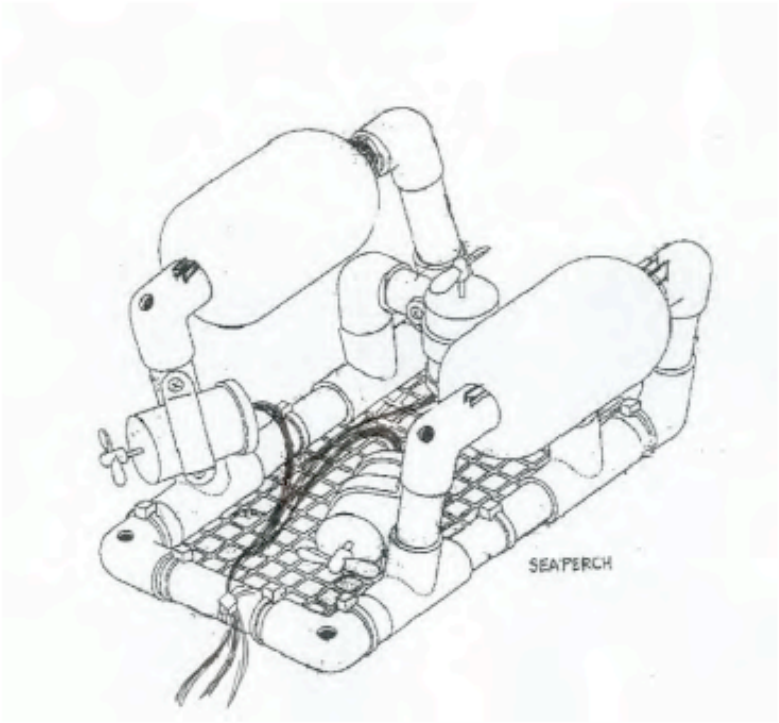
MIT SEA GRANT

Sea Perch

Construction Manual



DEPARTMENT OF THE NAVY
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MIT SEA GRANT

MIT Sea Grant's Sea Perch project introduces pre-college students to the wonders of underwater robotics. Part of the Office of Naval Research's initiative, "Recruiting the Next Generation of Naval Architects," this program teaches students how to build an underwater robot (called a Sea Perch), how to build a propulsion system, and how to develop a controller. This endeavor is one of many exciting new projects funded by the Office of Naval Research as part of its National Naval Responsibility Initiative. The initiative focuses on bringing academia, government and industry to work together to ensure that the talent needed to design the Navy's next generation of ships and submarines will be there when needed.

The Sea Perch project is based upon the book *Build Your Own Under Water Robot and Other Wet Projects* by Harry Bohm and Vickie Jensen. The Sea Perch ROV project can easily be turned into a multidisciplinary venture within the classroom. For instance, by incorporating novels that focus on ocean exploration, focusing on ship and submarine technology throughout history, adding environmental sensors for data collection and studying the math and physics involved in ocean exploration, teachers can develop extensive, in-depth programs for their classes.

Our project website is our main source of materials for the Sea Perch project. Please visit the site for PDF versions of the manuals, experiments, activities and additional online resources at:

http://seagrant.mit.edu

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Sea Perch Teacher Handbook

Safety Reminders

Make sure the workspace is well lit and ventilated.

Each student must wear:
- Safety goggles
- Close-toed shoes
- Aprons

- Each student must have adequate space for soldering
- Students should put soldering irons in holders whenever the soldering irons are not in use (while students questions, inspect work, listen to or read instruction, and/or help others)
- Students must use a vise or clamp while soldering or drilling.
- Students should hold solder by the solder case to avoid burns and avoid touching lead-based solder (if used).

Have spare pieces available for students to practice drilling and soldering before they attempt to drill or solder their ROVs.

UNIT 1:
Assembly of the Vehicle Frame

For this unit, you will need:

Tools	**Materials**
Ruler Marker PVC pipe cutter or saw Phillips Screwdriver Drill 1/4” drill bit 3/32” drill bit Vise or clamp	5 ft. (1.5 meters) of 1/2” PVC pipe 10 1/2” PVC elbows 4 1/2” PVC T’s 15” Plastruct H-beam 2 Football Floats 3 Motor Mounts 6 #6 x 1/2”Screws 6 #6 washers Netting Tie Wraps (zip ties)
Time: Unit 1 requires approximately **2 hours** to complete. We recommend: 1 class period to cut the PVC pipe and drill the holes 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” (6.4 cm) long
   - Two pieces – 4” (10.2 cm) long
   - Two pieces – 4 1/2” (11.4 cm) long
   - Four pieces – 1 1/2” (3.8 cm) long
   - Four pieces – 5” or (12.7 cm) long
   - Four pieces – ¾” –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.

   Tip: 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 they are the most labor-intensive option.
Band Saws are large pieces of shop equipment, and can get the job done, but may also be too dangerous to use around less mature or trustworthy student groups.

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. Securely place 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 will allow water to fill the frame when you put your SeaPerch ROV in the water and for the water to drain out when you take the SeaPerch ROV out.

Drill Safety:

Drills can be dangerous pieces of equipment. Always supervise students who are working with a drill or other power tool. Make sure everyone in the room is wearing safety goggles when power tools are being used.

It is necessary to secure the object that 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 10 1/2" PVC elbows with holes drilled from step 2 4 1/2"PVC T's	 **Figure 3:** PVC Frame Parts

PROCEDURE:

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

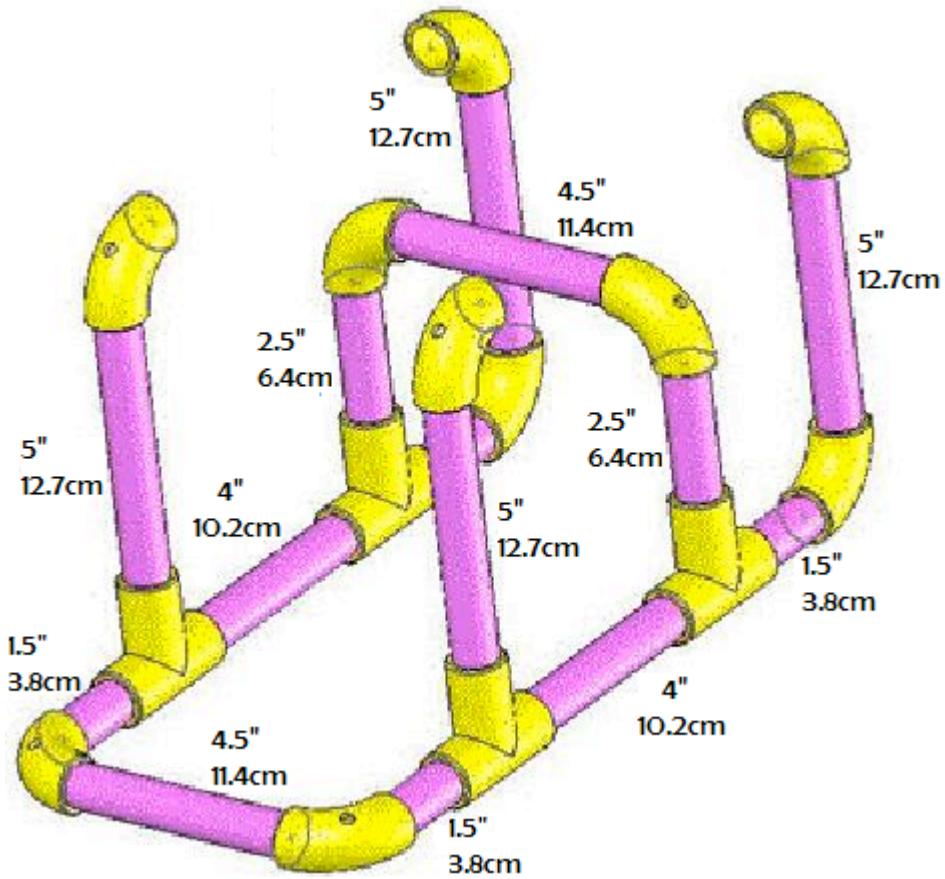
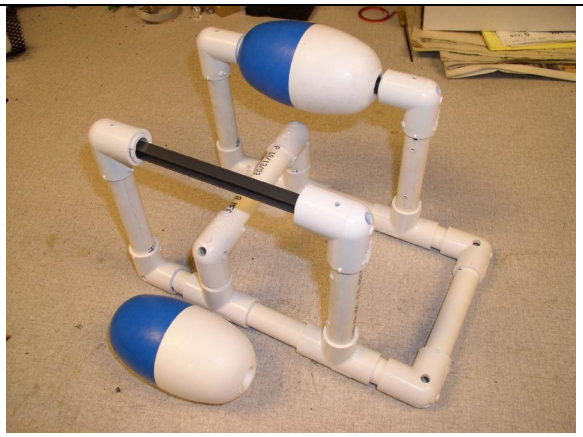


