

Moving and Maneuvering 2

Cornerstone Electronics Technology and Robotics III

(Notes primarily from “Underwater Robotics – Science Design and Fabrication”, an excellent book for the design, fabrication, and operation of Remotely Operated Vehicles ROVs)

- **Administration:**
 - Prayer
- **Bilge Pumps:**
 - One of the easiest ways to build a shallow water thruster for a ROV is to modify a bilge pump. A bilge pump is a pump to remove water that collects in the bottom of a boat.
 - Bilge pumps have a plastic housing that makes them submersible to depths of up to approximately 10 meters.
 - They are available at many gph (gallons per hour) ratings. For example, Rule Industries offers bilge pumps at 360, 500, 800, 1100, 1500, 2000, 3700, 4000, and 8000 gph.
 - Perform Moving and Maneuvering Lab 4 – Building Thrusters for the ROV.
- **Thruster Placement:**
 - The number and placement of the thrusters determines the possible movements of your ROV and as well as its performance.
 - Three Thruster Arrangement:
 - Two thrusters are positioned parallel and horizontal for horizontal movement and one thruster is mounted vertically for vertical movement.
 - Avoid placing other components of the vehicle in line with the water flow of your thrusters. These components can block the momentum of the water flow off the thruster.

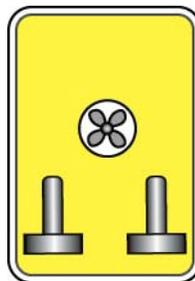


Figure 8: Looking Down on a Three Thruster Vehicle

- Ideally, the vertical thruster should be positioned in line with the center of gravity of the vehicle. This placement eliminates pitch or roll that an off-centered thruster would cause. If this placement is not possible, create a stable vehicle by locating plenty of floatation high and weight low on the vehicle. That way, pitch and roll are minimized by the vehicle’s stability and the vertical thruster can be placed almost anywhere.

- The two horizontal thrusters shown in Figure 9 give a wide range of movement.

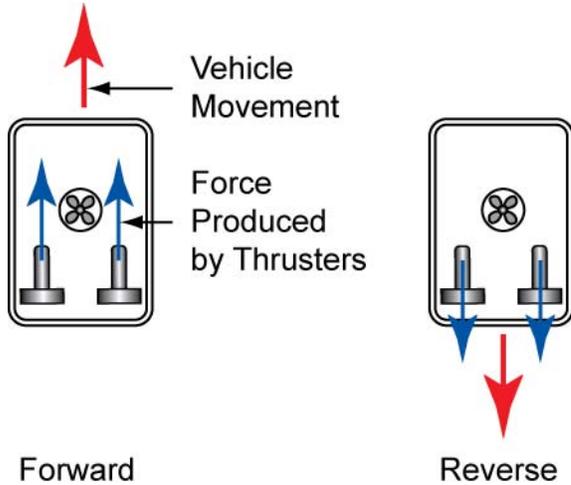


Figure 9a: Forward and Reverse Movements

For the vehicle to move straight forward, the both thrusters must generate equal thrust.

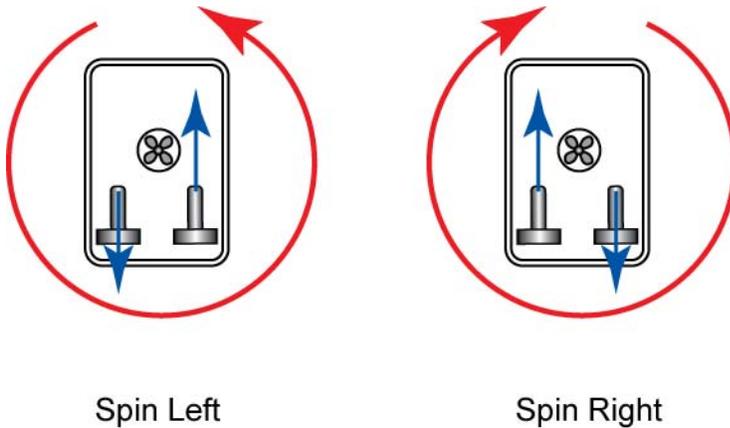


Figure 9b: Spin Left and Right

When the horizontal thrusters act equally but in opposite directions, the forward and reverse thrusts cancel but the two thrusters produce a force couple which spins the vehicle in place.

