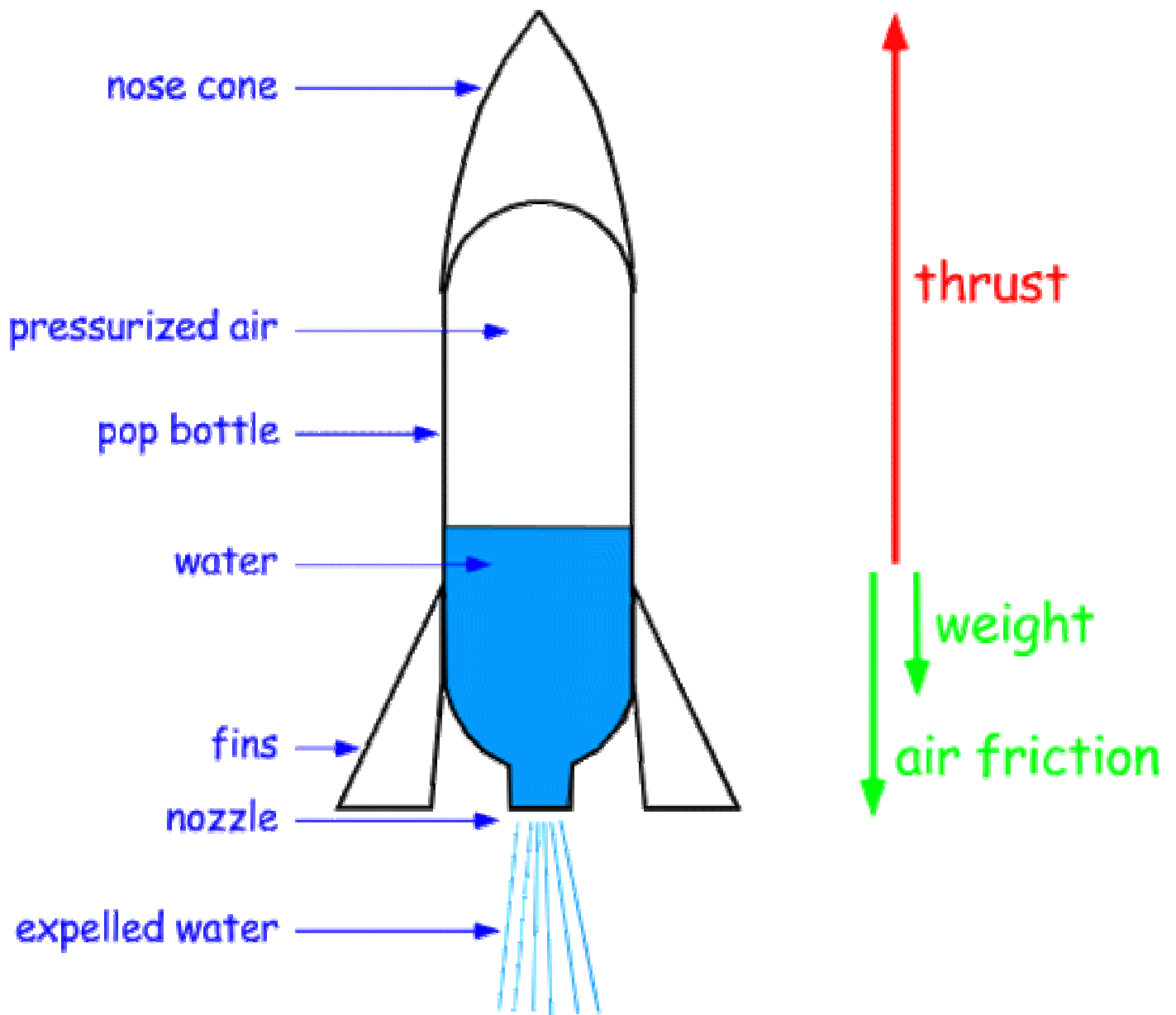


# Pack 530

## Water Bottle Rocket



## What is a Water Bottle Rocket?

A water bottle rocket is a 1 or 2-liter (soda) bottle with compressed air (for safety reasons we keep the air pressure around 40 to 50psi) and water released in an upward direction.