Figure 4: Frame Assembly

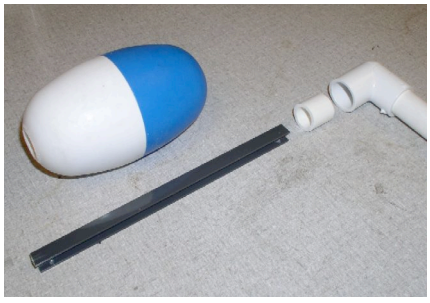
STEP 4

PURPOSE: Assemble the float supports and tighten the frame

MATERIALS: Assembled frame 15” Plastruct H-beam 2 Football Floats PVC pipe scraps **TOOLS:** PVC Pipe Cutter	 **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
Vise or clamp

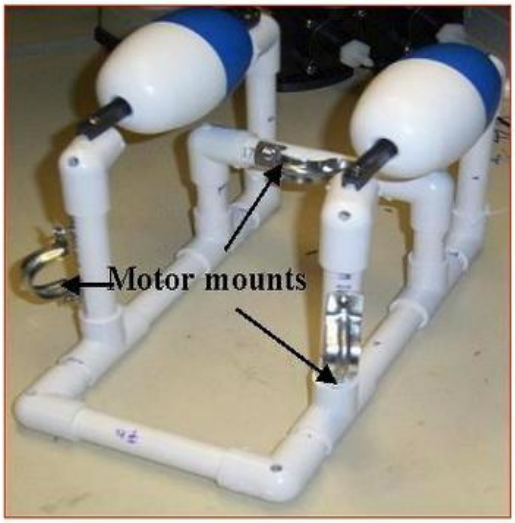


Figure 7: Motor mount placement

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 vise or clamp, and 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

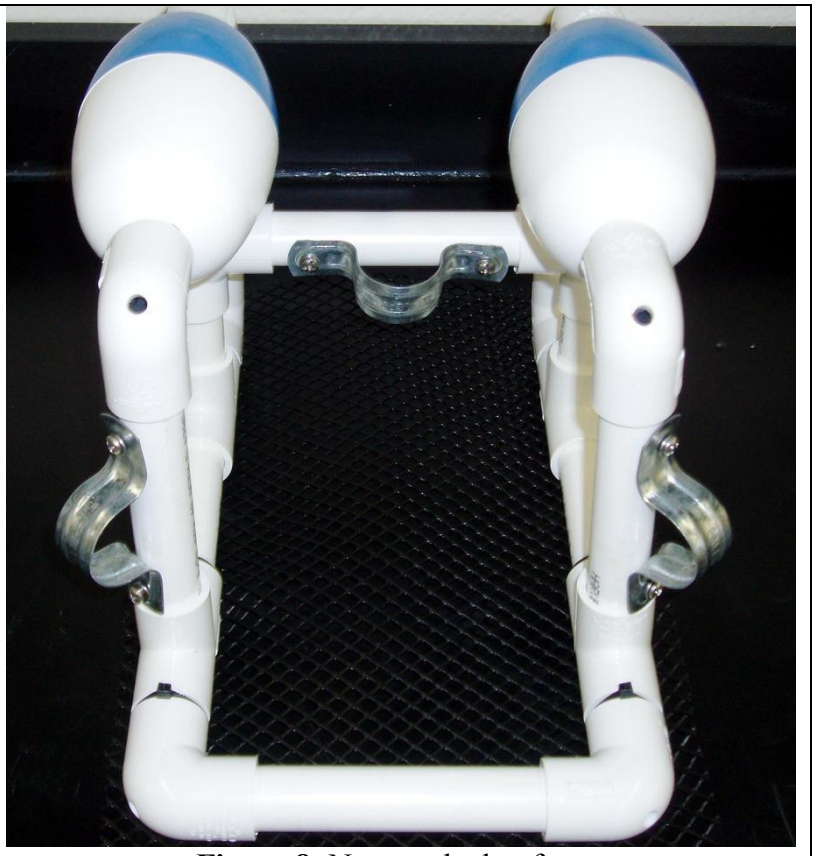
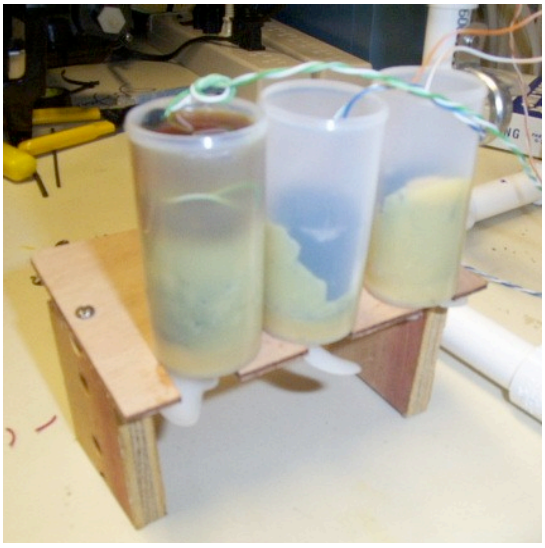


Figure 8: Net attached to frame

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.

UNIT 2:
Thruster Assembly



FOR THIS TASK YOU WILL NEED:

Tools	Materials
A cardboard box Pen Scissors Vise/Clamp Drill Hot Pot Metal for Ballast Pliers Saw Marker Ruler Scissors Soldering Iron Eye Protection Wire Stripper	Tether wire Solder 3 film cans with caps 3 12 volt DC motors 3 Bushings 3 Propellers Wax bowl ring (1/2 ring) Water Electrical tape Butyl Rubber tape #24 stranded hook up wire, Red #24 stranded hook up wire, Black 12 volt battery 1/2" PVC pipe scraps (~2" or 5cm long) Paper towels Rubbing Alcohol
Time: Unit 2 requires about **3 hours** to complete. We recommend: 1 class period to solder the tether wires to the motors 1 class period to pot (waterproof) the motors 1 class period to attach propellers, finish potting, and mount the motors on the frame	

STEP 1

PURPOSE: Create a holder for motors once they are potted (waterproofed).

MATERIALS:	1 cardboard box
TOOLS:	a pen

PROCEDURE:

1. Place the cardboard box in a stable orientation
2. Push the tip of the pen through the upper surface of the box, to make three holes. Be sure to space these holes out sufficiently—these holes will be where you place the motor shafts, as the waterproofed motors cool and try, so you need space for the motor housing on either side of the hole.

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	
	Wire Stripper	

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!

We will not be able to see the polarity markings on the motor housing once we wrap it in electrical tape, so we have to mark the polarity first.

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

STEP 3

PURPOSE: Seal the motors.

MATERIALS: 3 12 volt DC Motors Electrical tape **TOOLS:** Scissors	 **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 housing 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 think by wrapping too much tape around the sides.

You can push the tape right over the motor terminals so that they punch right through the tape, but it's best to avoid putting tape on the motor shaft, as this will increase friction 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 supervise students who are working with a drill or other power tool. Make sure everyone in the room is wearing safety goggles when power tools are being used.

It is necessary to secure the object that you are drilling in a vise or clamp before 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
Wire stripper

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.
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).

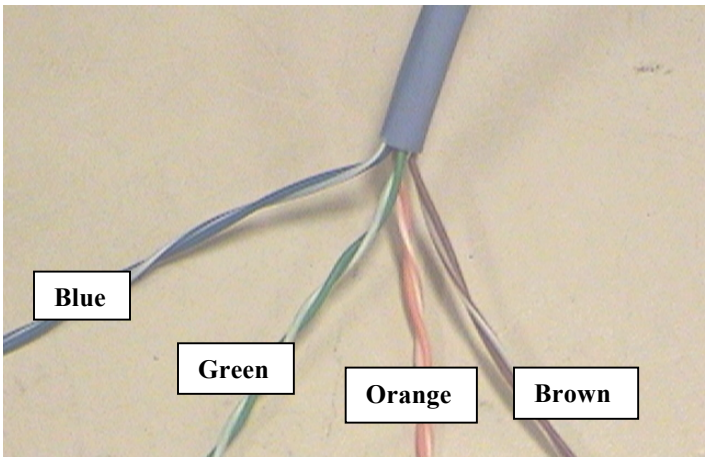
SEE FIGURES ON THE NEXT PAGE…

Soldering Safety:
Always wear safety glasses when soldering. Solder fumes are often toxic. Work in a well ventilated area, avoid breathing the fumes, don't put it in your mouth, and wash your hands after working with it.

