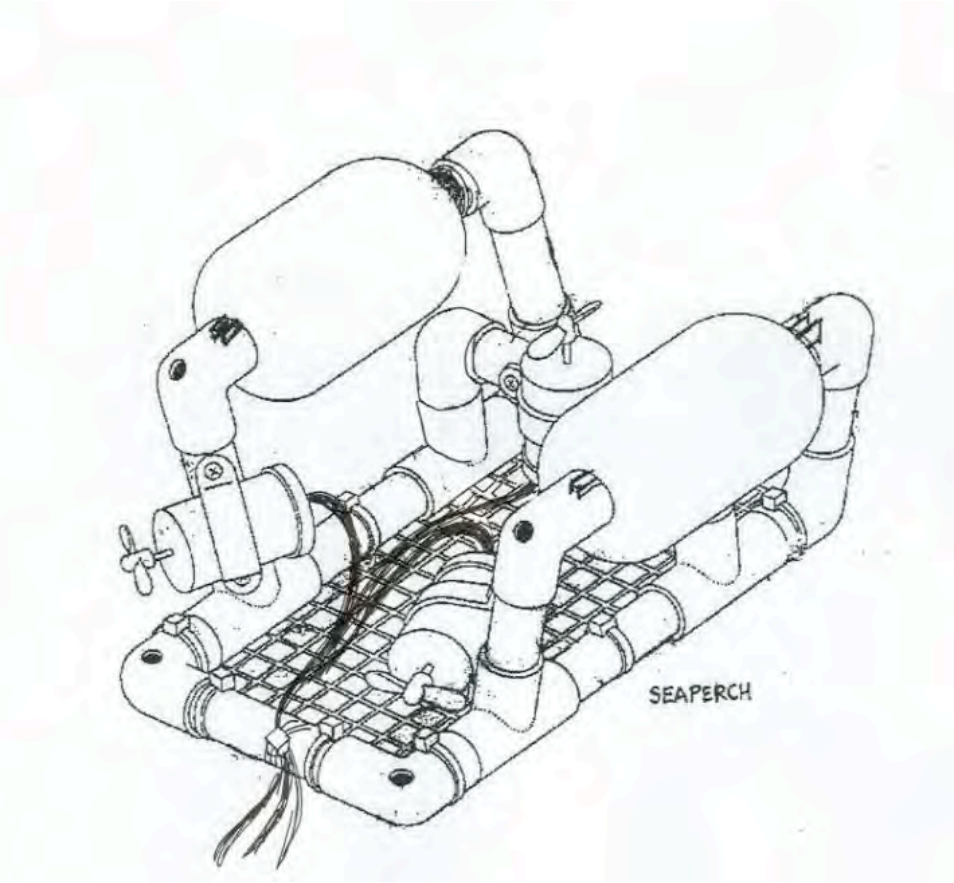
MIT SEA GRANT

# Sea Perch

## *Construction Manual*



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# SAFETY CHECKLIST
## EACH STUDENT, EVERY TIME!

- Make sure the work space is well ventilated and well lit
- Each student must wear
  - Safety goggles
  - Close-toed shoes
  - Aprons
- Each student must have adequate space while soldering
- Make students put soldering irons in holders while asking questions, inspecting work, taking instruction and helping others
- Students MUST USE A VISE/CLAMP WHEN SOLDERING AND DRILLING!
- Hold solder in solder case to avoid touching lead-based solder and to avoid putting fingers too close to hot iron

**It is a very good idea to practice skills such as drilling and soldering BEFORE using them on your vehicle!**

# • UNIT 1
# ASSEMBLY OF SUBSYSTEM ONE
# THE VEHICLE FRAME

**FOR THIS UNIT YOU WILL NEED:**

| **Tools** | **Materials** |
|---|---|
| Ruler<br>Marker<br>PVC pipe cutter or saw<br>Phillips Screwdriver<br>Drill<br>1/4” drill bit<br>3/32” drill bit<br>Vise or clamp | 5 ft. (1.5 meters) of 1/2” PVC pipe<br>10 1/2” PVC elbows<br>4 1/2” PVC T’s<br>15” Plastruct H-beam<br>2 Football Floats<br>3 Motor Mounts<br>6 #6 x 1/2”Screws<br>6 #6 washers<br>Netting<br>Tie Wraps (zip ties) |
| **Time:** Unit one requires approximately **2 hours** to complete:<br>1 class period to cut the PVC pipe and drill the holes<br>1 class period to assemble the frame, and attach the payload netting and motor mounts. | |

# STEP 1

**PURPOSE:** Cut the frame parts

**MATERIALS:**

5' (1.5m) of 1/2" PVC pipe

**TOOLS:**

Ruler
Marker
PVC Pipe cutter
(or saw)

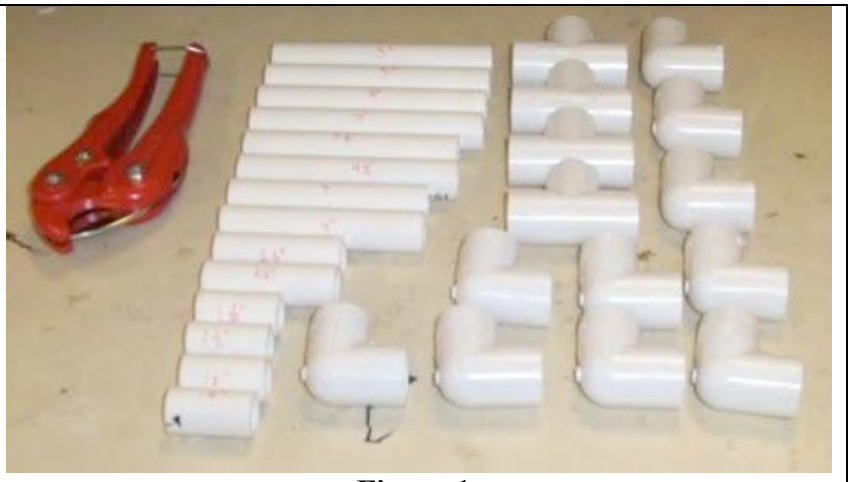


**Figure 1:**
PVC pipe cutter, Cut sections of PVC pipe, Elbows and T's

**PROCEDURE:**

1. From a straight end of the pipe measure and cut:
   Two pieces – 2 1/2" or 6.4 cm long
   Two pieces – 4" or 10.2 cm long
   Two pieces – 4 1/2" or 11.4 cm long
   Four pieces – 1 1/2" or 3.8 cm long
   Four pieces – 5" or 12.7 cm long
   Four pieces – _" –set aside for use in the next step

   Try to cut straight, so that the ends of each piece are square with the sides, but don't worry if it's not perfect.
2. You may want to write the length on each piece to keep track.

**Pipe Cutting Tips**

PVC pipe can be cut in many ways, each of which has its own concerns:
**Ratchet Style Pipe Cutters** are the easiest and safest option. To open the cutter, pull the handles FAR apart. Then click them closed through the pipe by pumping the handles together and apart.
**Non-ratchet Pipe Cutters** are a cheaper alternative, but more difficult to use. Place the pipe in the cutter, push down LIGHTLY, and turn the cutter around the pipe slowly, applying light pressure, until it cuts through all the way.
**Hack Saws** and other saws can cut through PVC, but are the most labor intensive option.
**Band Saws** are large pieces of shop equipment, and can be very dangerous. Make sure to get your teacher's permission and supervision before using one.

# STEP 2

**PURPOSE:** Create drain holes in vehicle frame

**MATERIALS:**

10 1/2” PVC elbows

**TOOLS:**

Hand drill or
drill press

1/4” drill bit

Vise or clamp

**Figure 2:** Drain holes drilled with 1/4” drill bit

**PROCEDURE:**

1. Secure a PVC elbow in the vise or clamp.
2. Place the 1/4" drill bit in the drill (or drill press), and drill a hole in the outer corner of the elbow.
3. Repeat for each of the ten PVC elbows.

These holes are meant to let water fill the frame when you put your SeaPerch in the water and for the water to drain out when you take the SeaPerch out.

**Drill Safety:**

Drills can be dangerous pieces of equipment, but are very useful if operated properly. Always get your teacher’s permission and supervision before using a drill or other power tool. Always wear safety glasses when using a drill or other power tool.

It is good practice to secure the object you are drilling in a vise or clamp before drilling. This keeps it steady, prevents it from spinning and hurting your hand if the drill should bind, and keeps your fingers away from the drill bit while drilling.

If you do not have a vise or clamp available, push the elbow onto one end of a long (5” or more) piece of PVC pipe, and hold the pipe while drilling the hole. DO NOT drill the elbow while holding it in your hand!

## STEP 3

**PURPOSE:** Assemble the vehicle frame

| **MATERIALS:** | |
|---|---|
| Cut pieces of pipe from step 1<br><br>10 1/2" PVC elbows with holes drilled from step 2<br><br>4 1/2"PVC T's | <br>**Figure 3:** PVC Frame Parts |

**PROCEDURE:**

Assemble the frame using all the PVC parts as shown in Figure 4 below.

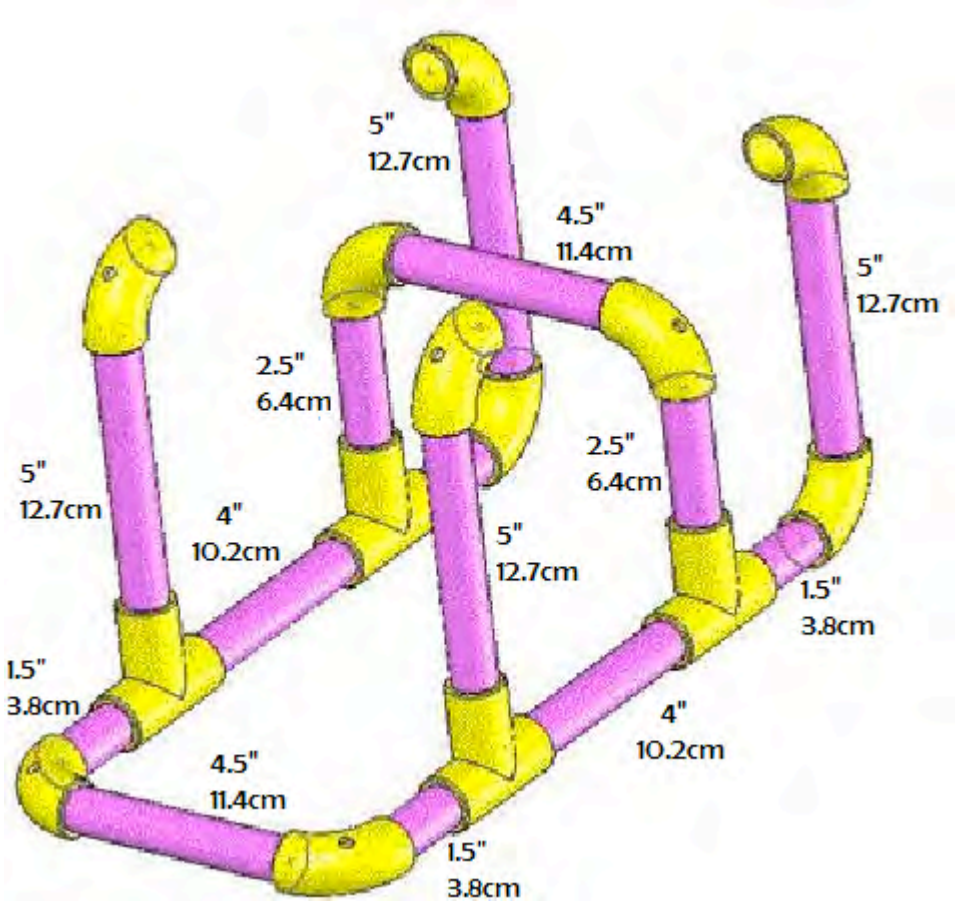



**Figure 4:** Frame Assembly

## STEP 4

**PURPOSE:** Assemble the float supports and tighten the frame

| | |
|---|---|
| **MATERIALS:**<br>Assembled frame<br>15” Plastruct H-beam<br>2 Football Floats<br>PVC pipe scraps<br><br>**TOOLS:**<br>PVC Pipe Cutter | <br>**Figure 5:** H-beam Assembly for floats |

**PROCEDURE:**

1. Cut the 15” Plastruct H-beam into two 7 1/2” pieces.
2. Cut Four 3/4” (2cm) pieces of PVC pipe from your scraps.
3. Insert one of the 3/4” (2cm) PVC pipe pieces into the open end of each of the four PVC angles on the top of your vehicle.
4. Insert an H-beam through each of your floats and between each pair of PVC angles.
5. Push all parts of your vehicle frame together HARD, so that H-beams cannot fall out of the PVC angles.

**Figures 6:** Assembly of H-beam float supports.

TIP: If you place the vehicle on your work bench and push down hard from all sides, you can squeeze all the frame sections together tightly. Unless you are building a larger frame, or have PVC that remains loose, it is not necessary to glue or screw the joints.

## STEP 5

**PURPOSE:** Attach the motor mounts to the frame

**MATERIALS:**
Vehicle frame
3 Motor Mounts
6 #6 x 1/2" Screws
6 #6 washers
Washers

**TOOLS:**
Marker
Phillips Screwdriver
Drill
3/32" drill bit

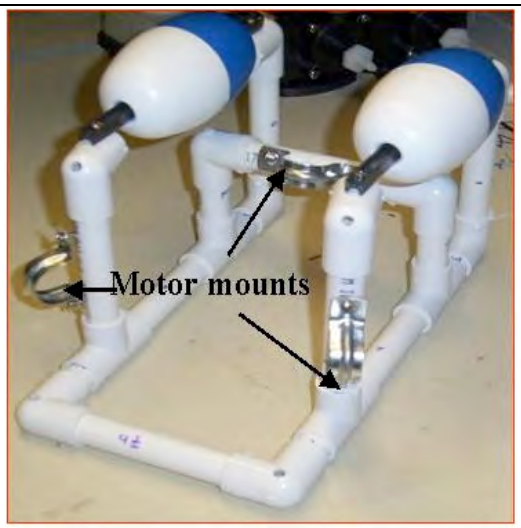



**Figure 7:** Motor mount placement

**PROCEDURE:**

1. Hold motor mounts against frame in locations shown in Figure 7. It's more important to center them between the joints on the pipe than to get the right angle around the pipe.
2. With a marker or pencil, mark vehicle frame through the holes in motor mounts.
3. Using the 3/32" drill bit, drill holes through the marks on the frame.
4. Place washers over the outside of the holes in the motor mounts, and place a screw through each washer and motor mount hole into hole in vehicle frame. If the heads on your screws are large enough that they don't pass through the holes in the motor mounts, then the washers are optional.
5. Using the screwdriver, LOOSELY attach the motor mounts to the frame. **DO NOT over-tighten and strip the holes in the PVC!!** You will be removing the motor mounts later anyway to get the motors under them.

**Motor angle tips:**

For now, don't worry about what angle your motors mounts are attached at. Since we do not glue the joints in the PVC we can adjust the angle later by simply turning the pipe in its joints using a pair of pliers. For now, it's easier to drill and attach the motor mounts on the back (outside) of the frame… we'll turn them in later.