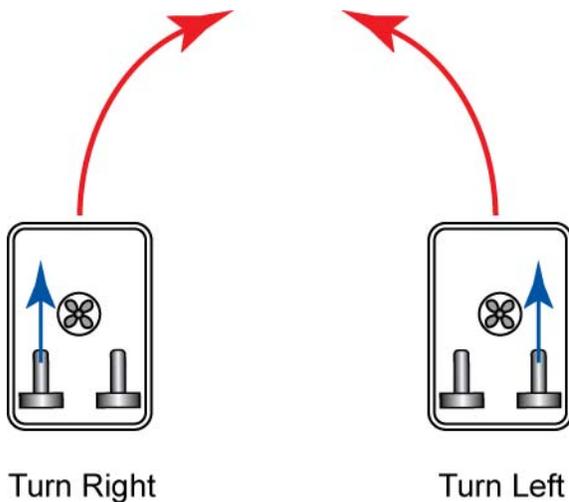


Figure 9c: Turn Right and Left

If only one thruster is acting, the vehicle moves forward, but not in a straight line. For example, if only the port thruster is activated, the vehicle will turn to the right. The thruster force and the force created by drag (which is located around the center of the vehicle) produce a force couple that turns the vehicle.

- Four Thruster Arrangements:
 - One possible four thruster arrangement is created by adding another vertical thruster to the three thruster vehicle for generating a stronger vertical thrust. See Figure 10.

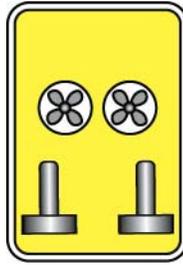


Figure 10: Four Thruster Vehicle with Two Vertical Thrusters

- Another arrangement is to position the fourth thruster for lateral movement. This option allows the operator to shift laterally without making any other movements which is very helpful when working with payload tools.

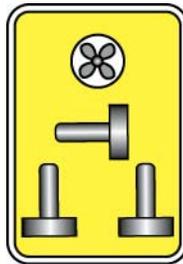


Figure 11: Four Thruster Vehicle which Can Move Laterally

- It may be difficult to clear the path through the vehicle for all of the thrusters operate without obstructing the water flow. Vectored thrusters, like the two shown below, give the designer flexibility to work around this problem.

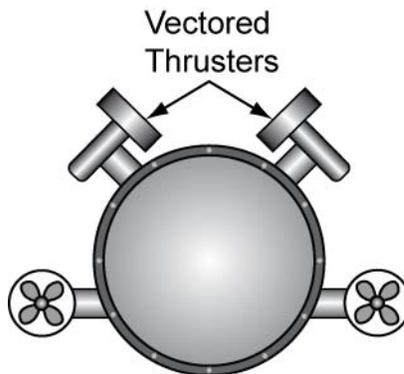


Figure 12: Four Thruster Vehicle with Two Vectored Thrusters for Vertical and Sideways Movement

The thruster's water flow is clear of any internal vehicle obstruction.

- The vectored thruster arrangement generates many vehicle movements. The stern (rear) view in Figure 13 illustrates four motions when the two thrusters produce equal thrust.