Soldering Technique:
Offer students a soldering technique demo and allow them to practice soldering on 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

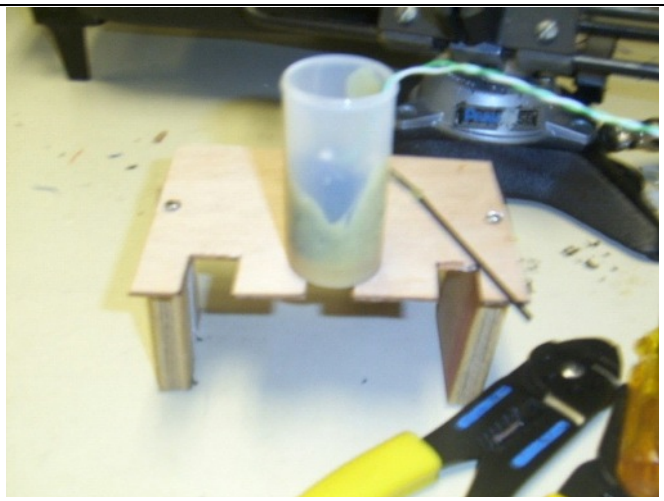
B:
Tether wire threaded through film cap

C:
Tether wire soldered to motor

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

STEP 6

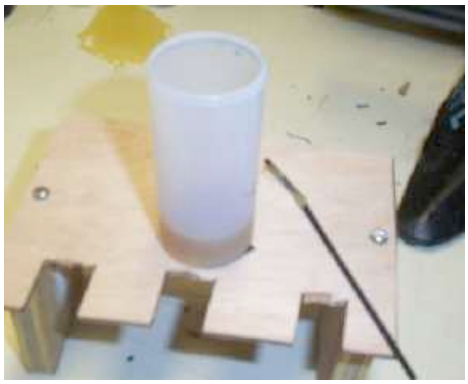
PURPOSE: Pot (waterproof) the motors with wax – first half.

MATERIALS: 3 Drilled Film cans Wax bowl ring (½ ring) Electrical tape Sealed motors **TOOLS:** Hot Pot Cardboard holder Pliers Scissors Eye Protection Paper Towels (for cleanup)	 **Figure 17:** Motor placed into wax

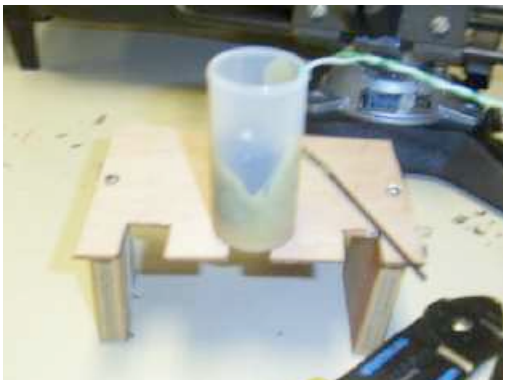
PROCEDURE:

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. Melt wax in the Hot Pot.
3. Put on your SAFETY GLASSES before working with hot wax.
4. Fill one film can with about 1/4" (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 pushing 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 and through the hole quickly, since the wax cools and hardens rapidly when the cold motor touches it (Figure 18D). The wax should push up around the sides of the motor, but should not fill in above the motor.
6. Repeat for each of your 3 motors.
7. Place the motor shafts in the holes in the cardboard box that you prepared earlier and 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.

FIGURES AND WAX MELTING TIPS ON NEXT PAGE…



A: Film can partially filled with wax



B: Motor placed into wax

Figure 18A and B: Potting the motors

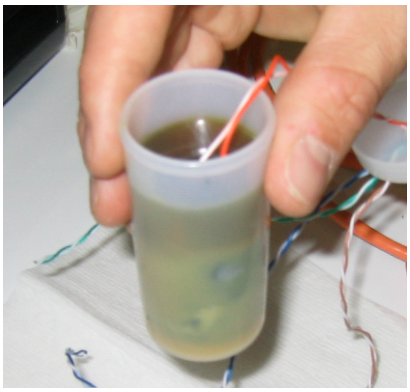
Wax Melting Tips:
Always wear SAFETY GLASSES when working with hot wax. The soft wax used in this project can get very sticky. An apron and gloves (latex, nitrile, etc.) are highly recommended. To facilitate cleanup, put a drop cloth on the work bench, on the ground below it, and on the wall behind it.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

1. 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.
2. One wax ring will usually pot about 6 motors (enough for 2 SeaPerch ROVs).

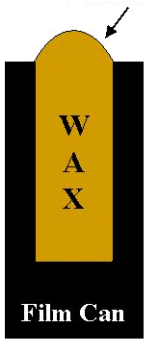
1. Once all three of your containers have a motor in them, we will fill them the rest of the way with wax, in 2 steps.
2. Fill the container with wax up to 1/2 inch below the top (Figure 19A & B). (We fill them up only partway, since the wax shrinks as it cools, and we want to make sure everything is filled with wax, not air pockets.) Pour the wax so that it fills in all the air spaces around the motor.
3. 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.
4. Set the container up on your stand to cool, and repeat for the other two.
5. 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!
6. 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.
7. Carefully fill one container to the top with wax, creating a positive meniscus (Figure 19C).
8. 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!

9. 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.**

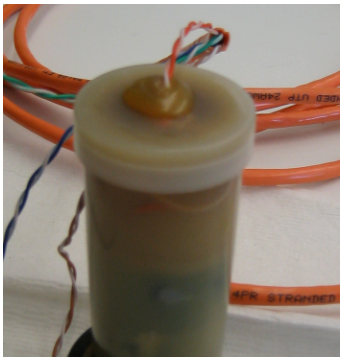
A: Second wax layer



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

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.

***TIP- 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.

Put your motors aside and allow the epoxy to harden to handling strength (60 minutes for the specified epoxy) before touching them again.

11. 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

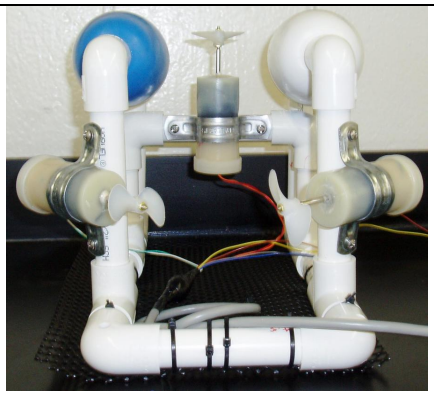
D: Prop shaft mounted on motor

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:

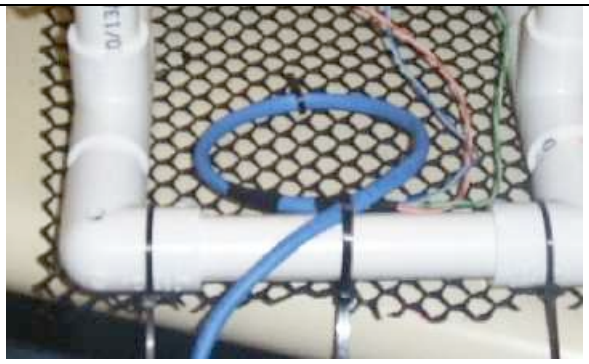
1. Using the screwdriver, remove the motor mounts from the frame.
2. Place a thruster inside each motor mount, according to the table below. The motor mount should go over the back end of the motor. It should not be over the back of the can where there is only wax, or over the center of the motor, where 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 strip the holes, pull apart the Sea Perch ROV and, re-drill the holes on another side of the PVC.
4. You can now use pliers to adjust the orientation of the PVC that the motors are mounted on to get the 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: Completed frame with thrusters Butyl Rubber tape Electrical tape **TOOLS:** Scissors	 **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.