Think about how the angle of the motors affects the performance of the ROV. What angles will get you the best forward and backward thrust? What angles will get you the best turning ability? What is the best compromise for your mission needs?

## STEP 6

**PURPOSE:** Attach the payload netting

**MATERIALS:**
Netting
Tie wraps (zip ties)
Assembled Vehicle frame

**TOOLS:**
Scissors
Pliers

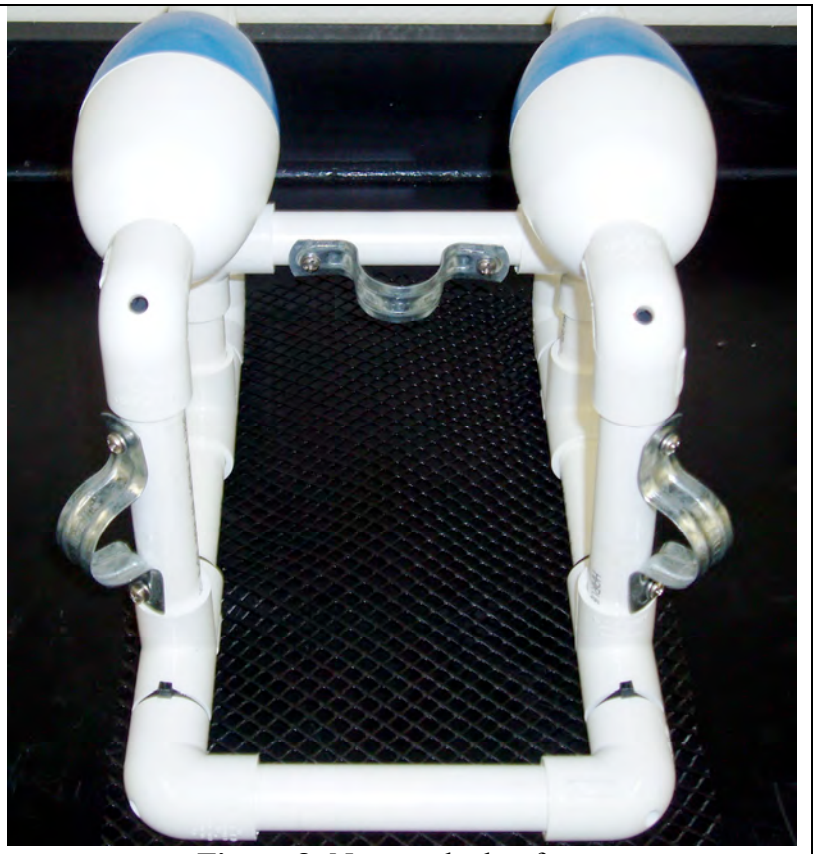


**Figure 8:** Net attached to frame

**PROCEDURE:**

1. If you wish to paint your vehicle's frame, do so before attaching netting, and make sure to use waterproof paint.

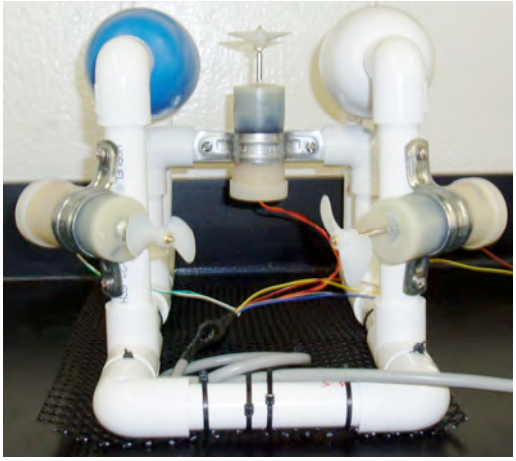
2. Place the netting underneath the vehicle frame and trim to size with scissors if necessary.

3. Attach the netting to the frame with about 6 to 8 tie wraps (aka. cable ties or zip ties). Pull them tight, using pliers if necessary.

4. Trim off the tie wrap ends with scissors.

5. You have now completed the vehicle frame of your SeaPerch ROV!

# l
# UNIT 2
# ASSEMBLY OF SUBSYSTEM TWO:
# THE THRUSTER ASSEMBLY



**FOR THIS TASK YOU WILL NEED:**

| **Tools** | **Materials** |
|---|---|
| Assembled potting holder (see step 1)<br>Drill<br>Drill Bit: 3/32”<br>Electric hot plate<br>Metal cups or beakers for melting wax<br>Lead sinkers<br>Pliers<br>Saw<br>Marker<br>Ruler<br>Scissors<br>Soldering Iron and solder<br>Phillips Screwdriver<br>Eye Protection | Tether wire<br>3 film cans with caps<br>3 12 volt DC motors<br>3 Propellers<br>3 Propeller Shafts<br>6 small brass nuts (#4-40)<br>Epoxy and mixing stick<br>Wax bowl ring<br>Water<br>Electrical tape<br>Butyl Rubber tape<br>#24 stranded hook up wire, Red<br>#24 stranded hook up wire, Black<br>12 volt battery<br>Paper towels<br>Rubbing Alcohol<br>Potting Holder, or wood and screws to make one. |
| **Time:** Unit 2 requires about **3 hours** to complete:<br>1 class period to solder the tether wires to the motors<br>1 class period to pot (waterproof) the motors<br>1 class period to attach propellers, and<br>A short amount of time to mount the motors on the frame after the epoxy has hardened | |

## STEP 1

**PURPOSE:** Assemble the potting holder.

**NOTE:** The potting holder is no longer necessary with the new instructions (June 2008) for gluing the propeller on to the shaft. It is still useful, but can be substituted with a cardboard box or other raised surface with small holes in it to stand up the motors.

**NOTE:** The Potting Holder is used later in this unit, and will probably have ALREADY been assembled for you. If not, follow the procedure below:

**MATERIALS:**
1 piece of thin plywood or stiff plastic

2 scrap pieces of wood

2 self tapping screws

**TOOLS:**
Saw
Screwdriver
Marker
Ruler

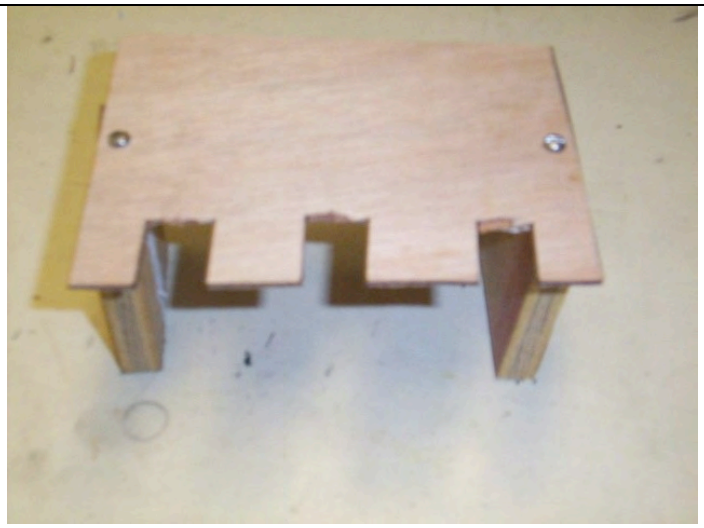


**Figure 9:** Assembled potting holder

**PROCEDURE:**

1. Measure and Cut a 6” x 4” piece of thin (approx. 1/8”) plywood or plastic.
2. Make three 1/2" wide 3/4” deep notches in the plywood/plastic.

***TIP**: Make three notches on two sides of the plywood/plastic to double the capacity of the potting holder

3. Measure and cut two 2 1/2” x 1 1/2” legs from the scrap wood.
4. Using screws, attach legs to the notched piece of wood.

**Figure 10:** Potting holder materials

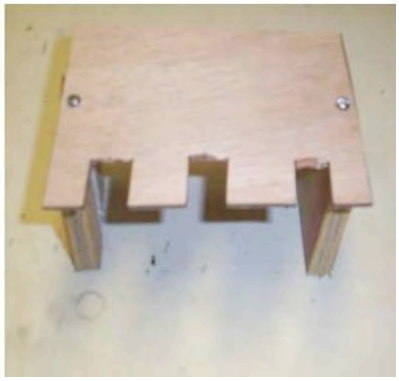


**Figure 11:** Assembled potting holder

# STEP 2

**PURPOSE:** Test the motors and mark the polarity of the terminals.

| | | |
|---|---|---|
| **MATERIALS:** | 3 motors | 12-Volt Battery |
| | 2 Alligator clips | 2 pieces of wire, red and black |
| **TOOLS:** | Marker | |

It is necessary to mark the polarity of the motor terminals, since we will not be able to see the polarity markings on the motor housing once we wrap it in electrical tape.

**PROCEDURE:**

1. Make a pair of test wires: (these are temporary, and will be disassembled for making your control box in unit 3)
    a. Strip 1/4" (7mm) of insulation from both ends of the loose black wire, without cutting the copper threads inside. Connect the black wire to the black alligator clip by twisting or screwing it on. **(NO SOLDER).**
    b. Repeat with the loose red wire and the red alligator clip.
2. Look carefully to see if the terminals on your motors are pre-marked with polarity (+/-). If so, continue with #3, if not, skip to "Trouble Shooting" below.
3. Locate the negative (-) terminal on the motor, and mark the actual terminal with a black marker. Connect the exposed end of the black wire (-) to the negative (-) motor terminal.
4. Mark the positive (+) terminal with a red marker (if available). Connect the exposed end of the red (+) wire to the positive (+) motor terminal.
5. Holding on to the motor, connect the alligator clips to the corresponding (+/-) battery terminals and ensure the motor is in good working order. The shaft should spin rapidly counter-clockwise.
6. Repeat steps 3 through 5 with the other 2 motors. If any motor is not working, get a replacement. Motors should spin COUNTER CLOCKWISE.

**TROUBLE SHOOTING:** IF you cannot see polarity markings (+ and – signs) near the terminals of the motor, THEN follow this procedure to find the + and – motor terminals:

1. Put a small piece of tape on the motor shaft, so you can easily see it spin.
2. Connect the black wire to one terminal and the red wire to the other, and connect the alligator clips to the proper battery terminals (red on +, black on -)
3. Observe the rotation direction of the motor.
4. If the motor shaft turns *counter-clockwise*, then you have chosen the correct terminals: black wire on negative (-) and red wire on positive (+).
5. If the motor shaft turns *clockwise*, then the wires are reversed. Switch them around and make sure the motor turns counter-clockwise
6. Mark at least one motor terminal with the correct color(s): (-)=black, (+)=red

**WARNING - TO AVOID ELECTRIC SHOCK AND SEVERE BURNS:**
**DO NOT touch exposed wires to the battery terminals.**
**DO NOT touch the battery terminals with or ANY metal object, especially tools!**

## STEP 3

**PURPOSE:** Seal the motors from the wax.

| | |
|---|---|
| **MATERIALS:**<br>3 12 volt DC Motors<br>Electrical tape<br><br>**TOOLS:**<br>Scissors | <br>**Figure 12:** 12VDC Motors sealed with electrical tape |

**PROCEDURE:**

1. Make sure the negative and/or positive terminals are marked on each motor so that you can tell them apart after covering the motor in tape. If not, go back to the previous step.

2. Completely wrap each motor with electrical tape to seal the holes. See the tips below before you begin!

3. Make sure **ALL** holes are sealed, and the motor is still thin enough to easily slide into the container (film can).

**Motor wrapping tips:**

The purpose of wrapping the motors is to keep the molten wax out of the motor when we waterproof it, so EVERY hole must be sealed, and folds in the tape where wax could pass through must be avoided. The care with which this is done will help determine how long your thrusters will last.

It may be easiest to cover the ends of the motor first with short pieces of tape, and then wrap longer pieces around the sides. But don't make it too thick by wrapping too much tape around the sides, since the motor still has to be thin enough to fit inside the thruster container (film can), while leaving some room for wax around it.

You can push the tape right over the motor terminals so that they punch right through the tape. It is best to avoid putting tape on the motor shaft, as this will reduce the efficiency and possibly stop the motor. Make sure **ALL** holes are sealed, and the motor is still thin enough to easily slide into the container.

## STEP 4

**PURPOSE:** Drill holes in the thruster containers.

**MATERIALS:**
3 film cans with caps
1 12 volt DC motor
1 pair of test wires

**TOOLS:**
Drill
3/32" drill bit

**Figure 13:** Drilled motor canisters (film cans)

**PROCEDURE:**

1. Using the 3/32" drill bit, drill a hole in the center of each film can cap. The holes in the caps are where the wires pass through, so high precision is not essential.

2. Now drill a hole in the bottom of each film can (see Figure 13). The holes in the cans are where the motor shafts pass through the cans, and form the shaft seals, so it is **VERY IMPORTANT** that these holes are drilled extremely carefully. First, pick any plastic lumps off of the center of the can with your fingernail or a screwdriver. Then carefully and slowly drill the hole straight into the very **CENTER** of the can. Pull the drill straight out to avoid enlarging the hole.

3. You can use one of your motors to polish the hole in the can to the perfect size. Hook the motor up to the battery using the test wires. With the motor spinning, carefully push the motor shaft into the hole you drilled, and hold it there for a few seconds, until the motor spins freely.

4. Check each can to make sure that the hole is drilled exactly in the center, and that a motor fits inside easily.

**Drill Safety:**
Always get your instructors permission and supervision before using a drill or other power tool. Always wear safety glasses when using a drill or other power tool. It is good practice to secure the object you are drilling in a vise or clamp before drilling. This keeps it steady, prevents it from spinning and hurting your hand if the drill should bind, and keeps your fingers away from the drill bit while drilling.

## STEP 5

**PURPOSE:** Attach the tether wires to the motors.

**MATERIALS:**
3 motors sealed with tape
3 film cans and caps with holes drilled in step 4
Tether wire
Solder

**TOOLS:**
Drill
3/32" drill bit
Soldering iron

**Figure 14:** Tether wire soldered to motor

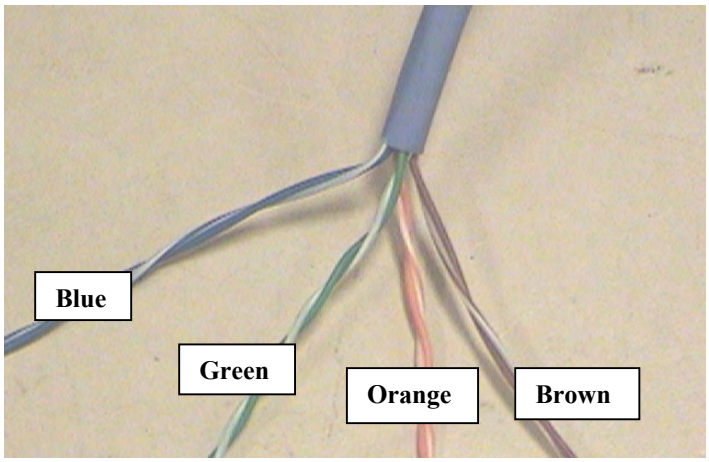
**PROCEDURE:**

1. On one end of the tether cable, strip off about 15" (38cm) of the outer sheath, being careful not to nick any of the inner wires. This can most easily be done with an Ethernet cable stripper. If using scissors, use extreme care not to cut the insulation on the inner wires. Using a knife is not recommended.
2. Separate the four twisted pairs in the stripped section, as shown in Figure 15 on the next page. The brown pair is not used, and can be left hanging for now.
3. Thread about 4" (10cm) of twisted pair through the hole in each film cap, and tie a knot INSIDE the cap for strain relief (Figure 16B).
4. Strip about 1/4" (7mm) of insulation from the end of each wire, for all 3 pairs.
5. Take a pair of wires with attached cap, and one of your taped motors. Solder one wire onto each of the two terminals on the motor: colored wire to (+), and white wire to (-). Repeat for each motor and tether wire pair. (Figure16C).
6. Check that all solder connections are good with the test wires **BEFORE** moving on to waterproofing. Attach test wires to appropriate wires at the control box end f the tether (Pos to Pos, Neg to Neg). This will also insure that you did not cut any of the inner wire pairs when stripping the outer sheath of the tether.