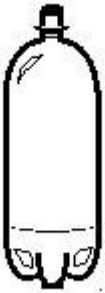
A water bottle rocket is both a simple project and a fun one that any level Cub Scout can build with a little help from a parent. Not only is it easy to build but it can also be used to teach Newton's Laws of motion, forces, energy and flight as well as the scientific method.

Once the rockets are built they can be launched at a den meeting or at a Pack outing. Our Pack has an annual Fall Family Campout and we launch them there. Your rocket launching could include events such as, long distance, hitting a target, landing an egg safely, or even making a field goal, but if you want to keep it simple the boy can have a blast just launching the water bottle and watching it go up.

## Construction

Almost any 1 or 2 liter bottle will work; however, some bottles have a mouth or opening (nozzle) that is too small to accommodate the launch tube. The launch tube is a regular 1/2 inch piece of PVC tubing. The tube should slide snugly into the nozzle of the bottle forming a nearly air tight seal. We have found that the majority of Coke™ related 2 liter bottles and Sam's Choice 1 liter water bottle will work while a majority of Pepsi™ related bottles will not. This is not to say that the smaller nozzle bottles are worthless, rather they should be used for other components of the rocket like the nose cones.

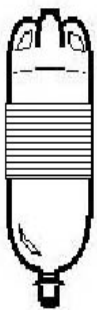
### #1 MAIN BODY/PRESSURE CHAMBER



The main part of your rocket is the body or PRESSURE CHAMBER. Peel the label off your bottle and try to clean the glue residue the best that you can. **Do NOT** use a knife or other object to scrape the label off. Scrape marks can weaken the plastic. Also, do not use hot water the plastic may shrink and weaken the bottle.

Some people have tried to use chemical solvents to remove the glue residue on the bottle. This might alter the walls of the bottle and make them too brittle or soft. Therefore we don't recommend it.

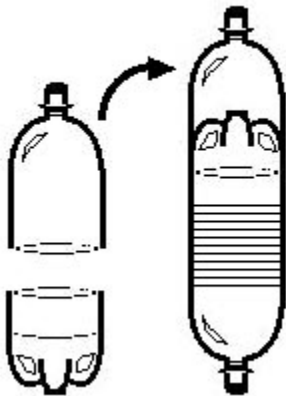
### #2 AFTER CLEANING



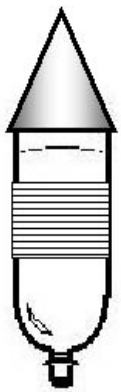
When launching, the pressure inside the bottle will cause the walls to expand. This expansion leads to a loss of energy and will make the rocket fly to a lower altitude. To solve this problem take some duct tape, strapping tape, or packing tape and pre-wrap three bands around the pressure chamber. You don't want the tape to be too bulky and watch for wrinkles. This will strengthen the walls of the bottle without adding too much mass and launch altitude will increase overall.

### #3 NOSE CONES

Nose cones are not only for performance but add character and style to your rocket. Be sure to take some time thinking out the design of your rocket before committing to a plan of action. Shown here is only two examples; so don't be afraid to be creative.



My favorite is the "Bertha Series" nose cones, they are easy to make as well, but require a little attention to detail. The "Bertha" nose cones are made by cutting the bottom off a **spare bottle** with a pair of scissors and attaching the top portion onto the pressure chamber. **(Note: Never cut the pressure chamber)** To mark a straight line around the bottle for cutting, I place the bottle in a short can and hold a marker on the lip of the can as I rotate the bottle. Before attaching the nose cone, add a small lump of Play-Doe or clay in the bottle's neck to increase the mass (see section on Rocket Concept). After the Play-Doe is pushed in place tape over it with some duct tape and replace the cap. Once you lance the rocket see how it hits the ground you will understand the reason for the tape. Make sure you have a cap on the nose cone. Before you tape the cone on, roll the rocket over a flat surface to make sure the cone and pressure chamber align. A curvy rocket will not be safe coming off the launcher.