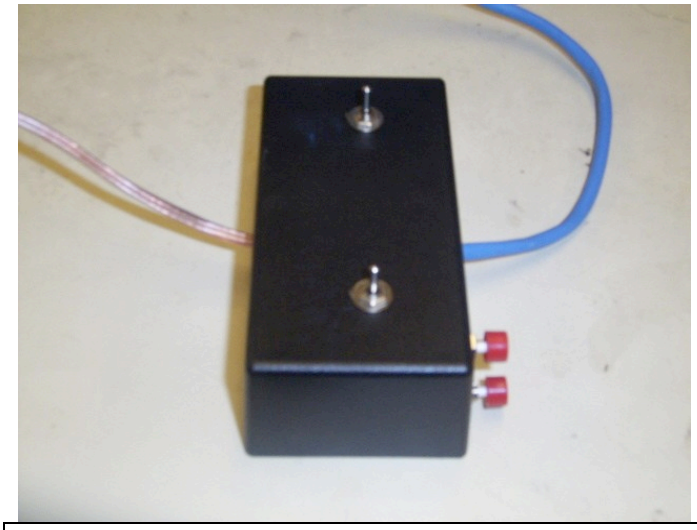
3. Knead and work it in well, so that it seals both around and between the wires and sheath, preventing water from getting into the tether cable.

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 the Control Box



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.

FOR THIS TASK YOU WILL NEED:

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

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.

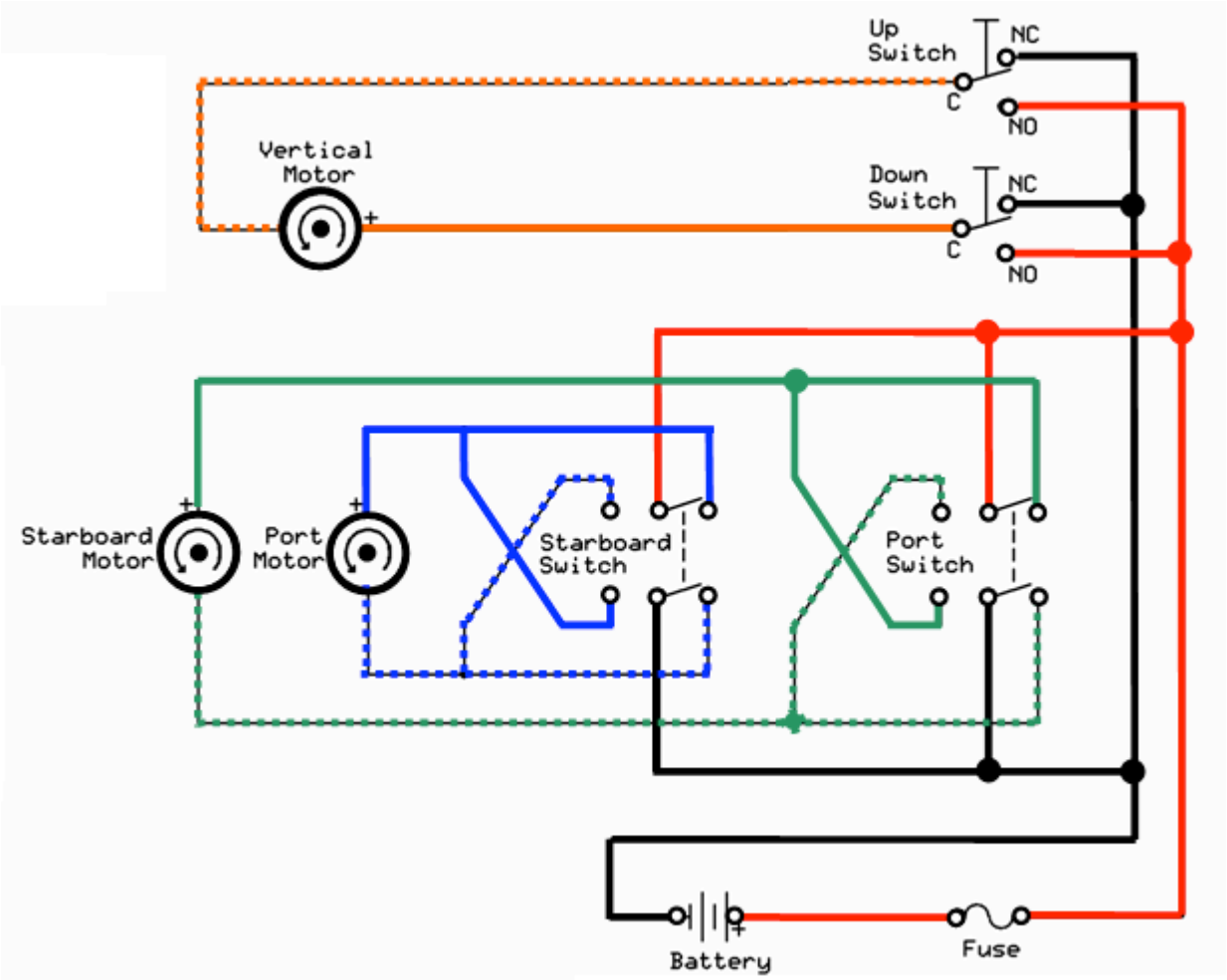


Figure 26: Sea Perch ROV Circuit Diagram

STEP 1

PURPOSE: Gather the parts for the control box assembly.

MATERIALS:
Control box
2 push-button switches
2 toggle switches (pole switches)
2 alligator clips
1 red alligator clip sleeve
1 black alligator clip sleeve
Fuse cap wire
Fuse (10 A slow blow fuse)
Speaker wire
1 loose red wire
1 loose black wire

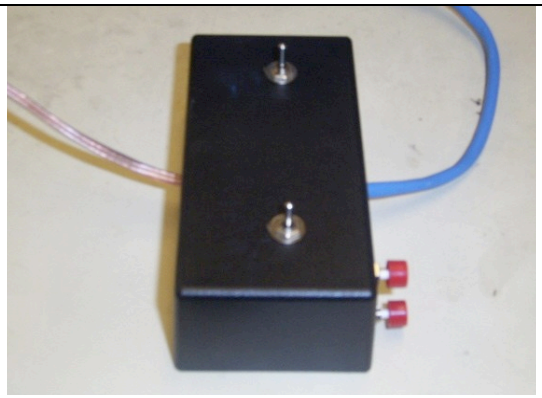


Figure 27: Completed control box assembly.

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:

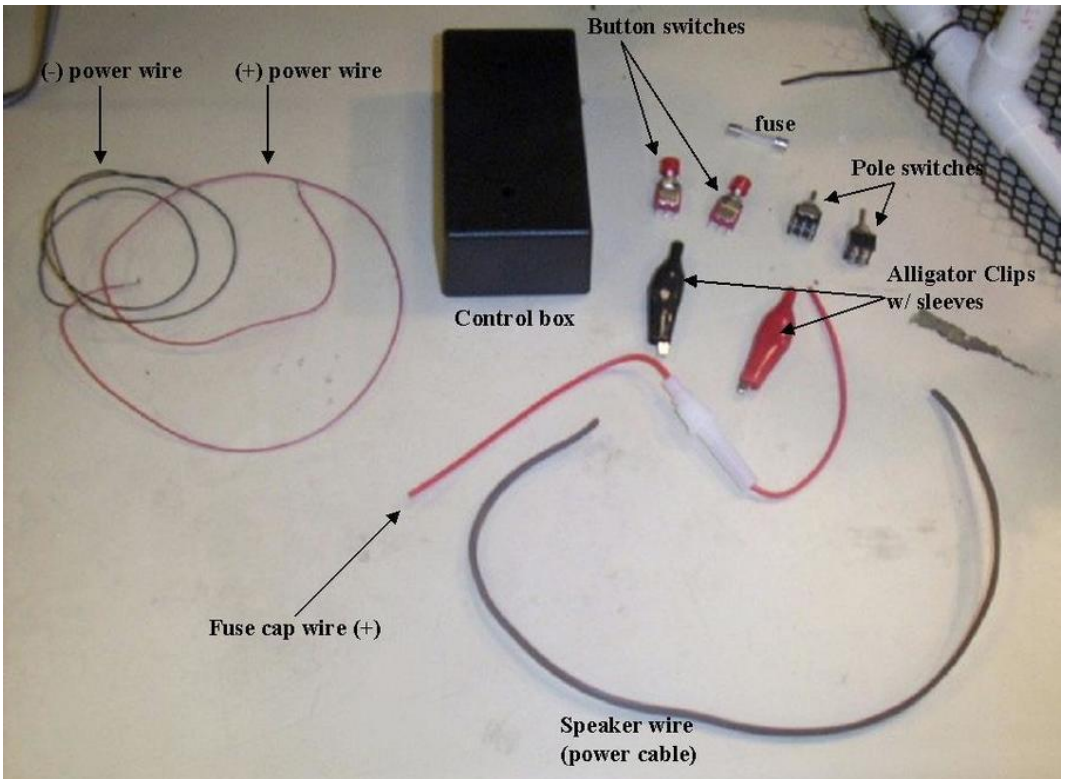


Figure 28: Parts for the control box assembly.
NOTE: Speaker wire/power cable may be WHITE (instead of brown)