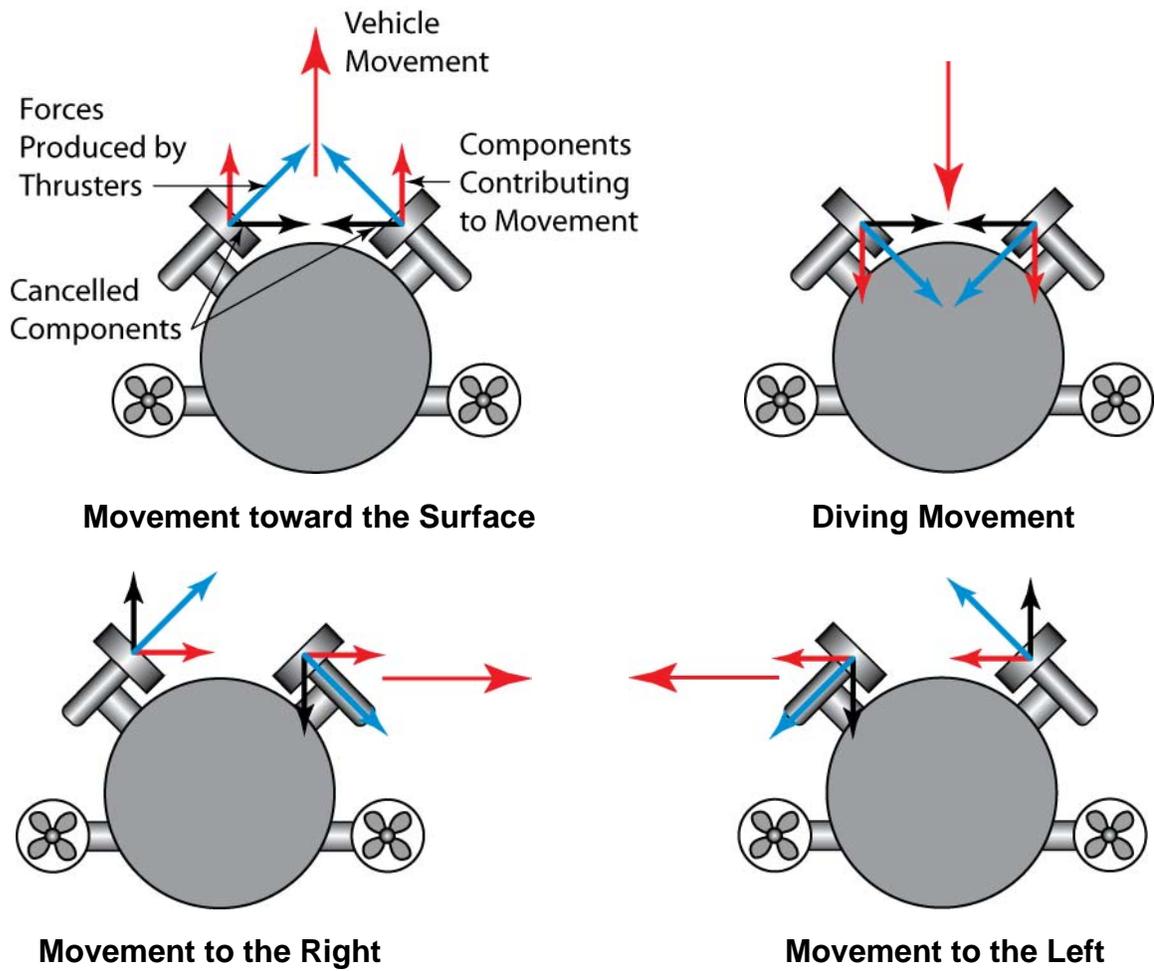


Figure 13: Four Vehicle Movements from the Vectored Thrusters Illustrated

- If each thruster has independently speed control, then the vehicle can move in any direction in the vector thruster plane. Here are two examples:

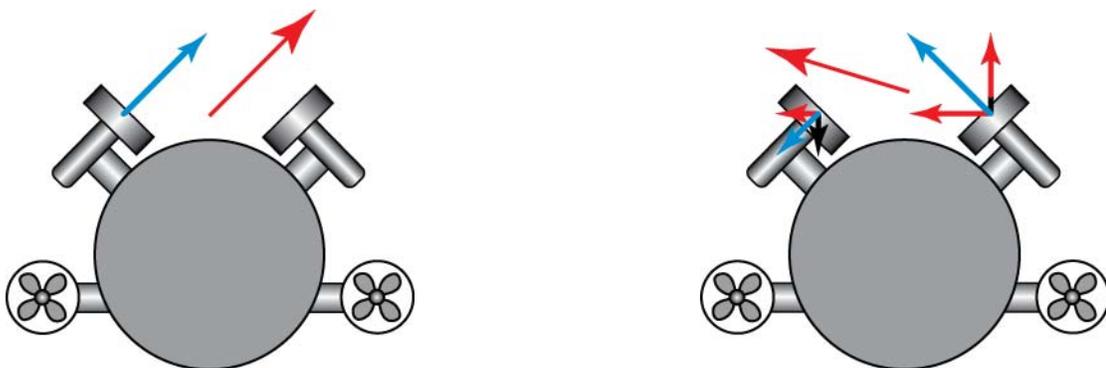


Figure 14: A Couple of Possible Movements if Thrusters Speeds Are Independently Controlled