This rocket is called "The Bullet". It is the easiest to make but lacks flight stability, this can be fixed to a degree by pressing a small lump (a few ounces) of clay to the inside of the nose cone. This will add mass to the cone and keep your rocket from flipping end over end while in flight. The cone is made from **poster board** or **tag board**. You can make the cone by simply cutting a large circle out of the poster board (about a 6 inch radius). Cut a line from the outer edge of the circle to the center on the radius. Overlap the cut edges and turn the circle while holding one edge stationary until you get the desired cone shape. Secure the cone shape with staples or tape. Attach to the bottle with tape or similar adhesive. **(Note: do not puncture or cut the pressure chamber).**

## #4 FINS

Fins are the guidance system for your rocket. Without them a rocket would tumble end over end. Fins can give your rocket life and beauty. Fins can portray aggressive power or aerodynamic grace. However, fins tend to be the single greatest downfall of many young rocket builders. With the incredible speeds and acceleration generated at launch, many fins get ripped off the rocket body within a fraction of a second.

Fins should be firm; if they flop around they are useless.

Fins should be adequately secured; duct tape works well. I do not use glue because it does not expand with the pressure chamber and may cause it to become brittle.

The best fins are made of rigid cardboard or styrofoam board.

The size of the fin does matter! The best rockets fly well with long and narrow fins.

Materials: (remember lightweight but sturdy)

Paper clips or Index Cards

Duct Tape or Clear packing tape

Cardboard (cheap, plentiful, soggy when wet)

Chipboard (cereal boxes)

Foam core (a little tougher but more \$, some water damage)

Sturdi-board (like plastic cardboard, great stuff, \$\$, no water damage)

Balsa wood (might be a little heavy, fragile on impact)

Styrofoam sheets\* (cheap, low mass, fragile on impact)

\*Requires PL Premium Construction adhesive to attach

### How many fins do I need?

To ensure stability and safety, the minimum number of fins on a rocket is three (3). Many people choose a 3 or 4 fin design. There is no maximum number of fins you may have but keep in mind that the more fins you have the more drag you will create and drag slows a rocket down.

#### BASIC FIN DESIGNS

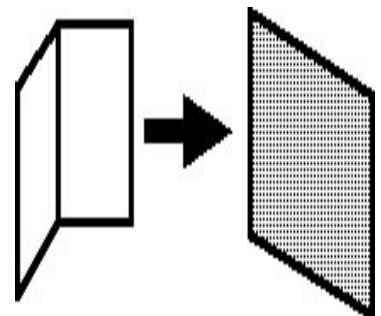


No forward swept fins



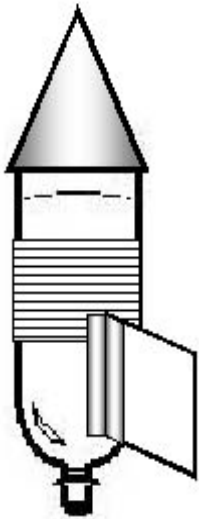
### Constructing fins

1. Be creative and cut out 3 or 4 identical fins. You can use any shape except "forward swept" fins.
2. Lay the fin on a flat surface.
3. Use a paper clip bent at 90 degrees and taped it to the fin or an index card taped onto the side of the fin. Be sure to leave a one-inch tab on the index card. You will later bend this tab out 90 degrees to make an attachable area for the rocket.
4. Repeat the same for the other side of the fin.



5. Repeat with other fins.

You should now have 3 or 4 fins each with either paper clips or two-index card tabs attached to the fins. (If you use cardboard laminate the entire fin surface with tape to reduce the amount of water damage to the fins.)



### **Fin placement**

The fins of your rocket can't be placed above the halfway point of your pressure cylinder. You want to place your fins at the base of the rocket to lower or maintain the center of gravity. If you were to place the fins above the center of gravity, the rocket would tumble and spin out of control once it left the launch pad.

### **Attaching the fins**

This is the tricky part. Gluing the fins on is not recommended including hot glue and "Liquid Nails" type adhesives are not flexible enough when it comes to the launch. The bottle pressure chamber might expand a millimeter or more in circumference when it is pressurized. That is enough to break the bonding seal of most glues. When the rocket is launched, the fins usually rip off. I have found that tape works the best at holding the fins on the rocket.