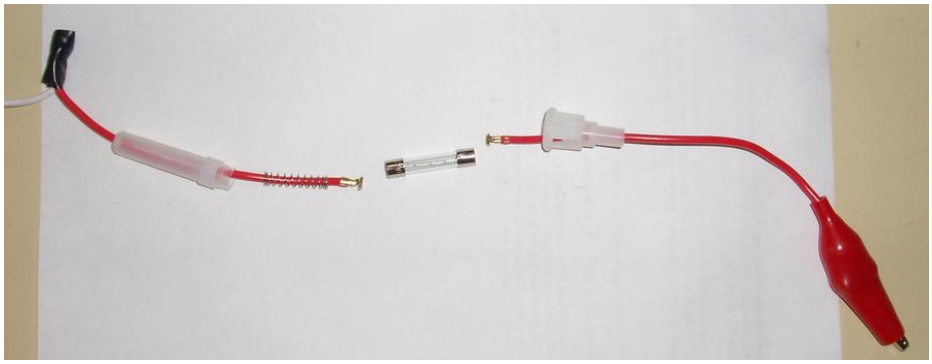
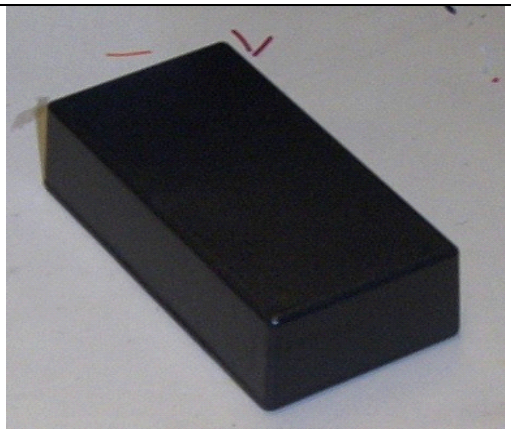


Figure 28a: This is what the Fuse Cap Wire looks like when taken apart. Some of these wires may fall apart during transport of the kits. If you find these pieces in your kit, reassemble them in the order shown above.

STEP 2

PURPOSE: Prepare the control box

MATERIALS: Control box **TOOLS:** Marker Drill 1/4” drill bit Vise or clamp	 **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 **½” 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.
2. Secure the control box in a vise or clamp and drill holes with the 1/4” drill bit in the marked locations.

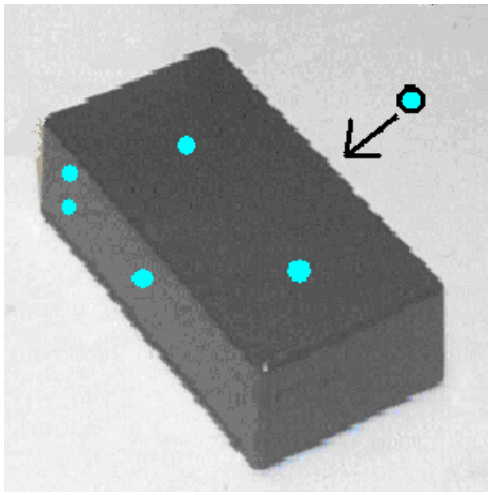


Figure 30: Control Box hole locations

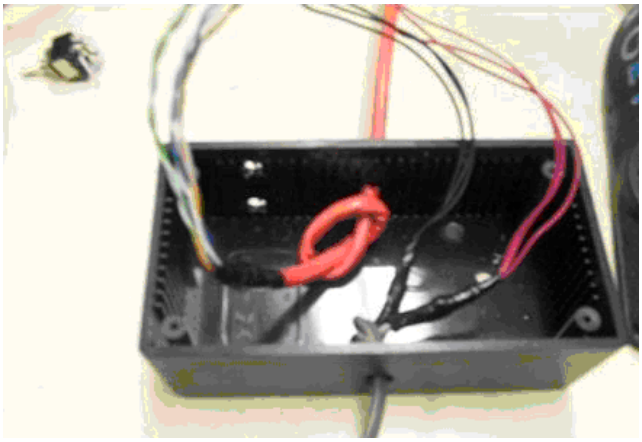


Figure 31: Cables in holes (see steps 3 & 4)

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

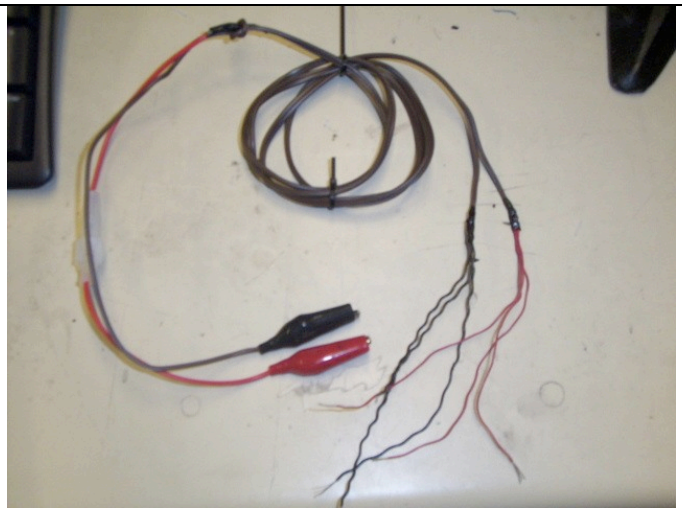


Figure 32: Completed power cable

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.

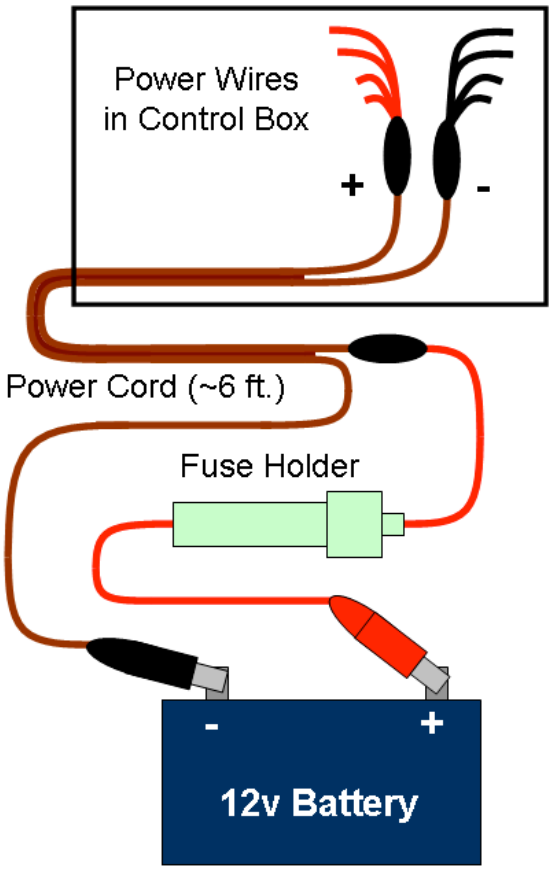


Figure 33: Power Cable wiring diagram.

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.

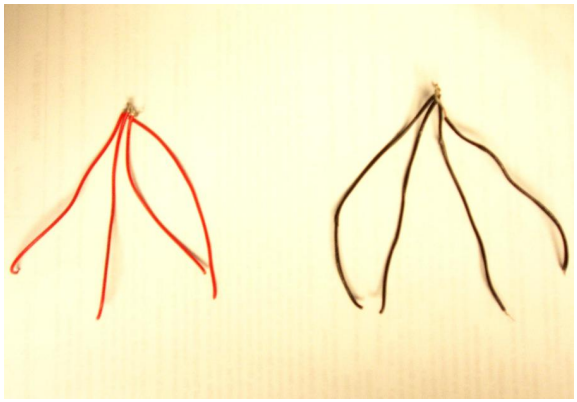


Figure 34: Spliced wire bundles

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.

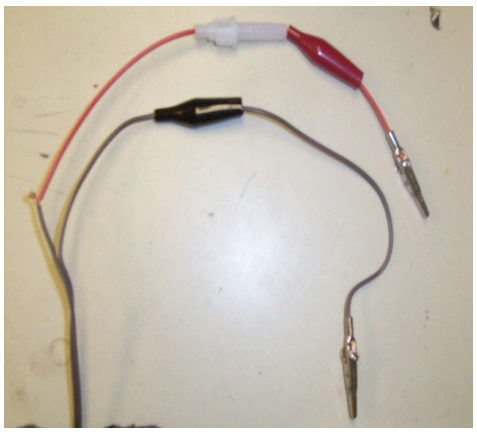


Figure 35: Battery end of the power cable.