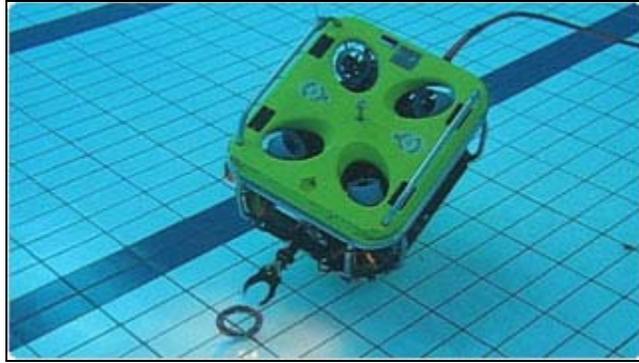


Figure 15: Four Vectored Vertical Thrusters

From: <http://www.ocean-modules.com/freedom.php>

- Vectored thrusters are used in the horizontal plane as well. Typically a vectored thruster is positioned at each corner of the vehicle.



Figure 15: Four Vectored Thrusters for Horizontal Movement

From: <http://www.seaeye.com/falcon.html>

The four horizontal thruster arrangement offers versatility in horizontal movement.

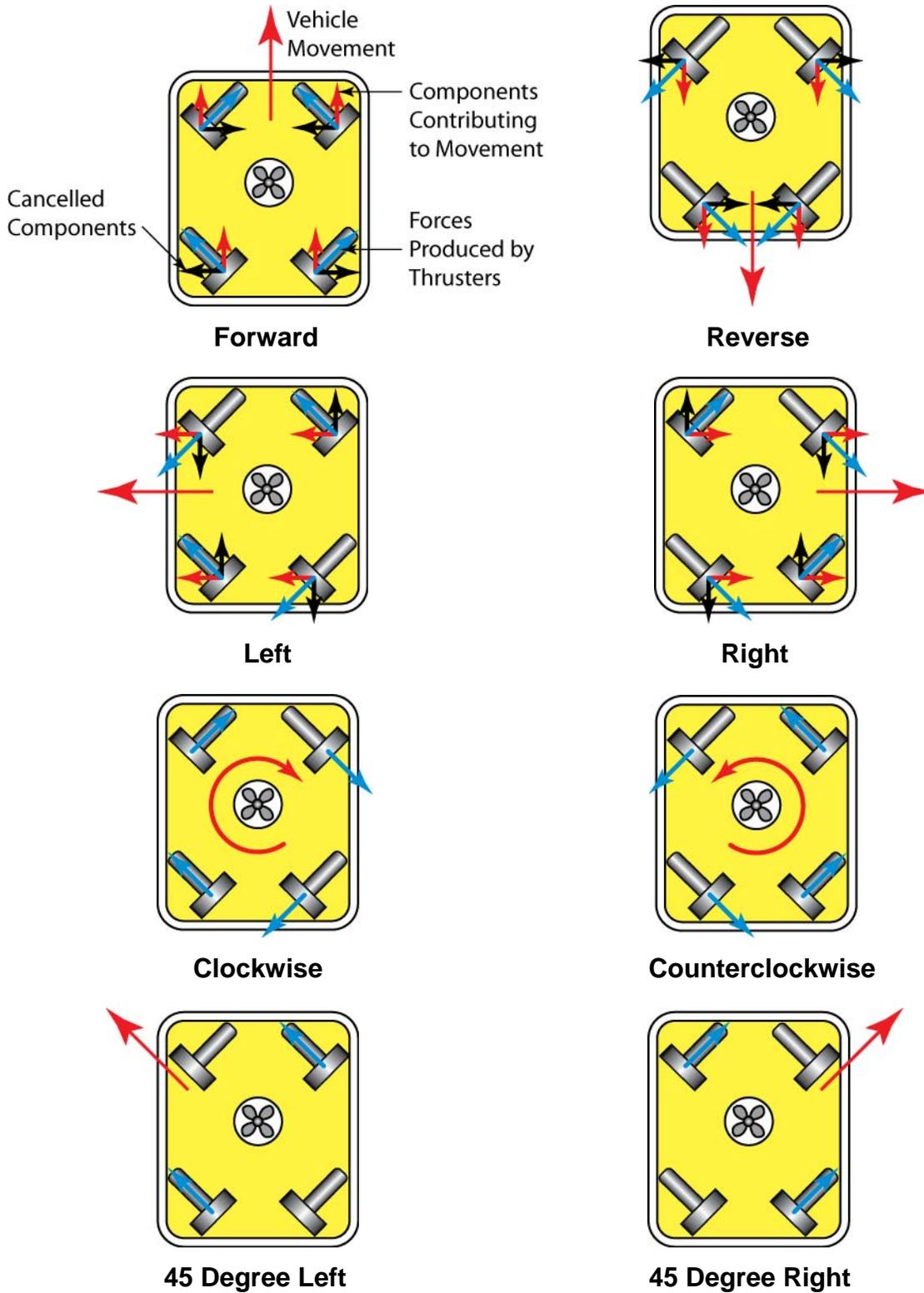


Figure 16: Examples of Motion with Four Horizontal Thrusters

This arrangement of thrusters offers redundancy should one of the thrusters fail.

- Issues to consider when placing thrusters:
 - Clear water flow pathways in front and behind the thrusters. Streamline the motor housing to minimize thrust loss.
 - Be aware that each thruster that acts along a line that does not go through the center of the vehicle results in a turning moment.
 - Be mindful that thrusters normally produce more thrust in one direction than in the opposite direction. For example, if your vehicle is trimmed for slight positive buoyancy, the most robust vertical thruster should be pointed downward to overpower the positive buoyancy.
 - Incorporate counter-rotating propellers whenever possible to avoid prop walk.
 - Adding more or larger thrusters for more power can shorten run times or require larger batteries.
 - Placing thrusters at the bottom of the vehicle increases stability, but it also increases the possibility of damaging contact with hard objects and stirring up sand or silt which can reduce visibility.