SEE FIGURES ON THE NEXT PAGE…

**Soldering Safety:**
**Always wear safety glasses when soldering**. Most solder is made of lead, which is poisonous. Avoid breathing the fumes, don't put it in your mouth, and wash your hands after working with it.

**Soldering Technique:**
If you have not soldered before, have your instructor show you how, and practice on some pieces of scrap wire. For best results, always twist the inner copper threads of a wire together right after you strip off the insulation, so that they don't fray and break off. Then poke the wire through the hole in the motor terminal, and twist it back around itself to make a good mechanical connection. Apply heat with the soldering iron to get the wire and the terminal up to solder melting temperature. Applying a little solder to the tip of the soldering iron helps transfer heat. Be careful not to get it so hot that you melt any surrounding plastic, or wire insulation. Once the parts are up to temperature, apply the solder wire between the soldiering iron and the connection, and melt a small drop of solder onto the connection. Remove the solder wire, but keep the soldering iron on the connection for a moment to allow the solder to "soak in", then remove the soldering iron. Try to keep the connection still until the solder cools and hardens (turns dull).




| POSITIVE (+) | NEGATIVE (-) | THRUSTER |
|---|---|---|
| Green | Green & White | Starboard (right) |
| Blue | Blue & White | Port (left) |
| Orange | Orange & White | Vertical |
| Brown | Brown & White | Not Used |

**Figure 15**: Tether Wire Color Index

**A:**
Film cans drilled with 3/32" drill bit

**B:**
Tether wire threaded through film cap

**C:**
Tether wire soldered to motor

**Figure 16A-C**: Wiring the 12 volt DC motors

## STEP 6

**PURPOSE:** Potting (waterproofing) the motors with wax.

**MATERIALS:**
3 Drilled Film cans
Wax bowl ring (_ ring)
Electrical tape
Sealed motors
Water

**TOOLS:**
Metal cup(s)
Lead Sinkers
Electric hotplate
Potting holder
Pliers
Scissors
Eye Protection
Paper Towels (for cleanup)

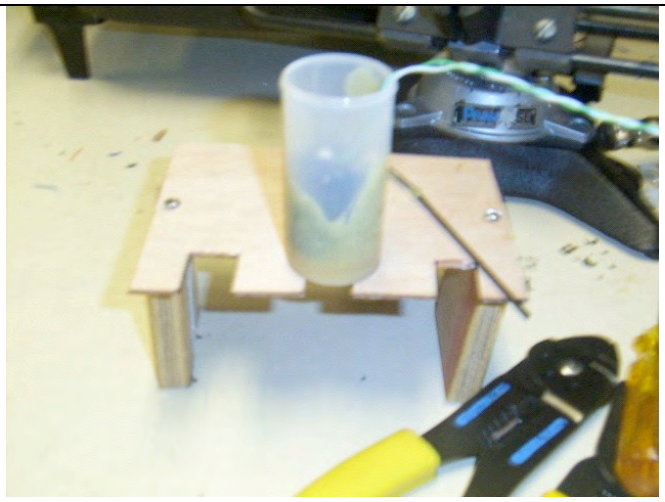


**Figure 17:** Motor placed into wax

**PROCEDURE:**

1. Put a small piece of electrical tape over the hole in the bottom of each of your 3 motor containers (film cans). The tape should be tapped on VERY LIGHTLY, so that it keeps the molten wax from flowing out the hole, but pushes aside easily when the motor shaft pokes through the hole. (Figure 18A)
2. Your instructor will probably have wax melted for you. (Figure 18B) If not, follow the steps under "Wax Melting Tips" on the following page.
3. Put on your SAFETY GLASSES and apron before working with hot wax.
4. Using pliers to lift a cup of molten wax, fill one film can with about 1/4 inch (7mm) of wax, not more! (Figure 18C)
5. Quickly but carefully place one of your sealed motors in the wax. Wiggle the motor until the shaft pokes through the hole in the bottom of the film can. It may take a little wiggling to get the shaft to go through, but DO NOT push so hard that you poke another hole in the can! This happens more easily than you might think, since the plastic softens when heated by the wax. Get the motor in the container and the motor shaft through the hole quickly, since the wax cools and hardens rapidly when the cold motor touches it (Figure 18D). The wax should push partway up around the sides of the motor, but should not fill in above the motor.
6. Repeat for each of your 3 motors.
7. Let the wax cool and harden. One end of your motor is now sealed in the wax, so be careful not to push on the motor shaft and break the seal.

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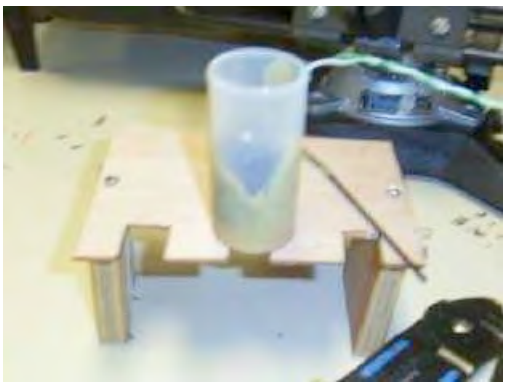
**A:** Film cans with tape over holes

**B:** Melting wax in metal cups

**C:** Film can partially filled with wax



**D:** Motor placed into wax

**Figure 18A-D**: Potting the motors – first wax

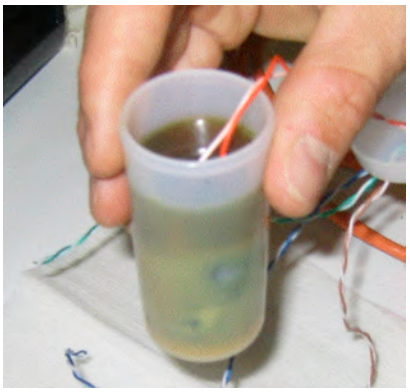
**Wax Melting Tips:**
Always wear SAFETY GLASSES when working with hot wax. The soft wax used in this project can get very sticky. An apron and gloves (latex, nitrile, etc.) are highly recommended. To facilitate cleanup, put a drop cloth on the work bench, on the ground below it, and on the wall behind it. Avoid getting wax on your clothes. To get wax off your skin, wash with warm water and dish soap.

1. Fill the electric hot plate or pan with a small amount of water, about 1/2" (1.5cm) deep. Make sure to keep adding water to the pan as it evaporates. DO NOT let the pan boil dry, as the wax will get VERY hot.
2. Turn the heat on to low or medium. It should get hot but not quite boil the water.
3. Place a couple lead sinkers or other small weights in your wax melting cup(s), to keep it from floating in the water. Fill the cup(s) with wax and place the cup(s) into the water in the hotplate. The wax will melt slowly. (Figure 18A)
4. The molten wax is hot, but should not be hot enough to burn the thick skin on your the palms of your hands. More sensitive skin or large quantities of hot wax may cause burns. In case of a burn, quickly rinse the area with LOTS of cold water.
5. One wax ring will usually pot about 6 motors (enough for 2 SeaPerch ROVs).

8. Once all three of your containers have a motor in them, we will fill them the rest of the way with wax, in 2 steps. (Note, this is different from the old procedure, where we mounted the propeller before filling the containers with wax.)
9. Using pliers to lift the hot cup of wax, fill the container with wax up to 1/2 inch below the top (Figure 19A & B). (We fill them up only partway, since the wax shrinks as it cools, and we want to make sure everything is filled with wax, not air pockets.) Pour the wax so that it fills in all the air spaces around the motor.
10. Lift your container and look at it from the side to see if you have any air bubbles. Get out any air bubbles while the wax is still liquid by squeezing the container.
11. Set the container up on your potting stand to cool, and repeat for the other two.
12. While you are waiting for your wax to cool, make sure your SAFETY GLASSES are on, and put on an apron and gloves since the wax often squirts out during the next steps!
13. Once the wax has cooled, push the caps up to the knots in the wires and coil the wires into the cans. Make sure the caps go on well, and then remove them again.
14. Using pliers to lift the hot cup of molten wax, fill one container to the top with wax, creating a positive meniscus (Figure 19C).
15. Quickly but carefully roll the cap onto the container, leaving as little air inside as possible (Figure 19D). Watch for wax squirting out the hole in the cap!
16. Repeat these steps for the other 2 motors, and let the wax cool and harden.

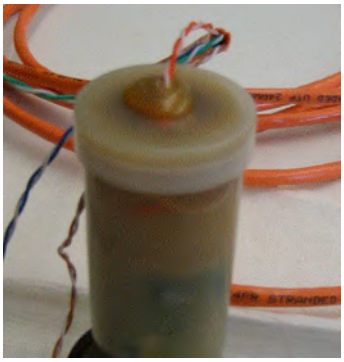
***TIP** Once wax is hardened, recheck motors with test wire to make sure connections are still good, and wax did not seize the motor.

**A:** Second wax layer



**B:** Filled part way

**C:** Positive meniscus



**D:** Filled all the way

**Figure 19 A-D**: Potting the motors – Final two wax steps

## STEP 7

**PURPOSE:** Mounting the propellers on the motors.

| | |
|---|---|
| **MATERIALS:**<br>3 propellers<br>3 prop shafts<br>6 small brass nuts<br>3 potted motors<br><br>**TOOLS:**<br>Epoxy<br>Mixing stick<br>Paper Towels<br>Rubbing Alcohol | **Figure 20:** Propeller and shaft mounted on motor.<br> |

The procedure for mounting the propeller on the motor has changed (August 2007), from one using a bushing and a vice to push it on, to one using a propeller shaft adapter, nuts, and epoxy to secure them.

**PROCEDURE:**

1. **WIPE ALL WAX OFF of the motor shaft with a paper towel and rubbing alcohol** (if available).
2. Look at the propeller and note that the side of the propeller with the groove in it is the side that goes towards the motor.
3. Screw one of the brass nuts onto each propeller shaft, as far as they will go.
4. Prepare your workspace to quickly glue everything, since with many epoxies (including the one specified in the parts list), you will only have about **3 minutes** of working time before they get too stiff to use. Lay out your three potted motors, your propeller shafts with a nut on each, your three propellers, and your three remaining nuts (Figure 21).

**Figure 21:** Parts ready to assemble

CONTINUED ON NEXT PAGE…

5. Get out your epoxy, mixing stick and a sheet of paper to mix on.
6. Mix the epoxy. If you are using the packets specified in the parts list, fold the packet so that the two halves are together. Tear off one end and squeeze the contents of both halves onto your piece of paper (Figure 22A). Quickly mix the contents together with the mixing stick until they are fairly uniform (Figure 22B).
7. Use the mixing stick to put a drop of epoxy on the propeller shaft and the nut, to hold the nut in place. Put another drop of epoxy on the threaded part of the shaft to hold the propeller (Figure 22C).
8. Place the propeller onto the threaded part of the shaft, grooved side first (Figure 22D). Put a drop of epoxy on the end where the threads stick out, and screw the remaining nut on finger tight, making sure it is held by epoxy (Figures 23A & B).
9. Place a drop of epoxy on the hollow end of the propeller shaft, and on the tip of the motor shaft (Figure 23 C). Push the hollow end of the propeller shaft onto the motor shaft, but **do not let the epoxy or the propeller shaft touch the motor canister!** (Figure 23D).
10. Repeat steps 6 to 8 for the other two motors before the epoxy hardens.

**NOTE: It is a good idea to share epoxy between groups of students, as each packet can mount up to ~10 prop shafts**

CONTINUED ON NEXT PAGE…

**A:** Squeeze out the epoxy

**B:** Mix the epoxy

**C:** Drop epoxy on nut and threads

**D:** Place propeller on the shaft

**Figure 22 A-D:** Mixing epoxy and attaching propeller.

**11.** Put your motors aside and allow the epoxy to harden to handling strength (60 minutes for the specified epoxy) before touching them again.
**12.** It takes most epoxies about 24 hours to harden to final strength. Do not turn on the motors or otherwise stress the epoxied connections until this time has passed.

**A:** Place nut and epoxy on prop

**B:** Prop epoxied to shaft

**C:** Epoxy on motor and prop shafts

**D:** Prop shaft mounted on motor

**Figure 23 A-D:** Attaching prop to shaft and shaft to motor.

**BE CAREFUL** that props do not push back due to hydraulic pressure, if this happens lightly push the shaft towards the motor for thee minutes, until the epoxy dries and the shaft no longer slides away from the motor.

## STEP 8

**PURPOSE:** Mount the thrusters on the vehicle frame.

**MATERIALS:**
Assembled thrusters
Assembled frame

**TOOLS:**
Phillips Screwdriver

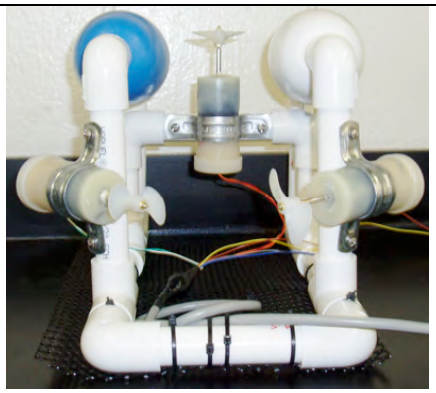


**Figure 24:** Mounted thrusters

**Note:** This step should only be done after the epoxy on the propellers has hardened to handling strength (60 minutes for the specified epoxy), but may be rushed as long as you do not turn the propeller shafts or stress the newly epoxied connection.

