# Construction Plans for the Cable Tie Water Rocket Launcher

Designed by Alex Kramer, March 2002
Based on a similar design by Ian Clark

# Description and Theory

The Cable Tie water rocket launcher mechanism was first designed by Ian Clark (http://www.smoke.com.au/~ic/). The reliability of this design is proven and its simplicity allows for fool-proof construction and operation. The "water rocket" is a 2-liter soda bottle that has been half-filled with water and pressurized with air. When the rocket is released the high pressure air forces out water through the bottle opening. This, in accordance with Newton's laws of motion, creates thrust. The thrust created is equal to the mass flow rate of the fluid multiplied by its relative exit velocity. Because water is about 1000 times more dense than air (depending on your altitude), much more thrust is created by the expulsion of water than air.

For the case of an open-mouthed 2-liter bottle, the entire water capacity is expelled by the time the rocket is about 8 feet from the launch pad. At this point, known as "burn out", the bottle will be traveling at about 150 mph! The "coast" phase is largely determined by the mass of the bottle and its aerodynamic drag. Apogee heights can be greatly increased by adding fins and extra weight to the bottle. The interested rocket scientist is can refer to Clifford Heath's Water Rocket Links website for detailed information about every aspect of water rocketry (http://homes.managesoft.com.au/~cjh/rockets/links.html).

# Construction

Enough with the theory and scientific nonsense. Lets build this thing! Construction will take about 45 minutes, probably shorter than the trip to the store.

## *Parts List*

The following parts will be needed to construct the launcher. All are available at the local Home Depot or Wal-Mart for a total cost of about $8.

1. (48") of ½" I.D. schedule 40 PVC pipe (a few more inches are optional as launch handle)
2. (4) ½" PVC solvent end caps
3. (3) ½" PVC solvent "T" fittings
4. (1) 1 ¼" PCV solvent coupler
5. (1) rubber tubeless tire valve (the ones for 0.453" rim hole work well)
6. (6) Cable ties 8" or longer (try to find ones with nice square heads) (the black ones are UV resistant, white ones are not, your choice)
7. (1) Screw type hose clamp that will fit ¾" diameter
8. (10') nylon cord for launch cord
9. PVC cement (clear looks best)
10. (1) Rubber O-ring. I use 7/16" I.D., 5/8" O.D. from Wal-Mart (available in an assortment pack for $.97) This part is very important for sealing.

## *Step 1: Cut the PVC Pipe*

Cut six **(6)** pieces of pipe each **5"** long. Cut another piece **18"** long.

You can use a hack saw or tubing cutter for this but the best is a PVC cutter because there are no burrs. File off any large burrs. The pieces should look like those in Fig. 1.

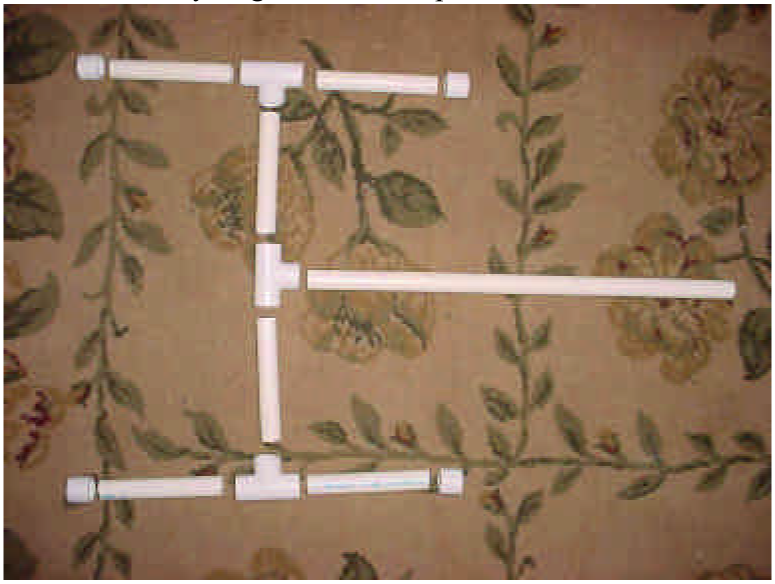

**Figure 1. Cut pipe pieces and solvent joints.**

### *Step 2: Install the valve*

Use a ½" drill bit to put a hole in the center of one of the solvent end caps, as in Fig. 2. Pressing it onto a piece of pipe helps hold it in place while drilling.