1. To find the location of the fins on the bottle, take a piece of string and wrap it around the outside of the bottle and mark the length using an ink pen. Remove the string from the bottle and lay it out in a straight line and mark the string in 3 or 4 equal lengths depending on the number of fins you are going to use. Wrap the string around the bottle again and transfer the marks to the bottle. If you are using 4 fins this will create 90-degree angles, 3 fins will be at 120-degree angles. To mark a straight line on the bottle, lay it in a door jam and use the straight edge to draw a line the length of your fin. You now have the locations of where to attach your fins.
2. Apply a piece of tape to the paper clip or index card tabs and carefully tape them to your rocket.
3. Look at your fin. Make sure it doesn't curve or it isn't crooked. It should be in a direct line with the body of your rocket. If it isn't perfect, take it off and try again.
3. Attach the other fins. Test the wiggle of the fins. Your fins shouldn't wiggle more than a few centimeters from side to side. Adding more tape to the top and bottom areas of the fin might fix this problem.

# Advance Design Water Bottle Rockets

The follow are some advance designs you can make with your rocket and require more work to build but are fun to build.

## PARACHUTE SYSTEMS

By now you may have spent about an hours building the rocket of your dreams. It may not be completely obvious to you yet, but as the old saying goes, what goes up... must come down. It's time to think about saving all that precious work by creating a recovery system for your rocket. Here are a few ideas to get you started. Fins have been removed for clarity. (Note: you may substitute "crepe paper streamers" for "parachute" in most of the following examples)

Here is a list of materials:

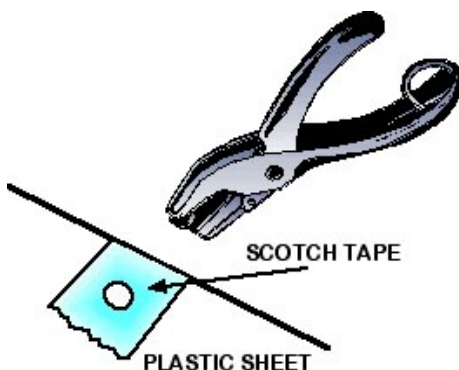
Tall kitchen garbage bag -or-  
Four-grocery plastic bags  
Scotch Tape

Kite string or Yarn  
Baby Powder

The size and shape of your parachute can be as varied as your rocket. A good rule of thumb is to make your chute 6 tot 12 inches across depending on a 1 or 2 liter bottle. Your chute could be larger but some rocket styles have narrow nosecones and the chute could get stuck.

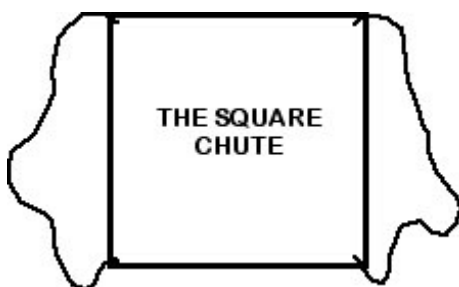
## Making the Chute

Carefully cut the garbage bag along one side and the bottom seam. Open the bag along the fold and lay it flat. If you want to use the grocery bags, cut each bag in the same way but lay them out side by side 2 X 2. Use some scotch tape and tape the center seams to make a larger surface area.

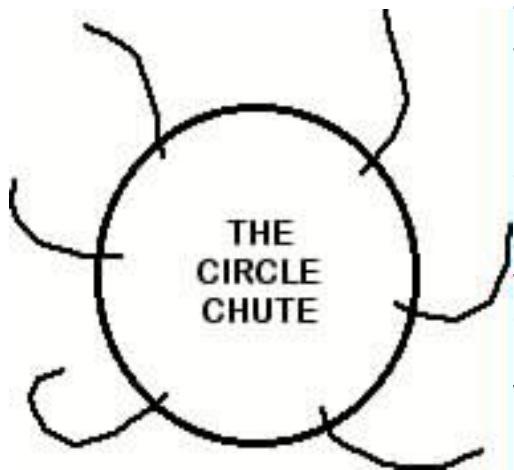


### The Square Chute

The simplest chute to make is the "Square Chute". Prepare the edges, where you will connect the strings, with scotch tape **grommets**. First apply a piece of tape to both sides of the plastic. Then, with a hole punch, punch a clean hole through the center of the tape and plastic tab. Repeat this procedure for each location where you are placing a string.