**PROCEDURE:**

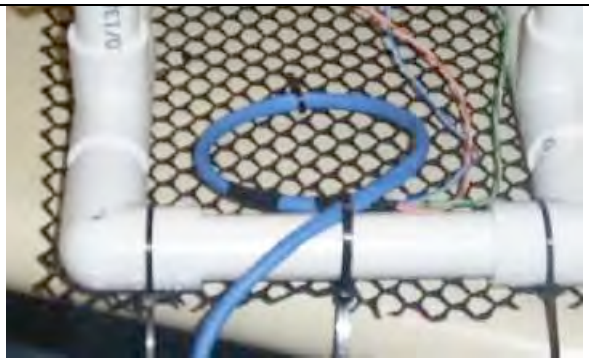
1. Using the screwdriver, remove the motor mounts from the frame.
2. Place a thruster inside each motor mount, according to the table below. The motor mount should go over the back end of the motor. It should not be over the back of the can where there is only wax, or over the center of the motor, where it might squeeze the motor casing, but over the back end of the motor, which will best resist the pressure of the motor mount.
3. Reattach motor mounts to the frame. It's OK if the motor cans get squeezed a little. Tighten screws just enough to hold the motor firmly, but be careful not to strip the hole in the PVC (tighten screws equally, three turn top, three turns bottom, etc., this will avoid stripping the PVC, and give you a tighter fit). If you do, re-drill the holes on another side of the PVC. It is fine if motor cases look "pinched" between the mount and the PVC.
4. You can now use pliers to turn the PVC that the motors are mounted on to get the motor angles you want. This is a good time to think about thrust, vectors and propulsion. How do the angles of the motors affect the performance of the ROV? What angles will get you the best forward and backward thrust? What angles will get you the best turning ability? What is the best compromise for your mission needs?

***TIP** It is easier to mount center thruster first, then mount the two side thrusters

| POSITIVE (+) | NEGATIVE (-) | THRUSTER |
|---|---|---|
| **Green** | **Green & White** | Starboard (right) |
| **Blue** | **Blue & White** | Port (left) |
| **Orange** | **Orange & White** | Vertical |
| **Brown** | **Brown & White** | Not Used |

## STEP 9

**PURPOSE:** Waterproof the tether cable.

| | |
|---|---|
| **MATERIALS:**<br>Completed frame with thrusters<br>Butyl Rubber tape<br>Electrical tape<br><br>**TOOLS:**<br>Scissors |  <br>**Figure 25:** Waterproofed tether tied in strain relief loop |

**PROCEDURE:**

1. Once the thrusters have been mounted, follow the wire pairs from the thrusters, to where they meet inside the tether sheath.

2. Take a small piece (about 1" or 2.5cm) of the butyl rubber tape (aka. monkey dung) and press it over the wire pairs and the sheath.

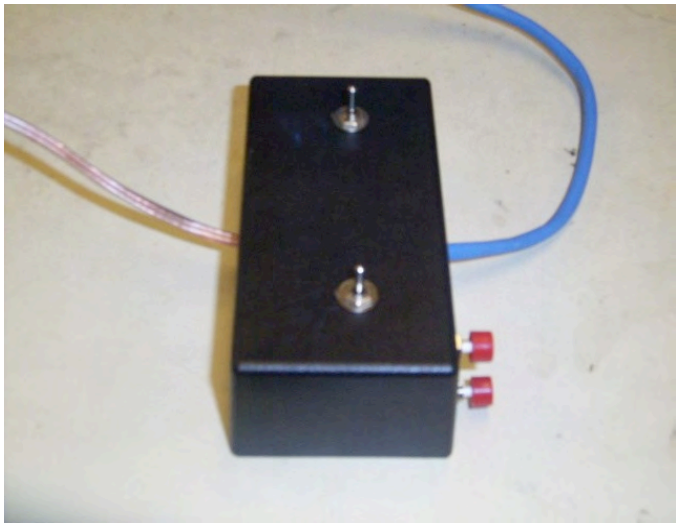
3. Knead and work it in well, so that it seals both around and between the wires and sheath, preventing water from getting into the tether cable.

4. Wrap electrical tape over the Butyl Rubber tape to keep it from sticking to anything.

5. After water proofing the tether, make a loop in the tether and attach to the vehicle frame with tie wraps (aka. Zip ties). Make sure the tether comes off from the center of the frame to avoid pulling our ROV to one side once in the water. This is "strain relief", intended to prevent any pulling on the tether cable from pulling on the motors. (Figure 25).

   **Note:** Since butyl rubber tape IS electrically conductive, make sure it DOES NOT touch any exposed wires. If you find that the wires are nicked where you cut the tether cable (exposing the inner copper wire), you must either seal them with electrical tape (if possible), or re-do the wiring for the motors.

# UNIT 3
# ASSEMBLY OF SUBSYSTEM THREE:
# THE CONTROL BOX



**FOR THIS TASK YOU WILL NEED:**

| TOOLS | MATERIALS |
|---|---|
| Soldering iron<br>Drill<br>1/4" drill bit<br>Nut driver<br>Wire cutter<br>Wire stripper<br>Small Phillips Screwdriver | Control box<br>2 push-button switches<br>2 toggle switches<br>2 alligator clips with sleeves (one red one black)<br>Fuse cap wire<br>Fuse (10 A slow blow fuse)<br>Speaker wire<br>1 loose red wire (#24 stranded hookup wire)<br>1 loose black wire (#24 Stranded hookup wire) |

**Time:** Unit 3 requires approximately 6 hours to complete:
1 class period to gather parts and prepare the control box (ergonomic design)
1 class period to make the power cable
1 class period to wire button switches
1 class period to wire the toggle (pole) switches
1 class period to finish the control box
1 class period to test Sea Perch in a "dry run" in the classroom

**WARNING:**
**SOLDERING IRONS GET VERY HOT AND CAN CAUSE SERIOUS BURNS.**
**HOT SOLDER MAY SPATTER. WEAR EYE PROTECTION!!!**
**TAKE CARE TO NOT SHORT BATTERIES OR SHOCK YOURSELF!**

## Sea Perch Circuit Diagram

In this section, you will build the control box for your Sea Perch ROV. Below is a circuit diagram which shows all the electrical connections that will be made. This diagram is a technical representation, to show the connections, but is not drawn to scale, and leaves out everything but the wires and electrical components. You can always refer back to this diagram to understand how and why the wiring should work. The individual steps have their own circuit diagrams, which are simply parts of this complete diagram. They also have wiring diagrams, which will help you understand what the wiring actually looks like.

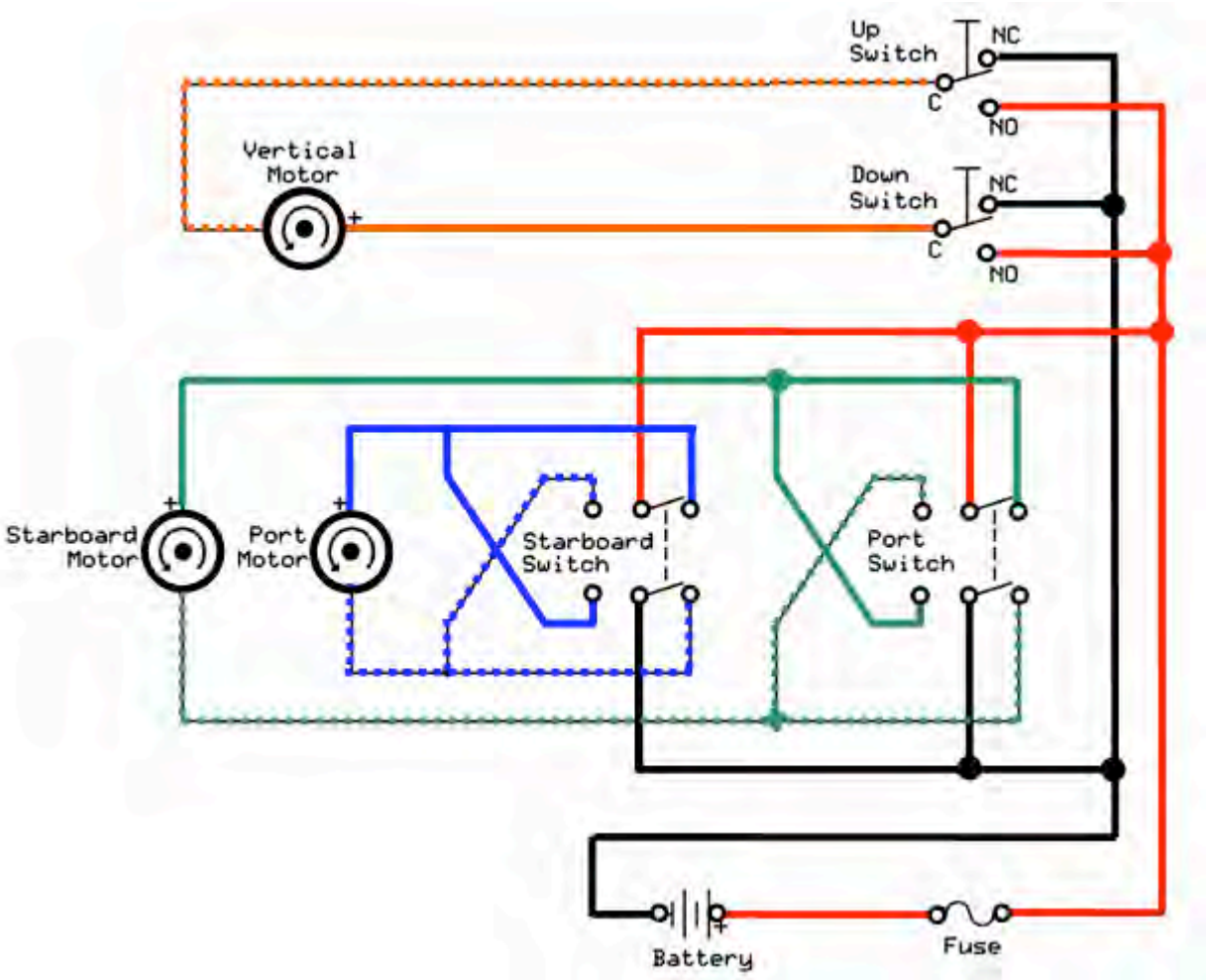
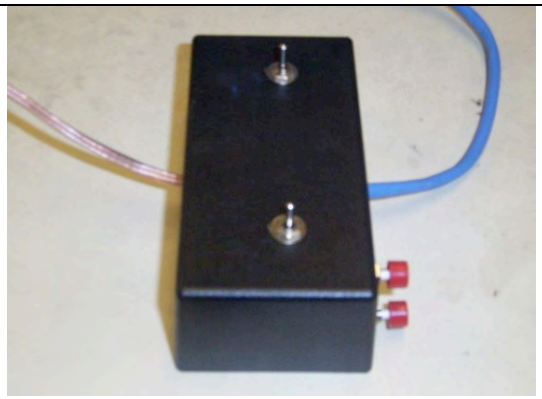



**Figure 26:** Sea Perch ROV Circuit Diagram

## STEP 1

**PURPOSE:** Gather the parts for the control box assembly.

| | |
|---|---|
| **MATERIALS:**<br>Control box<br>2 push-button switches<br>2 toggle switches (pole switches)<br>2 alligator clips<br>1 red alligator clip sleeve<br>1 black alligator clip sleeve<br>Fuse cap wire<br>Fuse (10 A slow blow fuse)<br>Speaker wire<br>1 loose red wire<br>1 loose black wire |  <br>**Figure 27:** Completed control box assembly. |

**PROCEDURE:**

1. Find the test wires that you used to test your motors in the previous unit.
2. Remove the alligator clips from the test wires. The alligator clips will be used on the power cable, and the wires will be used for the control box circuitry.
3. Gather the other parts required for the control box assembly, as shown in the diagram on the next page:

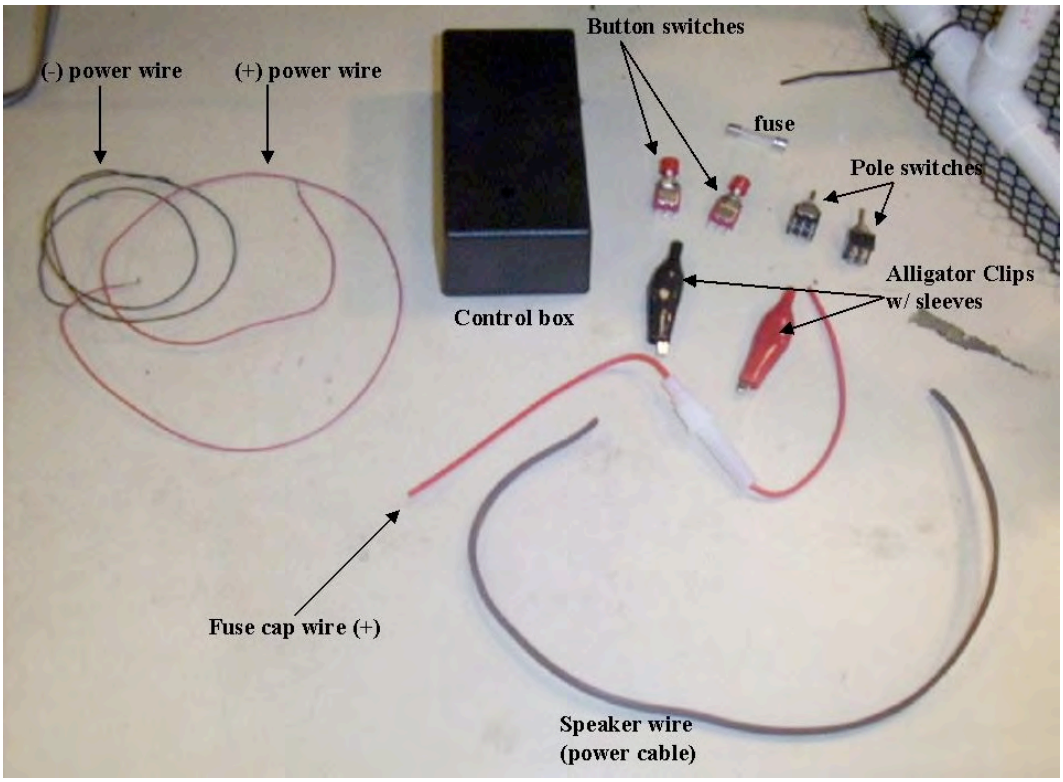



**Figure 28:** Parts for the control box assembly.
**NOTE: Speaker wire/power cable may be WHITE (instead of brown)**

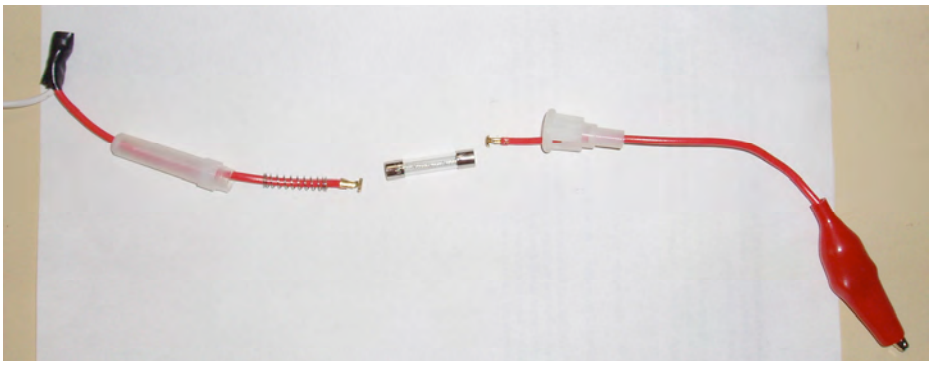
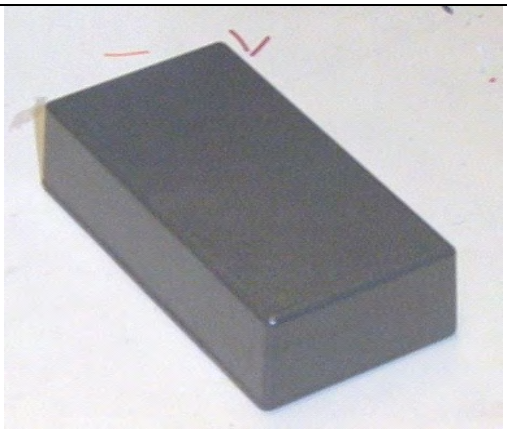


**Figure 28a:** This is what the Fuse Cap Wire looks like when taken apart, some of these wires may fall apart during transport of the kits. If you find these pieces in your kit, reassemble them in the order shown above.