**Figure 2. Drilling the valve hole.**

Once the hole is drilled use something sharp to remove any burrs. The inside surface should be clean so it will seal against the valve. Lubricate the valve with water and press/pull it through the hole as shown in Fig. 3.

**Figure 3. Pressing in the valve.**

## *Step 3: Install the O-ring*

On the **18”** piece of pipe, measure **6 3/4”** from either end and make a small mark. Using the mouth of a 2-liter bottle to help, draw a line around the pipe at your mark. This is where you will file a groove for the O-ring to sit in. I use a pipe cutter to make a perfect groove around the pipe to start filing in, but any method that gets a reasonably straight groove will work. Use the corner of a file to widen the groove. Placing the pipe on a flat surface and rolling it with your hand while filing helps keep everything even. When the groove is about 1/16” deep, switch to a small file, one which has teeth on its edge. The file on a Leatherman tool works perfectly. File the groove until it is smooth and square as shown in Fig 4.

**Figure 4. Filing the O-ring groove**

The depth of the groove will depend on your particular O-ring. If you think it’s deep enough, install the O-ring and try to carefully twist the mouth of a 2-liter bottle over it as in Fig. 5. Be sure to clean out any particles before putting the O-ring on. Some oil or water on the O-ring will help here. You want a snug fit but not so tight it damages the O-ring. If the bottle will not fit, remove the O-ring and file some more until it fits.

**Figure 5. Test fitting the O-ring.**

### *Step 4: Attach Cable Ties*

Measure **5/8"** from the O-ring on the **18"** pipe **towards the long side** as in Fig. 6. Use the 2-liter bottle mouth to draw a line around the pipe.


**Figure 6. Drawing cable tie alignment line.**

Tape four **(4)** cable ties as shown in Fig. 7, with the heads aligning to the mark you have just drawn. Secure these cable ties with two more cable ties and the hose clamp as shown in Fig. 8. Notice that one cable tie is underneath the four cable ties. This is optional but it helps open up the ties for easier rocket loading. The exact placement is not important, however leave enough room at the end of the pipe for a solvent joint, about ¾". Tighten the clamp snugly and trim the excess from the cable ties.