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!**

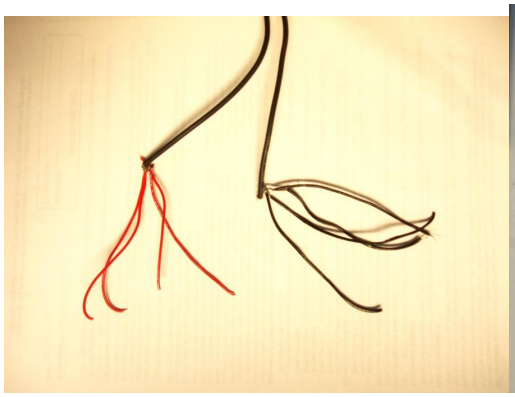


Figure 36:
Wire bundles soldered to end of power cord.

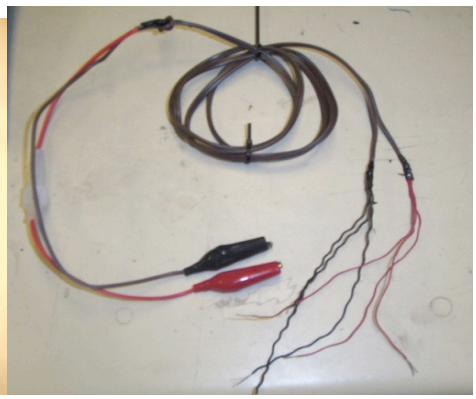
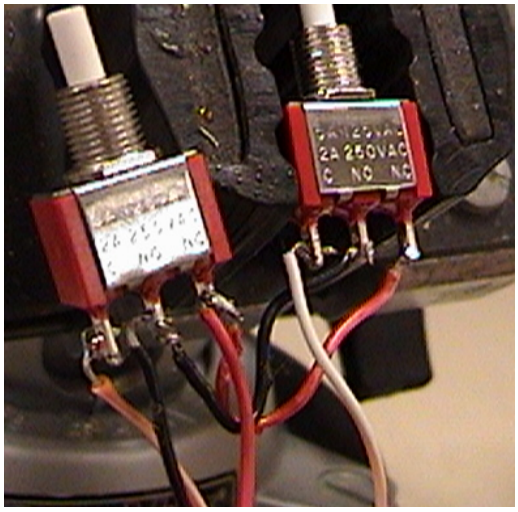


Figure 37:
Completed power cable assembly (without the control box).

STEP 4

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

MATERIALS: 2 button switches Solder Prepared control box Assembled power cable **TOOLS:** Soldering iron Vise or clamp	 **Figure 38**: 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.

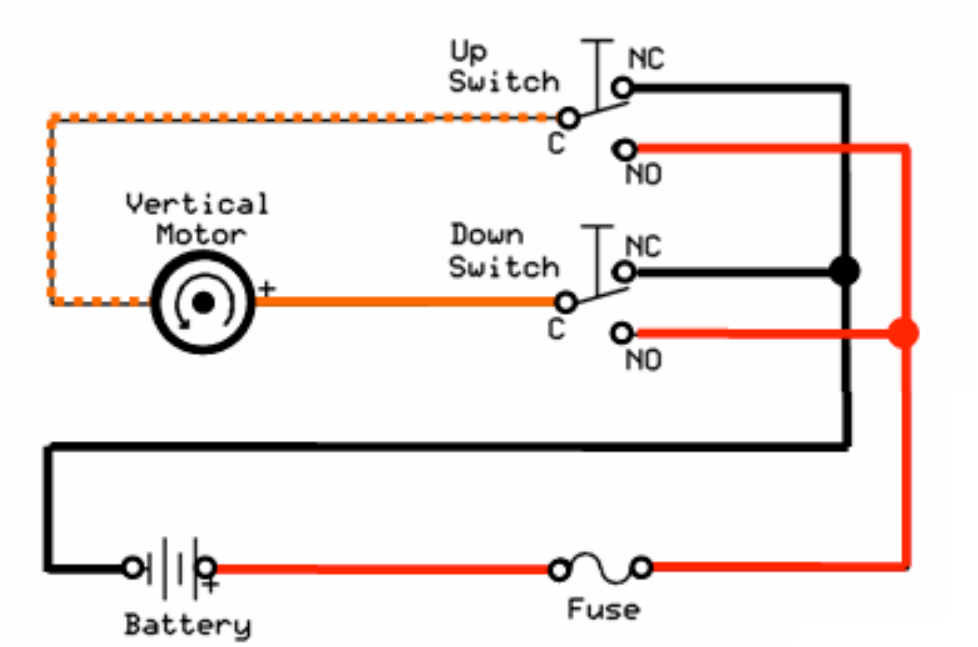


Figure 39: Vertical thruster circuit diagram.

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

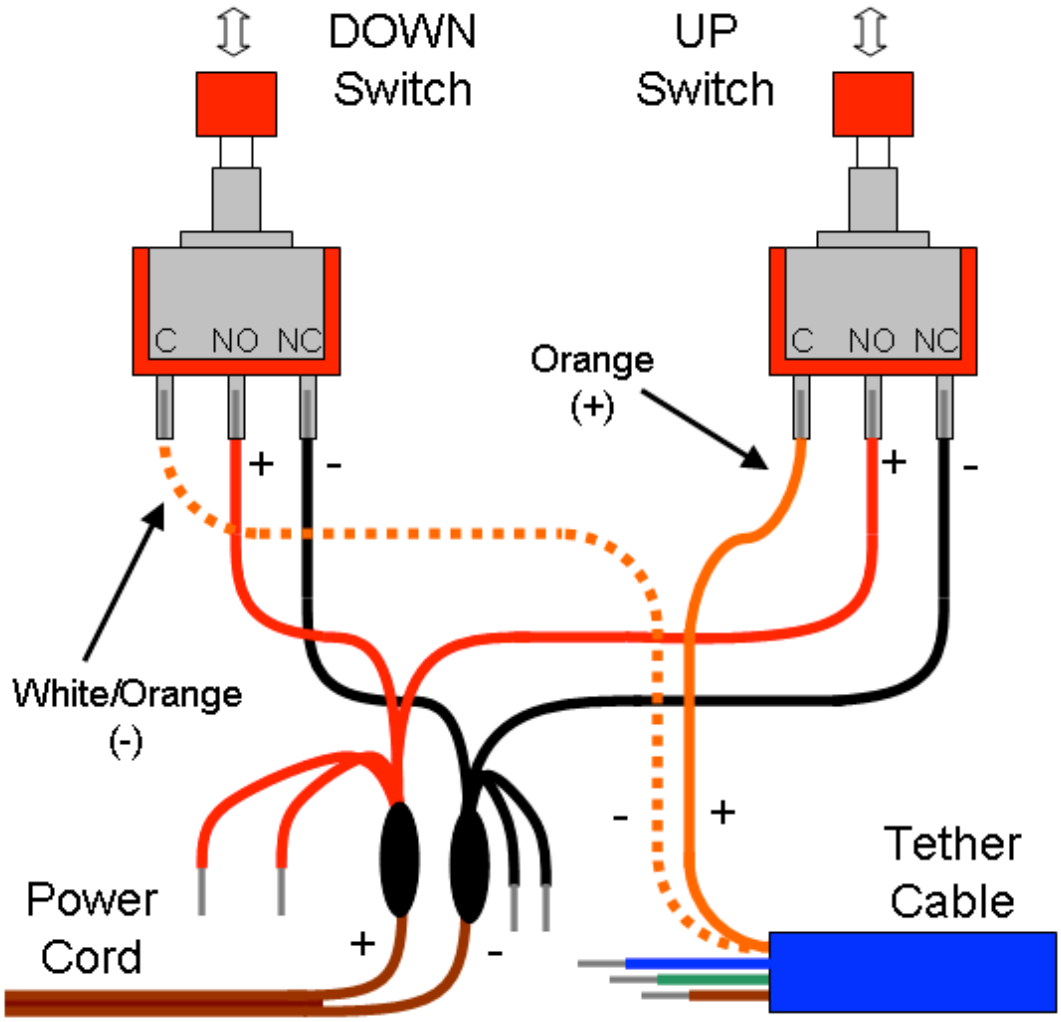
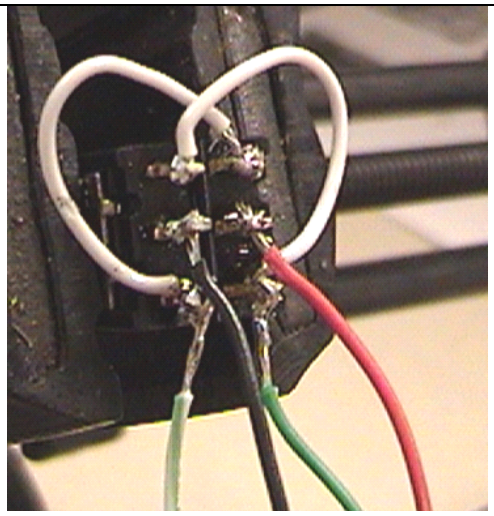


Figure 40: Vertical thruster control / pushbutton switch wiring diagram.