STEP 2

**PURPOSE:** Prepare the control box

| | |
|---|---|
| **MATERIALS:**<br>Control box<br><br>**TOOLS:**<br>Marker<br>Drill<br>1/4” drill bit<br>Vise or clamp |  <br>**Figure 29:** Control Box |

**PROCEDURE:**

1. Using the marker, mark the locations of the holes on your control box, as shown (approximately) in Figure 30 below. Make sure holes are at least _” **away from edges** to allow switches to fit inside. There should be one in the center of the back for the power to come in, one in the center of the front for the tether cable to go out, two on the right hand side of the front for the vertical thruster controls, and two on top for the horizontal thruster controls. Make sure that the holes for the vertical thrusters leave enough room for the switches against the sides of the box. Ask your teacher if you are unsure.
2. Secure the control box in a vise or clamp and drill holes with the 1/4” drill bit in the marked locations.

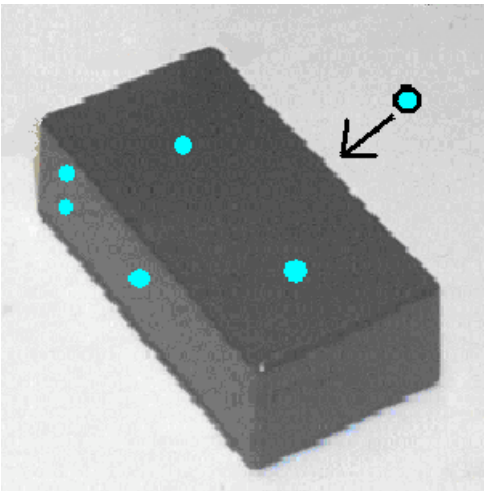


**Figure 30:** Control Box hole locations

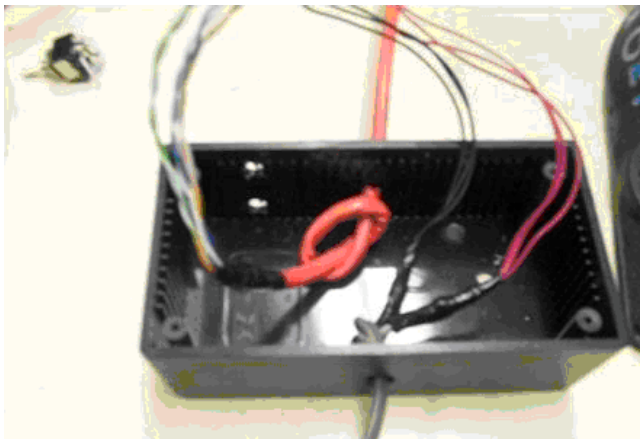


**Figure 31:** Cables in holes (see steps 3 & 4)

## STEP 3

**PURPOSE:** Assemble the power cable

**MATERIALS:**
Speaker wire (5-10' long)
2 alligator clips with sleeves
Fuse cap wire
Solder
Electrical tape
Loose red wire
Loose black wire

**TOOLS:**
Soldering iron
Wire cutter
Wire strippers
Small scissors
Vise or clamp

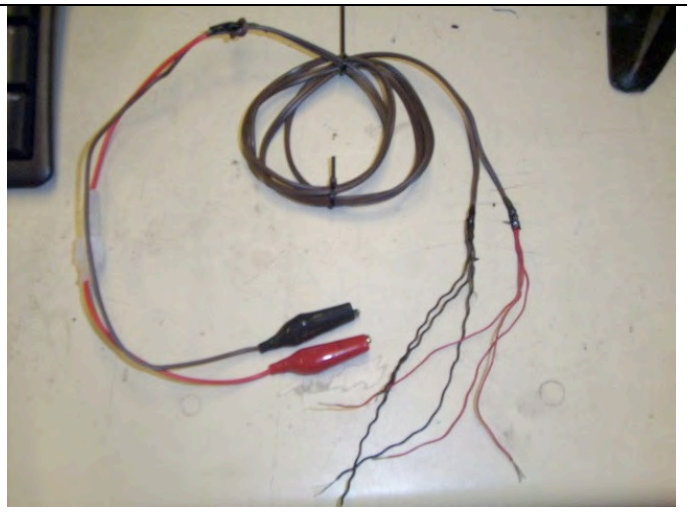


**Figure 32:** Completed power cable

In this step you will build the power cable for your control box. **A wiring diagram of the finished power cable is show in Figure 33.**

**PROCEDURE:**

1. Cut about 3" (7.5cm) of wire off of the end of the red and black loose wires. Set these short pieces aside for a later use with the toggle switches.
2. Cut the remaining red and black wires into four equal length pieces each (4 black and 4 red). If your pieces will be less than 5" (12.5cm), then ask your instructor for extra wire.
3. Strip about 1/4" (6mm) of insulation from each end of each piece. Twist the inner wires (strands) on each end to prevent fraying and breaking.

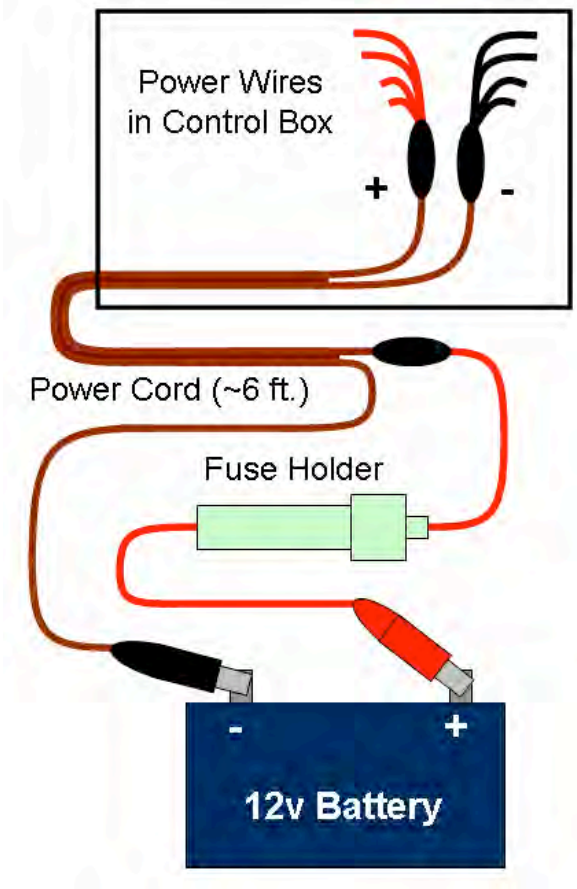



**Figure 33:** Power Cable wiring diagram.

4. Take one end of each of the four red wires and twist them all together, as shown in Figure 34 below.
5. Do the same with the black wires. These spliced wire bundles will distribute power in your control box.

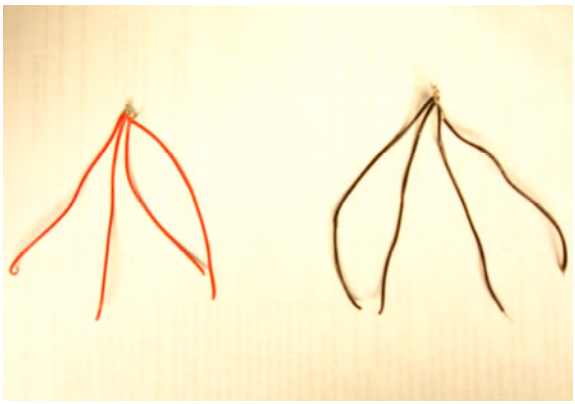


**Figure 34:** Spliced wire bundles

6. Find the power cable (speaker wire), and determine which side of it is positive and which is negative. Notice that there are two conductors inside, each with its own insulation, and attached to each other with a thin web of insulation material. Usually the insulation on one side is ribbed (like corduroy) and the other is smooth. Other times, one is marked with white or black stripes, or other indicators. We will call the ribbed or marked side the positive (+) side.
7. On each end of the speaker wire (power cord), carefully separate the two conductors for about 1" (2.5cm). This is best done by snipping the thin web of plastic between the wires with a small pair of scissors, or a fine pair of wire cutters. Be careful not to nick the insulation on the conductors.
8. On one end of the power cord, leave the separated section only 1" (2.5cm) long. On the other end, pull the two wires apart for about 14" (35cm).
9. On the part of the cord that you just separated, find the positive (ribbed or marked) side and cut off 13" (33cm) of the positive wire. This section will be replaced with the fuse cap wire, as shown in Figure 35 below.

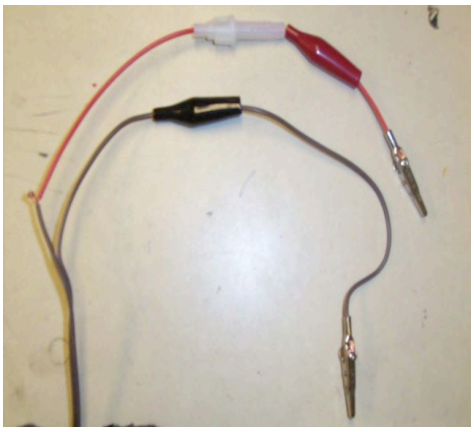


**Figure 35:** Battery end of the power cable.

10. Strip 1/2” (1.3cm) of insulation off both ends of the fuse cap wire. The fuse cap wire does not have a positive and negative side… it will work either way.
11. Strip 1/2” (1.3cm) of insulation off of all four ends of the power cord (speaker wire). Twist the conductor strands on each end together to prevent fraying and breaking.
12. Attach the fuse cap wire to the positive (ribbed/marked) side of the speaker cable, (where you cut off the 13”/33cm piece). Twist the wires together, solder the connection, and cover it with electrical tape.
13. Slide the red alligator clip sleeve onto the loose end of the fuse cap wire, and the black alligator clip sleeve onto the negative side of the power cord.
14. Attach alligator clips to the fuse cap wire (+), and to the negative side of the power cord (-). Stick the wire in through the back of the clip, and up through the hole near the screw. Loosen the screw and wrap the wire around it clockwise. Tighten the screw. You can solder the connection if you want to. At this point, your power cable should look like Figure 35.
15. Push the sleeves down over the alligator clips and put the fuse into the fuse cap.
16. **Pass the loose end of the power cable (no alligator clips) through the hole in the back of your control box**. Tie a strain-relief knot about 6” (15cm) up the cord, inside the control box. (Fig. 31
17. Take the spliced bundle of 4 red (+) wires, and twist the bundled end onto the positive (ribbed/marked) side of the speaker wire. Take the spliced bundle of 4 black (-) wires and twist the bundled end onto the negative (smooth) side of the speaker wire. Solder the connections and cover them with electrical tape, as shown in Figure 36. **ALWAYS USE A VISE OR CLAMP TO HOLD WIRES WHEN SOLDERING!**

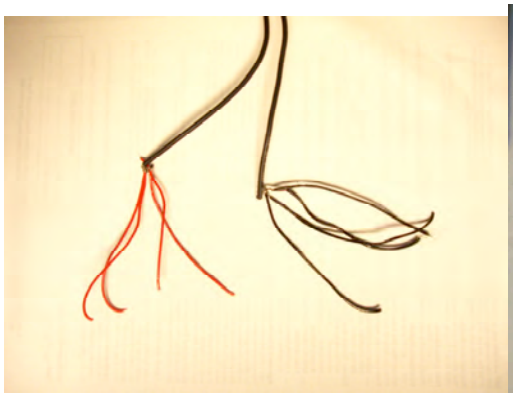


**Figure 36:**
Wire bundles soldered to end of power cord.

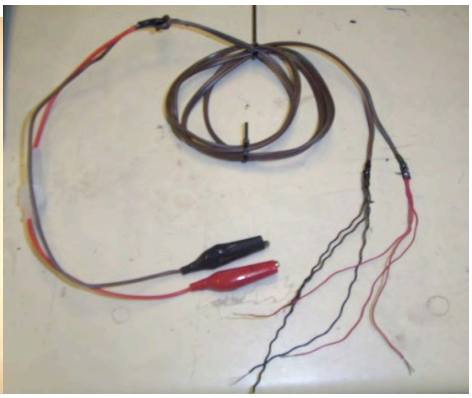
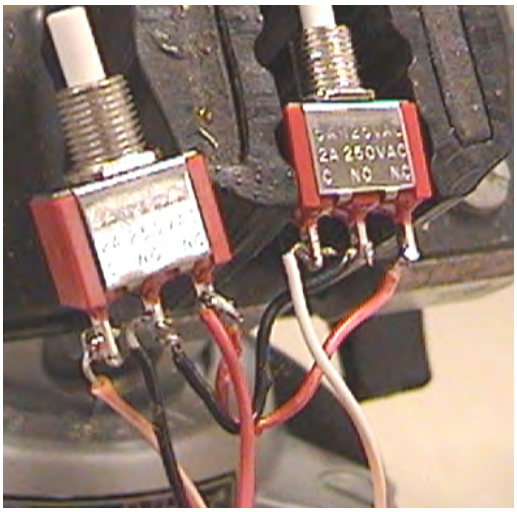


**Figure 37:**
Completed power cable assembly (without the control box).

## STEP 4

**PURPOSE:** Wire the push-button switches (vertical thruster controls)

| | |
|---|---|
| **MATERIALS:**<br>2 button switches<br>Solder<br>Prepared control box<br>Assembled power cable<br><br>**TOOLS:**<br>Soldering iron<br>Vise or clamp |  <br>**Figure 38**:<br>Vertical thrusters with tether wire and power connections. (Note: The switches in this photo are wired using the old method. The wiring described below will look slightly different.) |

**PROCEDURE:**

1. Refer to Figures 39 and 40 on the following pages for a circuit diagram and wiring diagram for the vertical thruster controls (the pushbutton switches).
2. Pull the end of the tether cable through the hole in the front of the control box. Tie a strain-relief knot about 8” (20cm) down the cable, inside the box.
3. Strip about 6” (15cm) of sheath off of the tether cable, being very careful not to nick the insulation on the inner wires.
4. Separate the four twisted pairs. We will be using the orange pair for the vertical thruster, so wrap up the others for now so they are out of the way.
5. Locate the terminal labels above the wire terminals on each switch. “C” stands for common, “NO” stands for normally open, and “NC” stands for normally connected.
6. Take one of the **red** (+) wires from your power cord (inside the control box), and twist it onto the NO terminal of one of the pushbutton switches. Repeat for the other switch.