 - The farther a thruster is placed from the center of rotation of the vehicle, the faster the speed of rotation. Experiment with the vehicle to optimize the turning speed.
 - Keep electronic sensors away from the electromagnetic fields generated by thrusters.
- Perform Moving and Maneuvering Lab 5 – Attaching the Thrusters to the ROV Frame.

Cornerstone Electronics Technology and Robotics III
Moving and Maneuvering Lab 4 – Building Thrusters for the ROV

- **Purpose:** The students build a ROV thruster from a Johnson Mayfair Proline 500 gph bilge pump.
- **Apparatus and Materials:**
 - 3 – Johnson Mayfair Proline 500 GPH Bilge Pump, available from: <http://www.amarket.com/imbp01.htm>
 - 3 – 1” PVC Slip Tee Fitting
 - 3 – Traxxis #1583 Propeller
- **Procedure:**
 - Twist off the bilge pump mounting bracket/strainer in the “UNLOCK” direction and discard.



Figure 1: Twist Bilge Pump Unit to Remove

- Lift and twist off the second plastic piece and then remove the tan impeller.



Figure 2: Remove Black Insert

- Drill a 9/64" or 5/32" hole in a piece of plywood about 1" from each edge. The hole will receive the motor shaft.



Figure 3: Drilled Hole in Plywood

- Carefully cut off the housing around the motor using a bandsaw. **Cut along the outside edge of the housing as shown.**



Figure 4: Cutting Off the Housing from the Motor



Figure 5: Cutting Too Close to the Motor Breaks the Waterproof Seal

- Sand the cut edge.



Figure 6: Sanding the Cut Edge

- Cut a 1" x 1" x 1/2" PVC Slip Tee fitting to receive the bilge pump. Make the slot approximately 16 mm wide.