**Figure 7. Cable tie alignment.**

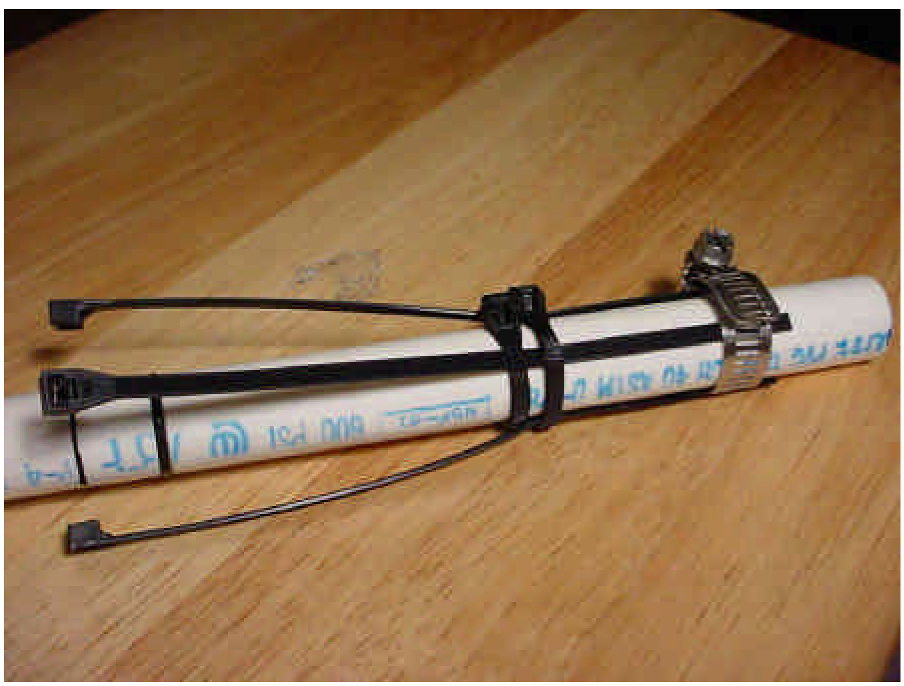

**Figure 8. Cable tie attachment.**

### *Step 5: Solvent bonding the PVC*

The frame is now done and is ready to be cemented together. Assemble as shown in Fig. 9 and solvent bond all joints. Be sure the structure is level and square.

**Figure 9. Launcher assembly after joints are cemented.**

### *Step 6: Launch Cord*

While the PVC cement is drying drill a hole through the 1 ¼" coupler and tie the nylon cord through it as shown in Fig. 10. The launch handle is optional.

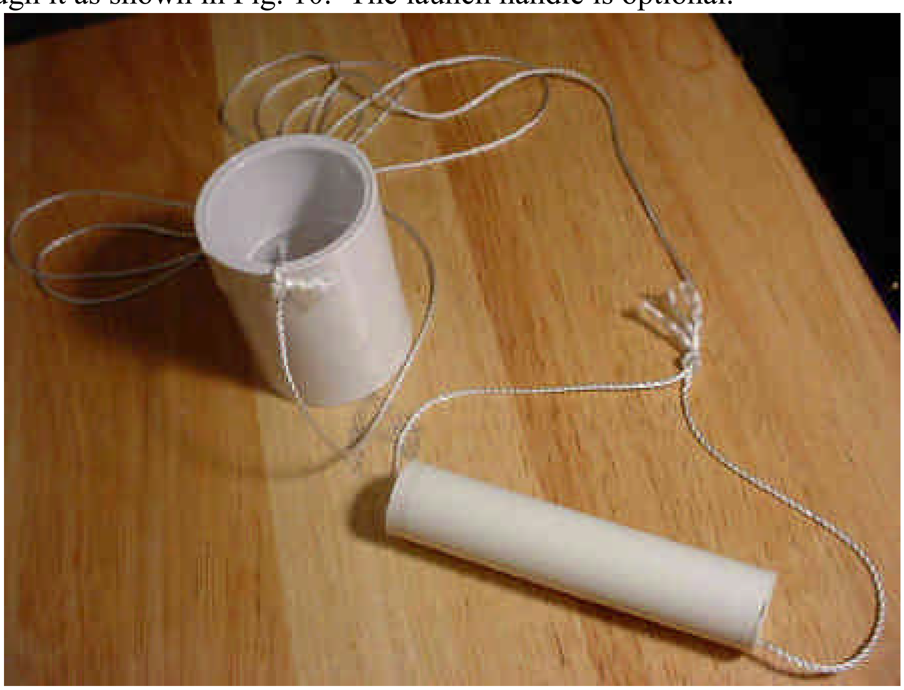

**Figure 10. Launch cord with optional handle.**

## *Step 7: Final Assembly and Bottle Test Fit*

The Launch ring (1 ¼"coupler) is placed on the launcher as shown in Fig. 11. To load a rocket (2-liter bottle), put the bottle over the pipe and O-ring and slide the launch ring up so the cable ties grab onto the plastic lip on the bottle as shown in Fig. 12. Route the launch cord as shown in Figs. 11 and 12. Construction is complete. Lets launch some bottles!