7. Twist the two **black** (-) power wires to the NC terminals on the two pushbutton switches. (**ONE black wire to each switch—See Fig 40 on next page)**
8. Now take the orange wire pair from the tether cable and untwist the pair for about 2” (5cm). Strip 1/8” to 1/4" (3-6mm) of insulation off the end of both the orange wire and the white & orange wire.
9. Twist the **orange** (+) wire to the **C** terminal on ONE of the switches. (This switch will move the sea perch downward.)
10. Twist the **white & orange** (-) wire to the **C** terminal on the other switch. (This switch will move the sea perch upward.)
11. Once you have attached all the wires to the switches, ask your teacher to check your wiring, as it’s much easier to correct it before you solder.
12. Solder the connections on the three terminals on each switch, being careful not to create any solder bridges between the terminals, and making sure to snip off any frayed pieces of wire sticking out toward other wires.

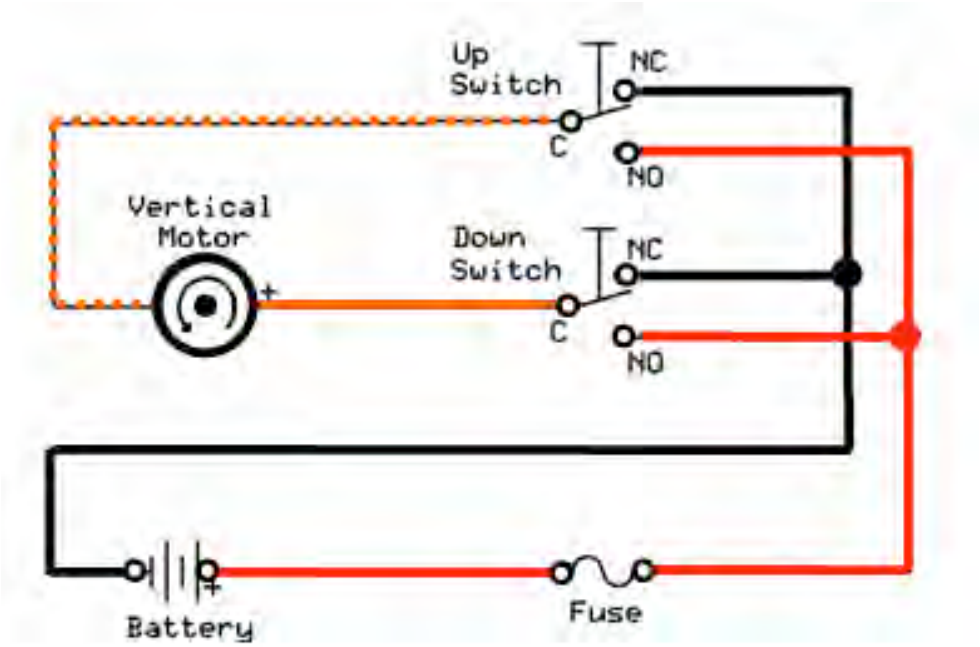



**Figure 39:** Vertical thruster circuit diagram.

***TIP** It can be useful to pre-mark switches for students

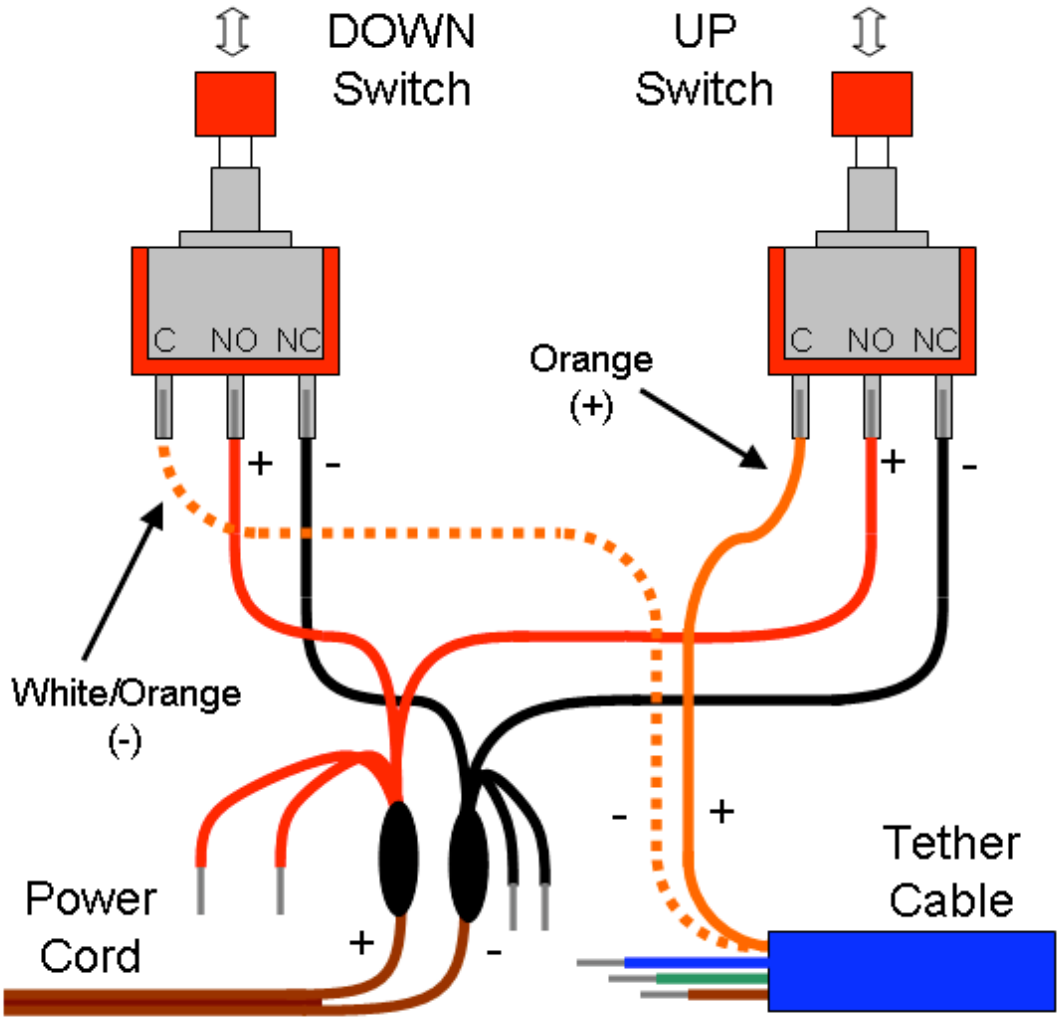
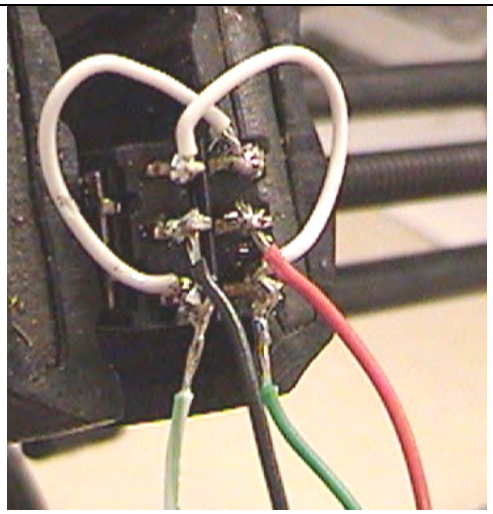



**Figure 40:** Vertical thruster control / pushbutton switch wiring diagram.

## STEP 5

**PURPOSE:** Wire the toggle switches (horizontal thruster controls)

| | |
|---|---|
| **MATERIALS:**<br>2 pole switches<br>Prepared control box<br>Solder<br><br>**TOOLS:**<br>Soldering iron<br>Vise or clamp |  <br>**Figure 41:**<br>Cross wired toggle switch with tether and power cable connections |

**PROCEDURE:**

1. Refer to Figures 45 and 46 on the following pages for a circuit diagram and wiring diagram for the horizontal (port & starboard) thruster controls (the toggle switches).
2. Before you solder anything on the toggle switches, attach ALL the wires by wrapping them through and/or around the terminals. Since some of the terminals have more than one wire connected to them, it is best to solder at the end, when ALL the wires are attached.
3. Cut four 1.5” (3.5cm) pieces of wire from either the small pieces wire you saved in an earlier step, some pieces of the brown tether wire, or other scrap wire. Strip 1/8” to 1/4" (3-6mm) of insulation off all of the ends.
4. Attach one of these pieces across the opposite corner terminals of each pole switch, making an “X” wiring pattern, as shown in Figure 42.

**Switch Soldering Tips:**
When soldering the switches, be very careful to avoid shorting out the many wires which end up in close proximity in the back of the switch. Attach all of the wires to the switch before soldering anything. Make sure that the wire strands are well twisted together, to avoid fraying strands that may short out against other wires or terminals. Solder quickly, so that the wires do not get too hot, and melt their insulation. Do not use too much solder, which could stick out and touch other connections.

**Figure 42:** Cross-wired toggle switch.

5. The pole switch terminals are arranged into 2 columns with 3 terminals in each column. Use the RIGHT column for positive (+) connections, and use the LEFT column for negative (-) connections.
6. Un-twist about 2" (5cm) of the blue and green tether wire pairs. Strip 1/8" to 1/4" (3-6mm) of insulation off of each wire end.
7. Attach the **green** (+) wire to the right corner terminal on your first pole switch. Attach the **white and green** (-) wire onto the terminal adjacent to it, as shown in Figure 43. Repeat with **blue** wires for the second switch.

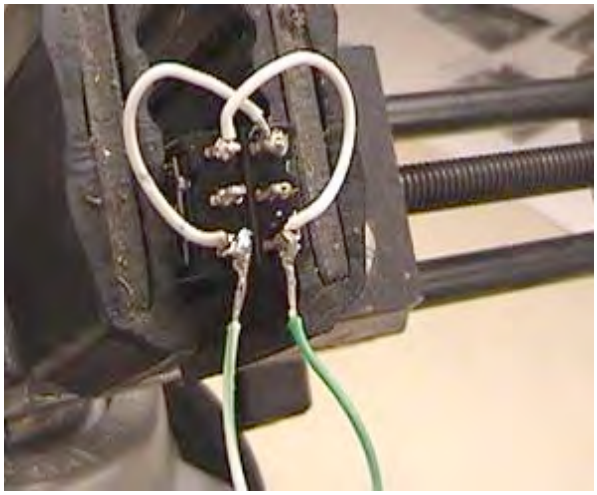


**Figure 43:** Cross-wired toggle switch with tether connections

8. Attach one **red** (+) power wire to the middle terminal of your first switch, on the same side as the solid-colored wire. Attach a **black** (-) power wire to the middle terminal on the other side, as shown in Figure 44. Repeat for the other switch.

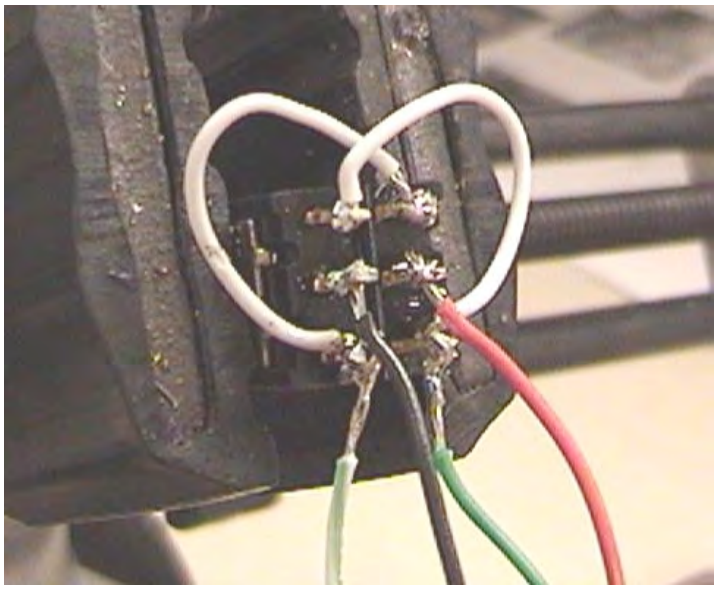


**Figure 44:**
Toggle switch with cross-wires, tether connections, and power connections.

9. Once all of the wire connections are made, check that the connections are clean, without fraying wire strands or other short circuits. Have your teacher check your wiring, and then carefully solder all of the connections on both toggle switches.
10. After soldering the connections, go back and check again that there are no shorts (touching wires or solder) between the switch terminals. If you find a short, de-solder and re-do it before continuing.