Figure 7: 1" x 1" x 1/2" PVC Tee and the Bilge Pump Seated in the Fitting

- Use a vise to press the bilge pump into the fitting. Hold the motor wires when the PVC Tee is about to fit around the motor; otherwise it will fall when it snaps about the motor.



Figure 8: Pressing the Bilge Pump into the Modified PVC Tee

- Install the Traxxis #1583 (right hand) or Traxxis #1584 (left hand) propeller on the motor shaft using a 5/64" Allen wrench. When opening the propeller package, **be careful** not to drop the set screw; it is loose in the package.



Figure 9: Traxxis #1583 Propeller Attached to the Bilge Pump

- Alternative Thruster Mount:
 - This thruster mount is in line with the thruster frame member (Figure 10).



Figure 10: Thruster Mount in Line with Frame Member

- The thruster is inserted into a short piece of 1 ½" schedule 40 PVC.
- Continued on the next page.

- A 1 ½" x 1 ½" x 1" reducing tee is cut off and reamed out so the 1 ½" pipe can fit inside (Figure 11).
- The ends of the reducing tee and the inserted pipe are sloped to be more hydrodynamic (Figure 10).

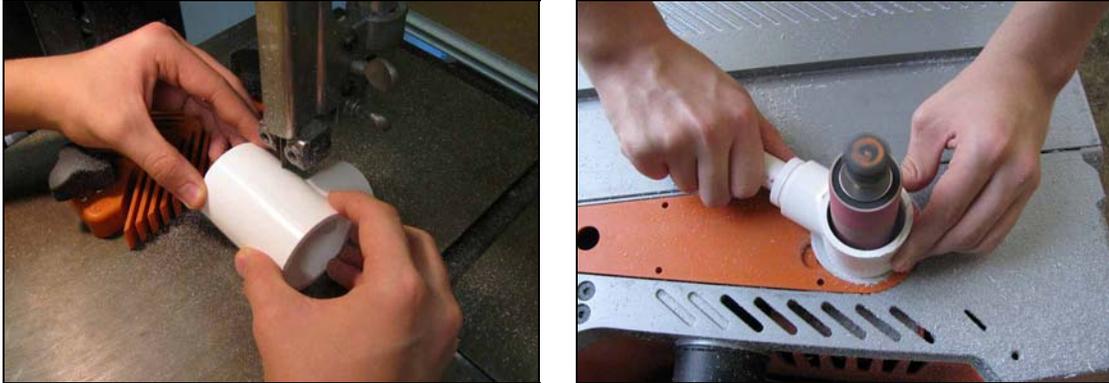


Figure 11: Cutting and Reaming the Reducing Tee

- Insert the 1" x ½" reducer bushing into the 1 ½" x 1 ½" x 1" reducing tee.
- Using a spindle sander, round one end of ½" PVC to butt into the reducing tee (Figure 12).



Figure 12: Rounding the ½" PVC on a Spindle Sander

- The thruster mount parts are ready for mounting.
- The frame will need a secure frame member parallel to the thruster mount since the ½" butt joint is rather weak.
- Thank you to N. Goodall for this alternate thruster mounting design.

Cornerstone Electronics Technology and Robotics III
Moving and Maneuvering Lab 5 – Attaching the Thrusters to the ROV Frame

- **Purpose:** The students choose the best position for the three thrusters on their ROVs and then mount the thrusters.
- **Apparatus and Materials:**
 - 3 – Johnson Mayfair Proline 500 GPH Bilge Pump Thrusters with Traxxis #1583 Propeller Attached Mounted on 1" PVC Slip Tee Fitting
 - ROV Frame from Lesson 5
 - Miscellaneous ½" PVC T's, L's, and couplings
 - Miscellaneous Pieces of ½" Schedule 40 PVC Pipe
- **Procedure:**
 - From the information gathered in Lessons 11 and 12, choose the optimum placement for the two horizontal and one vertical thruster. Keep in mind that the pressure canister will be installed at a later time.
 - Using the miscellaneous PVC fittings and pipe, install the three thrusters. Do not glue the PVC pieces into place since some later adjustment may be required.