STEP 5

PURPOSE: Wire the toggle switches (horizontal thruster controls)

MATERIALS: 2 pole switches Prepared control box Solder **TOOLS:** Soldering iron Vise or clamp	 **Figure 41:** 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.

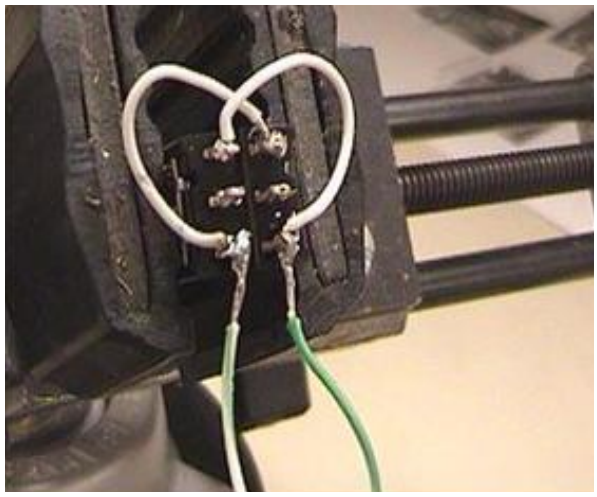


Figure 43: Cross-wired toggle switch with tether connections

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.

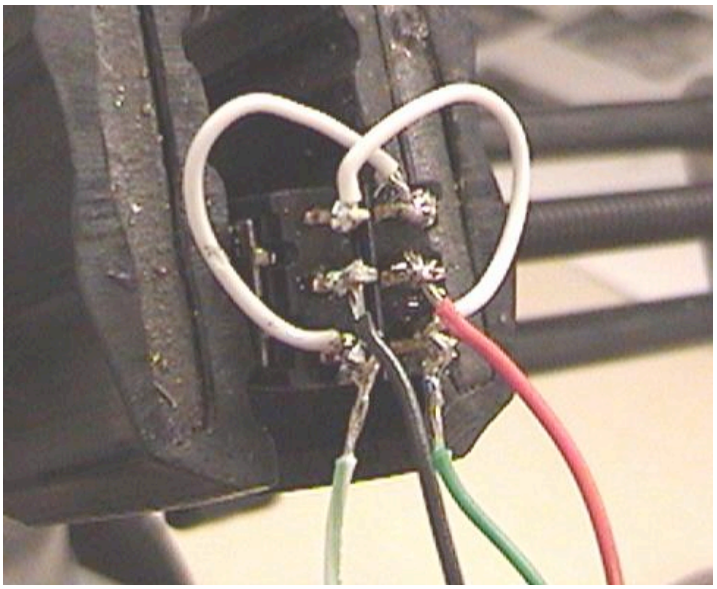


Figure 44:
Toggle switch with cross-wires, tether connections, and power connections.

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.

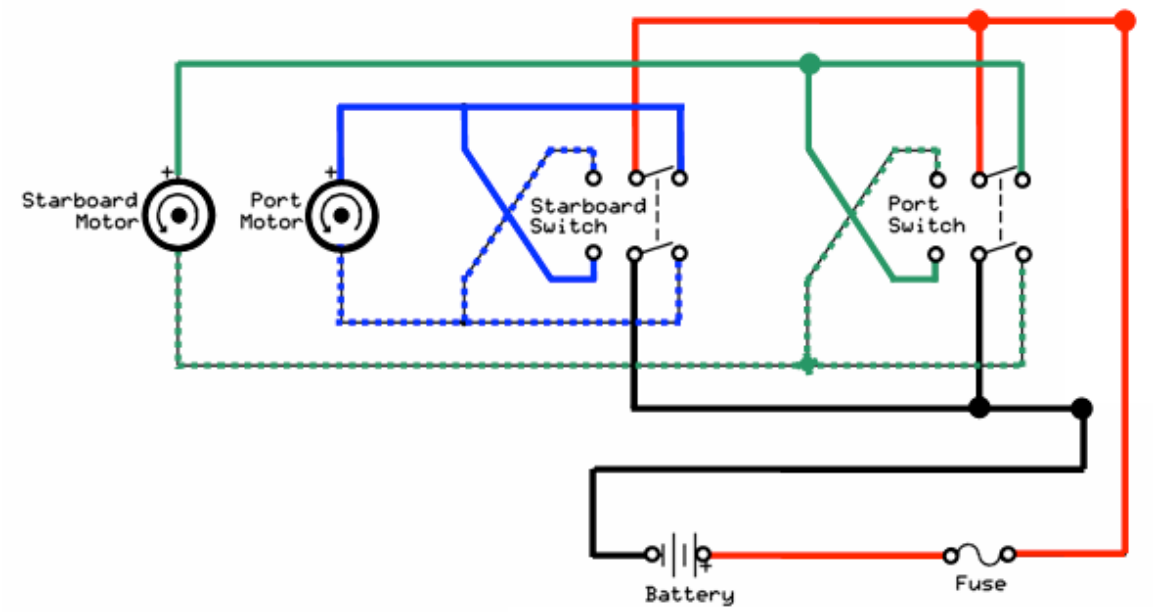


Figure 45: Circuit diagram for horizontal (port & starboard) thruster controls.