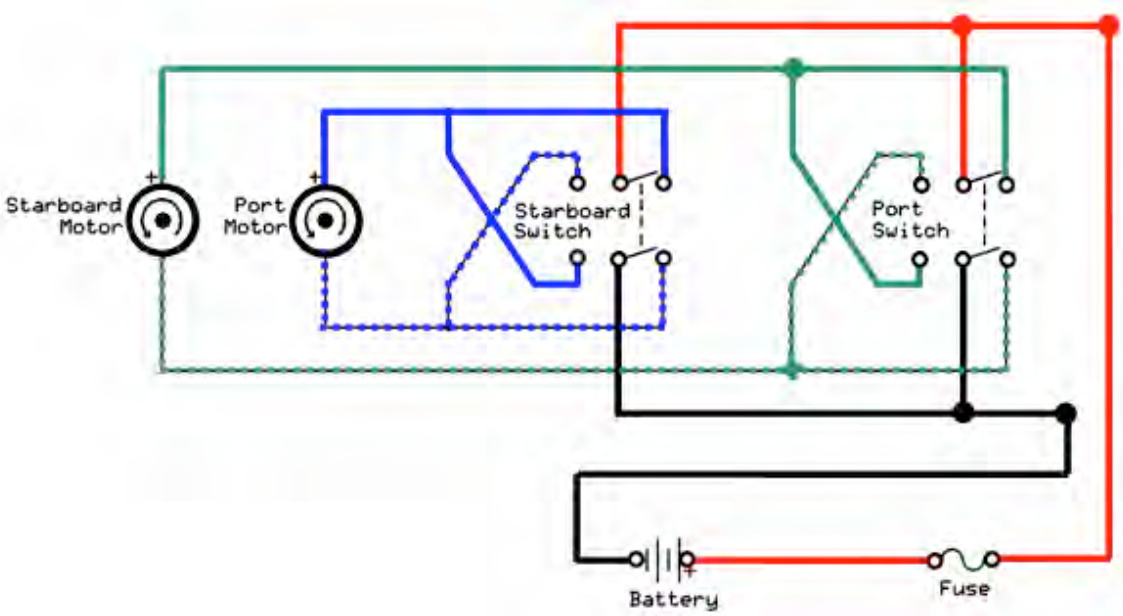



**Figure 45:** Circuit diagram for horizontal (port & starboard) thruster controls.

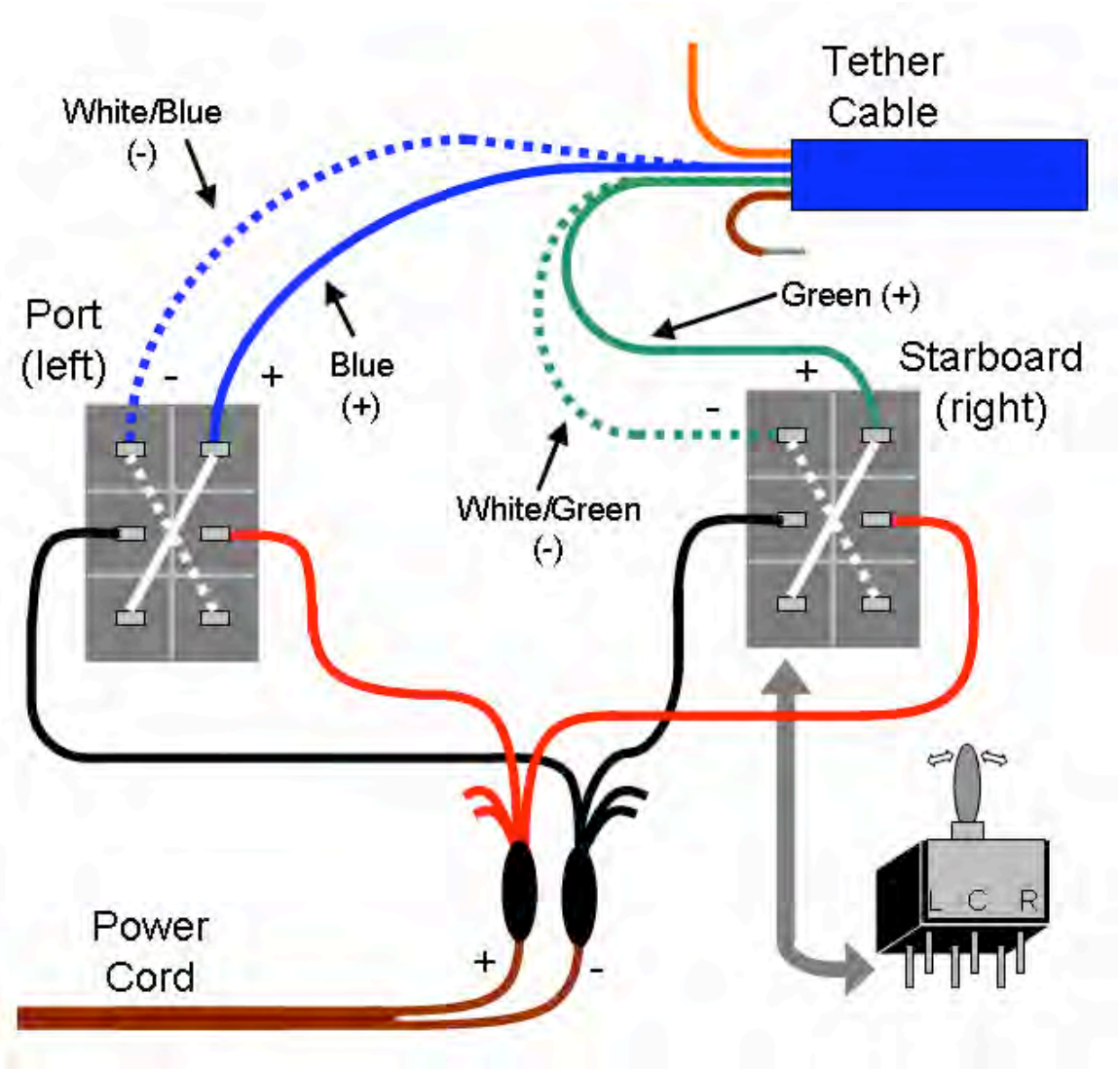
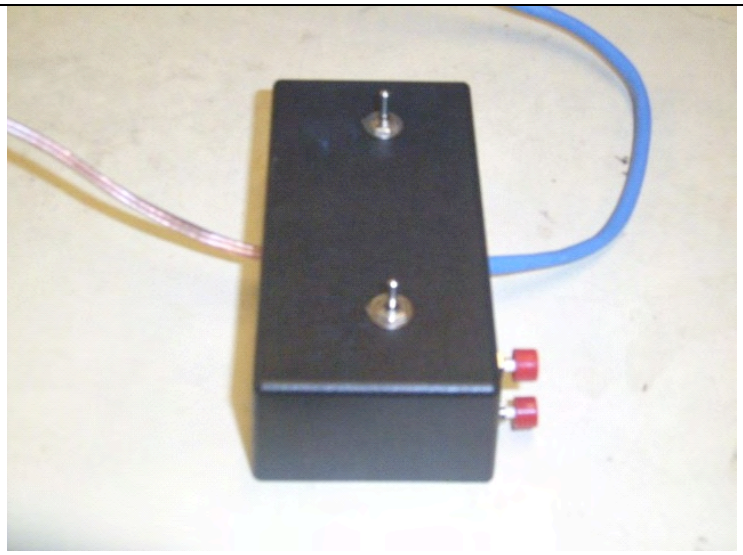



**Figure 46:** Toggle switch/Port and Starboard thruster wiring diagram

## STEP 6

**PURPOSE:** Finish the control box

| | |
|---|---|
| **MATERIALS:**<br>Control box<br>Wired Switches<br><br>**TOOLS:**<br>Phillips Screwdriver<br>5/16" Nut driver or Pliers |  <br>**Figure 47:** Completed control box |

**PROCEDURE:**

1. Place the pole switches in corresponding holes in the control box. Check the direction that the switches move the motors before securing them into place, (ex. Pressing forward will make the ROV move forward, etc.) Tighten into place with a nut driver or pair of pliers.
2. Remove the red button caps from the button switches by pulling up hard on the red caps. Be careful not to break the white stem.
3. Place button switches through the 2 holes next to the tether cable. Again, check the direction of the switches before securing into place. Tighten with nut driver or pliers. Replace the red button caps by pushing them on very snugly.

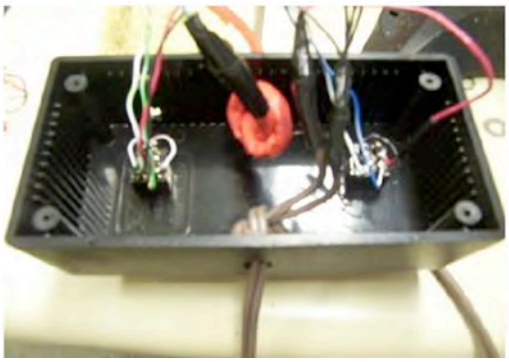
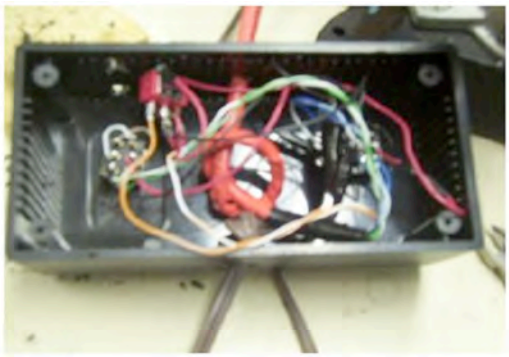



**Figure 48:** Control box with toggle switches and then all switches installed.

4. Screw the back onto the control box using the screwdriver.
5. Place the fuse in the fuse holder.
6. Congratulations, you have completed your Sea Perch ROV! (Figure 49).

NOTE: The direction of the forward/reverse thrusters will affect the efficiency of your Sea Perch. Play around with the direction of your thrusters when you test your Sea Perch to see what works the best!

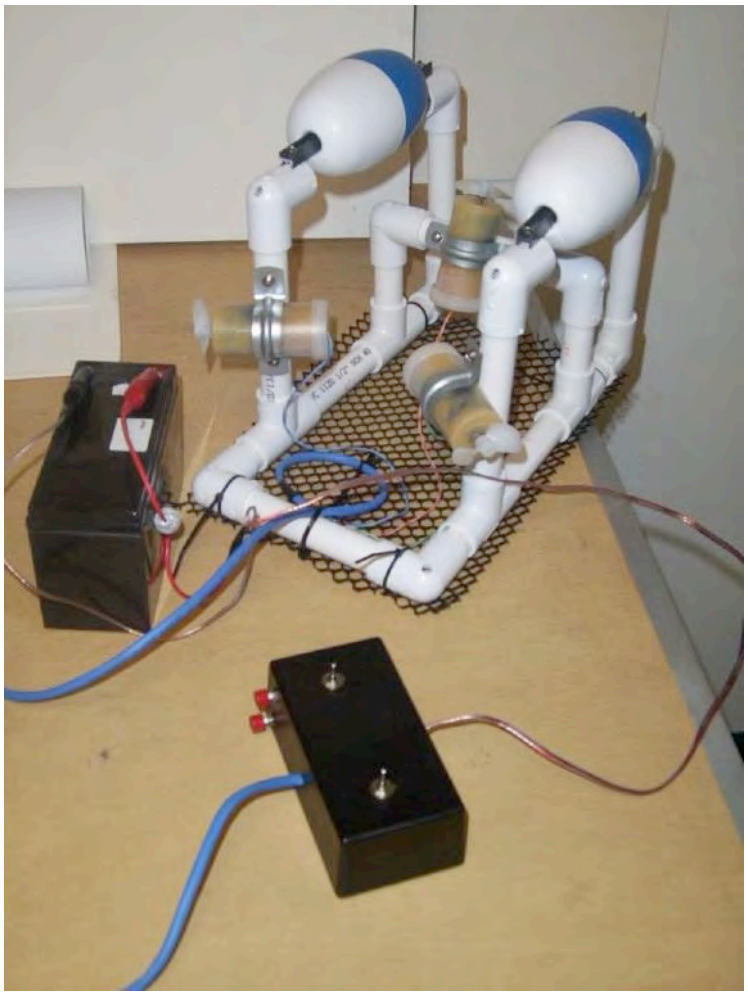
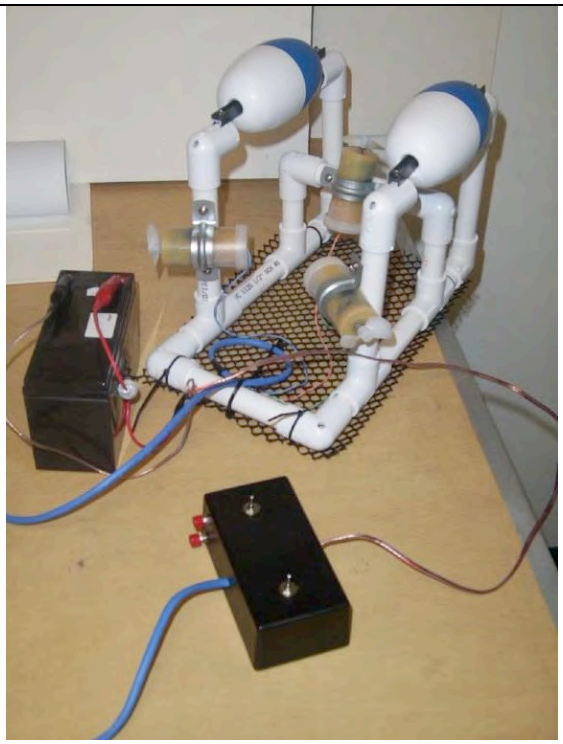


**Figure 49**: Finished Sea Perch ROV

## STEP 7

**PURPOSE:** Testing your Sea Perch ROV

| | |
|---|---|
| **MATERIALS:**<br>Completed ROV<br><br>**TOOLS:**<br>12 volt battery |  <br>**Figure 50:** Completed Sea Perch ROV |

The first time you power-up your Sea Perch ROV, there are a few steps you should take to make sure everything is working properly:

1. Before beginning, make sure that you have a good fuse installed, and that all of the switches on your control box are turned off – pushbutton switches are not pressed, and toggle switches are in the center position.
2. The first time you attach the power cable to the battery, clip the black (-) alligator clip onto the Negative (-) terminal on the battery. Then, quickly tap the red (+) alligator clip against the Positive (+) terminal on the battery. You should NOT get a large spark when you do this. A tiny spark is ok, but a large spark indicates a possible short in your system. A short circuit can wreak havoc on your Sea Perch, as it may cause wires to heat up and melt, in the control box, or worse, inside the tether cable or the motors.
3. If you do get a large spark, check that your switches are all off, and try again. If you still get a large spark, unclip the black alligator clip from the battery, use a multi-meter to find where the short is in your system, and fix the short. The circuit diagram at the beginning of this section, and the wiring diagrams in the previous steps are good references for troubleshooting.
4. Once you have confirmed that there are no initial shorts, clip both alligator clips onto their corresponding battery terminals. Quickly tap the switches (rapidly on

and off) one at a time, and listen if a motor turns each time you do. If all of the switches satisfactorily engage a motor, then your system is ready to run. If a motor does NOT turn when you activate each switch, you have either a broken connection (blown fuse, unclipped battery, broken wire, broken solder joint, etc.), or you have a short circuit somewhere.

5. Turn on each motor one by one, and check that it is turning in the correct direction. If not, the easiest way to fix this is to physically re-position the switch in the control box. This is usually simpler than re-soldering the wires.

You are now ready to run your Sea Perch ROV!

To run the Sea Perch, clip the alligator clips onto the corresponding terminals on the battery (red +, black -). Be careful not to short the battery. If the Sea Perch stops working, first check the fuse to see if it has blown.

Place Sea Perch in the water and attach weights to the payload netting until it has just slightly positive buoyancy, meaning that it sits in the water with the floats just out of the water by about 1/4" (5mm) or less. A typical Sea Perch without cameras or other sensors on board usually requires about 4 to 10 ounces (125 to 300 grams) to achieve proper buoyancy. If your Sea Perch sinks without applying the downward thruster, it is too heavy. If your Sea Perch has trouble diving, or floats up to the surface very quickly, then it is too light.

The motor angles can be adjusted for optimal thrust, maneuverability, or stability, as described in Unit 1.

***Make sure to charge your battery after using it. Lead-acid batteries will last much longer if they are not left discharged. ***

Always make sure to rinse your Sea Perch with fresh water when you have finished operating it. Pay special attention to the motor shafts as they are often the first place to rust. Clean all seaweed and other buildup off of the motor shafts, **and rinse them well with fresh water.**

The Sea Perch website ( http://seaperch.mit.edu ) has many resources and ideas for using Sea Perch ROVs for fun and education. Don't forget to take some photos of your expeditions. If you send them to us, we may be able to put them on the website!

Remember to be safe when working around the water.

Have Fun!

MIT SEA GRANT

# Sea Perch ROV

## Parts and Tools Lists

These lists have been compiled in order to assist you in building the Sea Perch in your classroom and in ordering the necessary parts and tools. Please consult the construction manual and reference your Sea Perch training to verify what you will need.

The suggested vendors have been selected for convenience, price, and/or ease of use. Many of the items may be available at lower cost from other sources, or may be already available at your school (especially tools). Many items come in bulk, or are only available in quantities or packages larger than that needed for a single Sea Perch kit. In these cases, the cost per kit is calculated as a fraction of the minimum order quantity and price. When ordering for multiple kits, verify the quantity needed to order with the quantity needed for each kit and the minimum order quantity. Do not rely solely on the quantity column for the number to order. Many vendors have significant quantity discounts available, and some may have educational discounts.