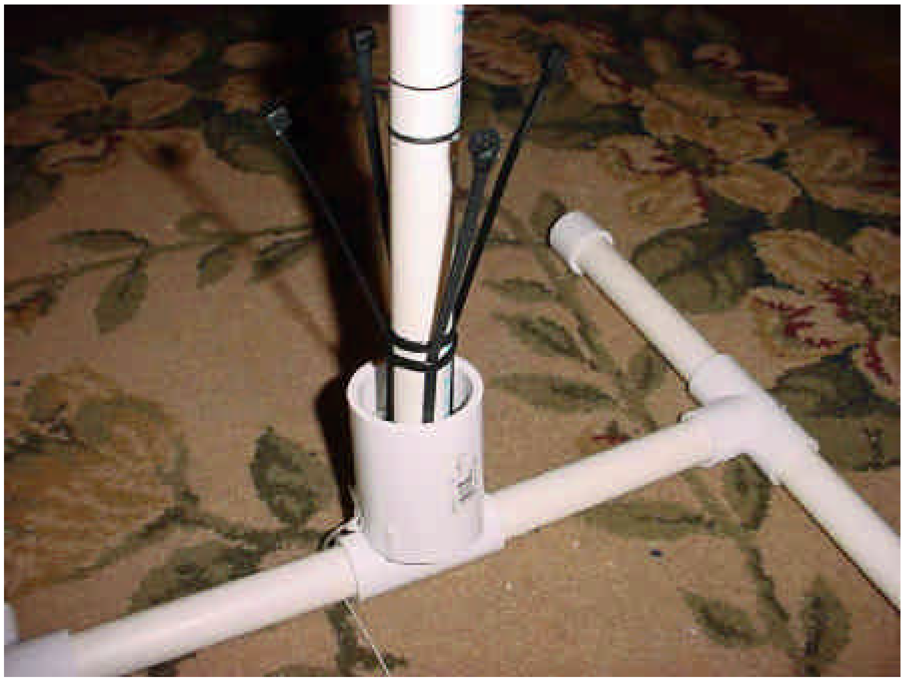

**Figure 11. Launch ring positioning.**

**Figure 12. Loaded rocket locked with launch ring (launch cord routing shown).**

## Launching Rockets

You should pressure test a bottle before you launch it. That way you know it can withstand the pressure you will be subjecting it to. Always pressure test bottles completely full of water. Compressed air is dangerous because it will expand rapidly if the bottle fails. Water under pressure is less dangerous due to its incompressibility. Filling the launcher tubes also will speed up the pressurizing process because there will be less air volume to pressurize.

As a test launch, fill a bottle half full with water and load it onto the launcher. Connect a pump or compressor to the valve and pressurize to about 40 psi. A pump with a built-in pressure gauge is best for this. Make sure the area is clear and everyone around you knows what you are doing. Stand back, count down, and pull the launch cord. If it launched, job well done. If not, the O-ring might be too tight against the bottle mouth. This can be fixed with more filing.

Water rockets are most efficient when filled about 40% full of water. Feel free to experiment with this, however. Try adding fins or extra weight to the rockets and gauge improvements. An empirical formula that approximately calculates rocket apogee height for open mouthed bottles is given by:

$$H=1.23t^2-3$$

Where t is the time the rocket is in the air in seconds, H is apogee height in meters.

## Note on Safety

Water rockets can be dangerous. Please be careful! If a bottle is damaged it can explode when pressurized. Be ready for this. I always keep my back to the rocket when pressurizing so any shrapnel would bounce off my back instead of my face. I have never accidentally exploded a bottle but I have done it once on purpose and it sounds like a shotgun blast. Use this launcher at your own risk.

 Alex Kramer, email: dr249@hotmail.com