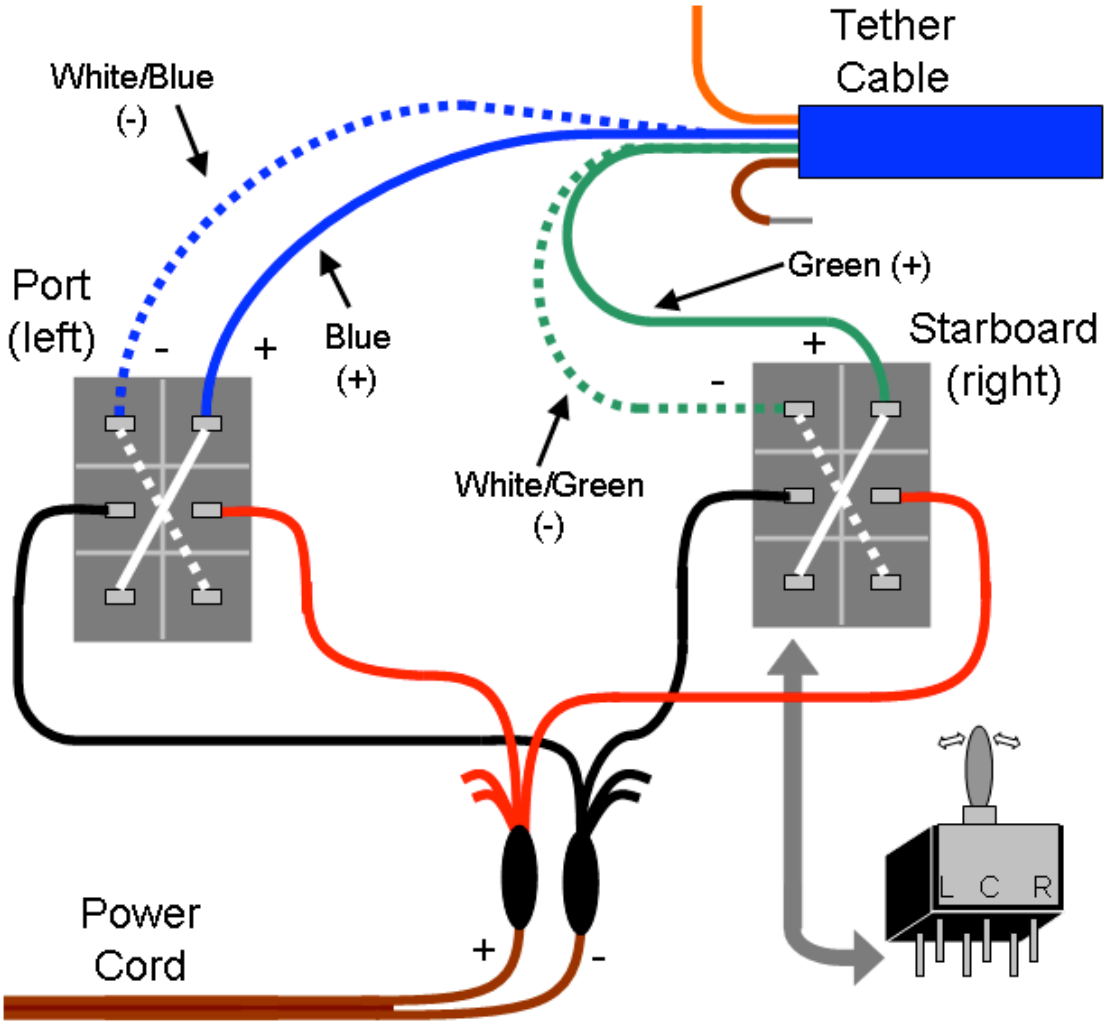


Figure 46: Toggle switch/Port and Starboard thruster wiring diagram

STEP 6

PURPOSE: Finish the control box

MATERIALS:
Control box
Wired Switches

TOOLS:
Phillips Screwdriver
5/16" Nut driver or Pliers

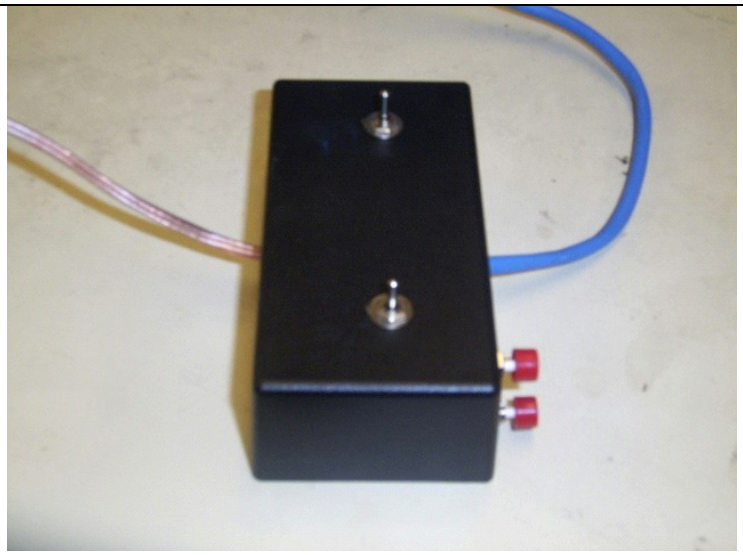


Figure 47: Completed control box

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.

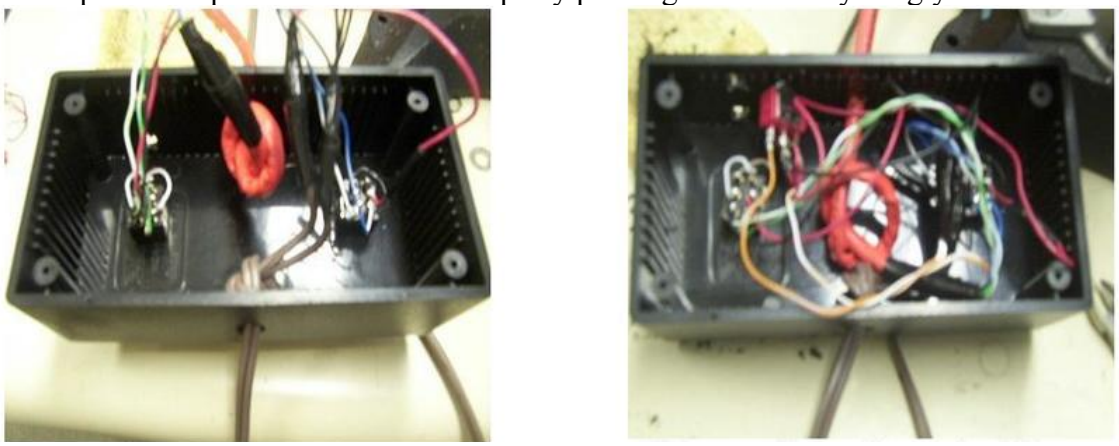


Figure 48: Control box with toggle switches and then all switches installed.

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!

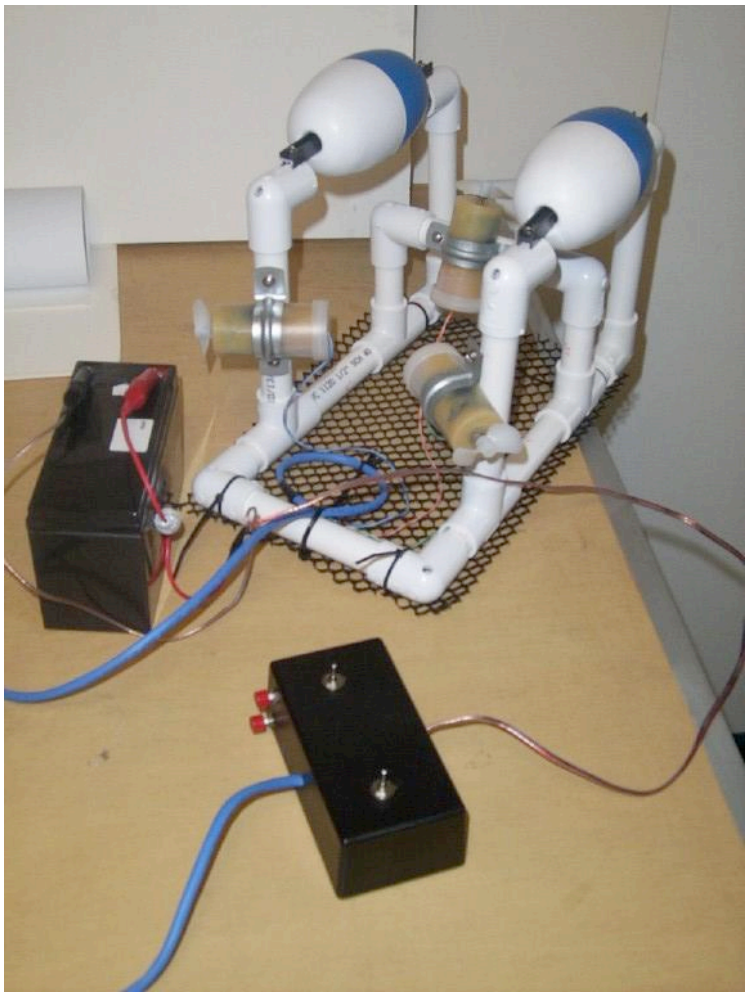
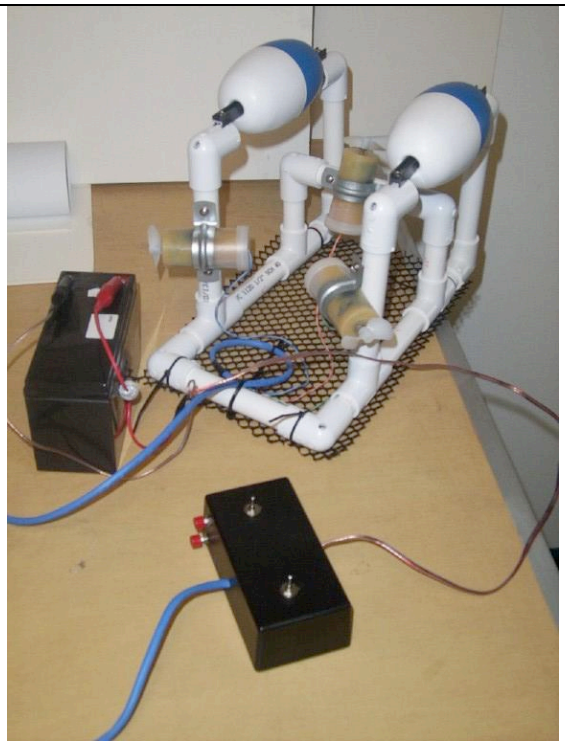


Figure 49: Finished Sea Perch ROV

STEP 7

PURPOSE: Testing your Sea Perch ROV

MATERIALS: Completed ROV **TOOLS:** 12 volt battery	 **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**	

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