Key

| | |
|---|---|
| Qty. | Quantity - number of items needed for 1 kit, or length needed for items such as wire. |
| Size | Size or amount of item required, or unit of measure. |
| Item | Description of item. |
| Suggested Vendor | Suggested source for purchase of items. |
| Cat.No. | Catalog Number of item in suggested vendor's catalog |
| Minimum Package Quantity | Minimum amount available from vendor in a single order - may be more or less than needed for 1 kit |
| Per Package Cost | Cost of minimum order. |
| Order Quantity (# Pack.) | Number of packages of minimum order size needed for 1 kit. |
| Minimum Order Cost | Cost of quantity needed to order (minimum order) |
| Per Kit Cost | Cost of material needed for 1 kit (ignoring minimum orders) |
| Notes | Additional information, including quantity discounts and alternative sources |

These lists were last updated in August 2007. All items were available from the suggested vendors at that time, but availability may change.

We strongly suggest ordering some extra film cans (sample vials), fuses, and hookup wire, as these items often need replacing.

## Sea Perch

**Master List - Parts for 1 vehicle**

| Qty. | Size | Item | Suggested Vendor | Cat. No. | Minimum Package Quantity | Per Package Cost | Order Quantity (# Pack.) | Minimum Order Cost | Per Kit Cost | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| **Vehicle Frame** | | | | | | | | | | |
| 1 | 14 in | 3/8", ABS H-Column | Plastruct | H-12 | 1 | $ 1.45 | 1 | $ 1.45 | $ 1.45 | Quantity discount: 4 for $5.55 |
| 1 | 5 ft | 1/2", Sch. 40 PVC Pipe | McMaster-Carr | 48925K91 | 1 | $ 1.97 | 1 | $ 1.97 | $ 1.97 | |
| 10 | each | PVC elbows, 1/2" Sch. 40 | McMaster-Carr | 4880K21 | 1 | $ 0.31 | 10 | $ 3.10 | $ 3.10 | |
| 4 | each | PVC Tees, 1/2" Sch. 40 | McMaster-Carr | 4880K41 | 1 | $ 0.38 | 4 | $ 1.52 | $ 1.52 | |
| 1 | 12"x8" | Polyethylene Mesh (sold 36" wide, per foot) | McMaster-Carr | 9314T33 | 1 | $ 1.05 | 1 | $ 1.05 | $ 1.05 | |
| 3 | each | Conduit straps (motor mounts) | McMaster-Carr | 9429T36 | 50 | $ 5.00 | 1 | $ 5.00 | $ 0.30 | |
| 6 | each | #6 x 1/2" stainless steel sheet metal screws | McMaster-Carr | 92465A148 | 100 | $ 7.36 | 1 | $ 7.36 | $ 0.44 | |
| 6 | each | #6 stainless steel flat washers | McMaster-Carr | 90107A007 | 100 | $ 4.08 | 1 | $ 4.08 | $ 0.24 | |
| 2 | each | Football floats 3"x5" | Aquatic Ecosystems | NF7 | 1 | $ 1.80 | 2 | $ 3.60 | $ 3.60 | 24+ @ $1.60ea. |
| 4 | each | 1 oz. and/or 2 oz. large steel nuts (ballast weight) | | | | | | | | Or use large fishing sinkers |
| | | | | | | | | | | |
| **Thruster Assembly** | | | | | | | | | | |
| 3 | each | Plastic Sample Vial, 50ml (or use free film cans!) | US Plastics | 81037 | 1 | $ 1.57 | 3 | $ 4.71 | $ 4.71 | Quantity Discount available |
| 6 | each | Brass Hex Nuts, 4-40 | McMaster-Carr | 95130A110 | 100 | $ 3.13 | 1 | $ 3.13 | $ 0.19 | |
| 3 | each | Threaded Coupler 4-40, 0.095" (Propeller Shaft) | Tower Hobbies | GPMQ3832 | 2 | $ 1.39 | 2 | $ 2.78 | $ 2.09 | |
| 3 | each | 1/8" plastic propeller 0.19, 0.35 | Tower Hobbies | DUMB1860 | 1 | $ 1.15 | 3 | $ 3.45 | $ 3.45 | |
| 3 | each | Motors 12 volt | Jameco | 232021 | 1 | $ 2.25 | 3 | $ 6.75 | $ 6.75 | 100+ @ $1.79ea. |
| 40 | ft. long | Cat 5 cable, 4 twisted pair, stranded (by the foot) | Jameco | 201582 | 25 | $ 9.45 | 2 | $ 18.90 | $ 15.12 | Quantity discounts available |
| | | | | | | | | | | |
| **Control Box** | | | | | | | | | | |
| 1 | each | Plastic box 4.9"x2.5"x1.5" | Jameco | 18913 | 1 | $ 3.69 | 1 | $ 3.69 | $ 3.69 | 10+ @ $3.32ea. |
| 2 | each | DPDT center off toggle switches | Jameco | 21952 | 1 | $ 1.55 | 2 | $ 3.10 | $ 3.10 | Quantity Discount available |
| 2 | each | SPDT mom. push button switches | Jameco | 121304 | 1 | $ 3.59 | 2 | $ 7.18 | $ 7.18 | Quantity Discount available |
| 2 | each | Alligator clips | Jameco | 256525 | 2 | $ 0.50 | 1 | $ 0.50 | $ 0.50 | Quantity Discount available |
| 1 | each | Insulator for alligator clip - Red | Jameco | 248972 | 2 | $ 0.51 | 1 | $ 0.51 | $ 0.26 | Quantity Discount available |
| 1 | each | Insulator for alligator clip - Black | Jameco | 248962 | 2 | $ 0.51 | 1 | $ 0.51 | $ 0.26 | Quantity Discount available |
| 1 | each | Fuseholder, In-line, 1.25"x.25" fuse | Jameco | 151918 | 1 | $ 1.19 | 1 | $ 1.19 | $ 1.19 | Quantity Discount available |
| 1 | each | Fuse: 10A, slow-blow | McMaster-Carr | 7085K15 | 5 | $ 6.44 | 1 | $ 6.44 | $ 1.29 | Quantity Discount available |
| 6 | ft. long | #18AWG speaker wire, 6 foot length | McMaster-Carr | 70405K34 | 1 | $ 0.18 | 6 | $ 1.08 | $ 1.08 | 250'+ @ $.09/ft. |
| | | | | | | | | | | |
| **Expendable Supplies** | | | | | | | | | | |
| 0.5 | ring | Wax Toilet Bowl Ring (1/2 ring for each vehicle) | McMaster-Carr | 2793K31 | 1 | $ 1.40 | 1 | $ 1.40 | $ 0.70 | @ HomeDepot: 8 rings for $3.35 |
| 1 | each | Epoxy packet & mixing stick | McMaster-Carr | 7493A34 | 10 | $ 12.04 | 1 | $ 12.04 | $ 1.20 | |
| 2 | ft. long | #24 stranded hookup wire, red (sold by 100' roll) | McMaster-Carr | 7587K921 | 100 | $ 6.83 | 1 | $ 6.83 | $ 0.14 | |
| 2 | ft. long | #24 stranded hookup wire, black (sold by 100' roll) | McMaster-Carr | 7587K922 | 100 | $ 6.83 | 1 | $ 6.83 | $ 0.14 | |
| 15 | 6 in. | 6" cable ties (aka: zip-ties or tie-wraps), black | McMaster-Carr | 7130K42 | 100 | $ 4.14 | 1 | $ 4.14 | $ 0.62 | |
| 3 | inches | Butyl Rubber Tape aka. "Monkey Dung" (16 yd. roll) | McMaster-Carr | 76385A15 | 576 | $ 18.25 | 1 | $ 18.25 | $ 0.10 | |
| 1 | roll | Electrical tape | Jameco | 285587 | 1 | $ 0.99 | 1 | $ 0.99 | $ 0.99 | Higher quality tape also available |
| 1 | roll | Solder, 60/40 rosin core (contains lead) | Jameco | 170457 | 1 | $ 1.39 | 1 | $ 1.39 | $ 1.39 | |
| 1 | bottle | Rubbing Alcohol | | | | | | | | |
| 1 | roll | Paper Towels | | | | | | | | |
| | | Newspaper, cardboard or dropclots to protect waxing table, wall & floor | | | | | | | | |
| | | | | | | | | | | |
| **Total for ROV** | | | | | Total for minimum order quantity | | | $ 144.92 | **$ 69.79** | per kit, w/o battery or charger |

## Sea Perch

| | | | | | | |
|---|---|---|---|---|---|---|
| **Battery & Charger** | | | | | | |
| 1 | 12 v | Battery, Sealed Lead Acid (SLA), 12 volt, 7 AH | batterymart.com | SLA-12V7-F1 | $ 14.95 | also @ Jameco # 264057, $18.15 ea. |
| 1 | | Charger - 12v, 500mA Automatic SLA Charger | batterymart.com | ACC-12BC0500D-1 | $ 15.95 | also @ McMaster # 7448K67, $38.33 |
| 1 | | Cord for Charger | batterymart.com | ACC-D-1766 | $ 1.95 | (cord not needed with McMaster Charge above) |
| | | | | | | |
| **Total for Battery and Charger** | | | | | **$ 32.85** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Individual Tools (suggested for each Sea Perch kit)** | | | | | | |
| 1 | | PVC Pipe Tubing Cutter (RATCHET Style!) | PlumbingStore.com | 4657 | $ 17.88 | also available at McMaster #8336A13, for $44.37 |
| 1 | | Screwdriver, flat, medium | McMaster-Carr | 5682A18 | $ 4.46 | |
| 1 | | Screwdriver, phillips, small | McMaster-Carr | 5682A27 | $ 3.32 | |
| 1 | | Scissors | McMaster-Carr | 3608A14 | $ 11.51 | |
| 1 | | Slip joint pliers (and/or needle-nose pliers) | McMaster-Carr | 5624A8 | $ 8.12 | |
| 1 | | Diagonal cutter pliers (wire cutters) | McMaster-Carr | 3621A11 | $ 5.81 | |
| 1 | | Wire strippers (for 26-16 AWG Stranded wire) | McMaster-Carr | 7294K58 | $ 9.91 | |
| 1 | | Safety Glasses (Eye Protection) | McMaster-Carr | 54185T601 | $ 2.30 | For over prescription glasses, use #52755T9, $5.02 ea. |
| 1 | | Plastic Tote: parts and/or tool container (optional) | McMaster-Carr | 4387T51 | $ 4.34 | |
| 1 | | Soldering Iron | Jameco | 224611 | $ 7.95 | Many options available, for +/- $ |
| 1 | | Soldering Stand | Jameco | 36329 | $ 4.95 | |
| 1 | | Soldering Iron Tip, conical | Jameco | 226018 | $ 0.95 | |
| 1 | | Sharpie (marker) | Office Depot, etc. | | | |
| 1 | | Ruler | Office Depot, etc. | | | |
| 1 | | Pen | Office Depot, etc. | | | |
| 1 | | Pencil | Office Depot, etc. | | | |
| 1 | | Pad of paper (lab notebook) | Office Depot, etc. | | | |
| 1 | | Paint set, enamel, regular colors (optional) | Tower Hobbies | LXHH93 | $ 7.89 | |
| 1 | | Paint brush set (optional) | Tower Hobbies | LXB838 | $ 3.39 | |
| | | | | | | |
| **Shared Tools (shared by multiple Sea Perch kits)** | | | | | | |
| 1 | | Drill bit, 1/4" | McMaster-Carr | 2901A124 | $ 2.16 | Quantity Discount available, 12+ |
| 1 | | Drill bit, 3/32" | McMaster-Carr | 2901A113 | $ 1.06 | Quantity Discount available, 12+ |
| 1 | | Twisted Pair Cable Stripper (for tether sheath) | McMaster-Carr | 4333K26 | $ 23.28 | @ Jameco: #230447, $18.89 |
| 1 | | Hand drill, variable speed - corded or cordless | Sears, Home Depot, etc. | various | $ 29.99 | Many types available: $30-$200 |
| 1 | | Electric Skillet (by Presto) | Ace Hardware, etc. | 65987 | $ 29.99 | Any Hot plate and pan will do |
| 1 | | Metal cup or beaker for melting wax | | | | cups with handles suggested |
| 1 | | Digital Multimeter for debugging (optional) | Jameco | 220812 | $ 9.65 | |
| 1 | | Desoldering Pump, aka. "solder sucker" (optional) | Jameco | 19166 | $ 4.95 | Or use solder wick, Jameco # 41081, $1.75 ea. |
| 1 | | Bench vise, 4" (optional) | McMaster-Carr | 5310A42 | $ 49.16 | cheaper @ HomeDepot, etc. |
| | | Thruster potting holder parts: wood, fine nails, wood glue (optional) | | | | |
| | | | | | | |
| **Total for a complete set of Tools** | | | | | **$ 243.02** | |

# Sea Perch

## Web Addresses of Vendors

| | |
|---|---|
| Ace Hardware | www.acehardwareoutlet.com |
| Allied Electronics | www.alliedelec.com |
| Aquatic Ecosystems | www.aquaticeco.com |
| BatteryMart.com | www.batterymart.com |
| Home Depot | www.homedepot.com |
| Jameco | www.jameco.com |
| McMaster-Carr | www.mcmaster.com |
| Plastruct | www.plastruct.com |
| The Plumbing Store | www.PlumbingStore.com |
| Sears | www.sears.com |
| Tower Hobbies | www.towerhobbies.com |
| US Plastics | www.usplastic.com |

**Old Suppliers (no longer used in this list, but still useful as backup)**

| | |
|---|---|
| Radio Shack | www.radioshack.com |
| Small Parts Inc. | www.smallparts.com |
| Newark Electronics | www.newark.com |
| Contact East | www.contacteast.com |
| DataComm Warehouse | www.warehouse.com |
| Go Fishin | gofishin.com |
| IWP | www.rubbermaidproducts.com |

## Optional Accessories for the Sea Perch

**Alternative switches**

Some educators have been successfully using larger toggle switches to replace both the toggle and pushbutton switches. They are cheaper and easier to hookup because of their screw terminals.

| | | | | |
|---|---|---|---|---|
| They are avalable from: | http://www.kelvin.com | Part# 270013 | $1.75 ea. | ($1.45 ea. for >10) |

**Cheaper Tether Cables**

Ethernet cable is available in bulk from various vendors. Searching online will yeild cheaper sources, as prices fluctuate. Be sure to get Cat5 or Cat5e cable with 4 twisted pairs, and STRANDED wires!

**Sensors**

| | | |
|---|---|---|
| Hobo Data Loggers | http://www.iscienceproject.com/ | K-12 teachers can sign them out for free! |

**Underwater cameras**

| | | | |
|---|---|---|---|
| Resources Unltd | http://www.resunltd4u.com/ | part# GM-300KX-10 | $179 |
| Security labs | http://spycorder.com/waterproof.htm | Model # SLC-131 | $150 |
| Polaris | www.polarisusa.com | | |
| Matco | www.matco.com | | |

**Tank for testing ROV (allows for testing during adverse weather)**

| | | |
|---|---|---|
| Aquatic Eco Systems | http://www.aquaticeco.com/ | QT502, $352, Portable Tank, 450 gallons - 30 inches high, 6ft diameter |