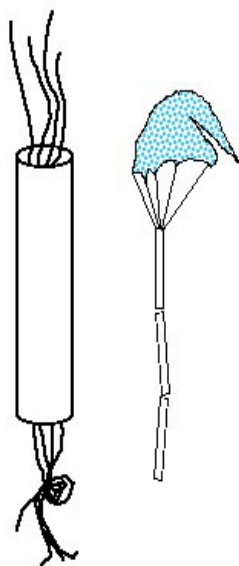


To complete the "Square Chute", measure two 24-inch lengths of string and tie each end to one of the grommet holes. Bring the centers of the string loops together and tie them off.



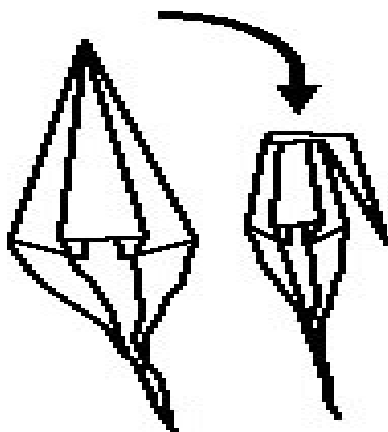
### The Circle Chute

The "Circle Chute" is a classic, timeless engineering masterpiece. But don't let me influence you. If you have a large tire or similar round object you can trace the circle on the plastic with a marker and cut. If you don't have anything large enough to trace, fold the plastic in half, then in half again, then fold on the diagonal. This will give you a triangular wedge. With a sharp pair of scissors, cut along the section that has the open edges. You don't have to worry about cutting on the curve, just cut straight across the bottom. If you want to practice this first, try cutting a piece of paper first. Finish the edges with tape grommets as mentioned above. Lastly, tie separate 24 to 36 inch string leads to each grommet. Gather the leads together and finish the strings off with a good knot.



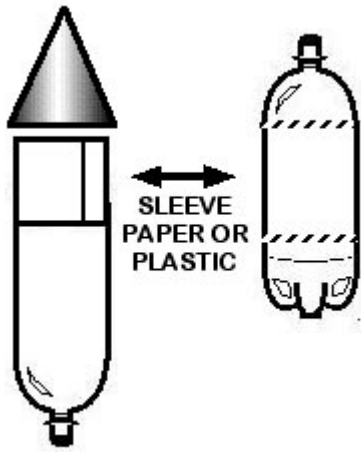
### Anti-Tangle Armature

One of the unforeseeable happenings in rocket parachuting is getting the strings caught or tangled in the fins or safety lines of the rocket. An easy way to avoid this problem is to build this simple cable shield for your chute. Cut two or three straws into 4 or 6-inch sections. Slip the extra long string leads, from your parachute, into the straw sections. The armature should protect the strings as the chute deploys and then slide down out of the way when your chute opens up. (NOTE THE ILLUSTRATION IS NOT TO SCALE.)



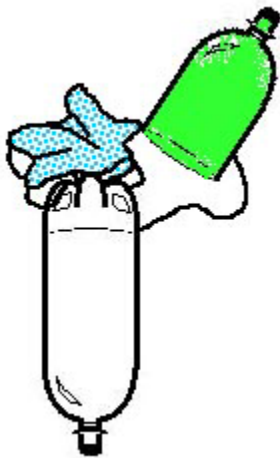
### Folding the Chute

Dust the chute with baby powder to ensure that it doesn't stick to the side of the rocket or itself. Grab the chute between two fingers, in the center, and pull it up toward the ceiling. Let the chute fold naturally as you lift it. Once you have the chute pulled up, fold it once in half at the center. You don't want to fold the chute too tightly but you can fold your chute into thirds if space is a factor. Wrap the excess string loosely around the chute. Fold the straw armature sections onto the chute but not part of the excess string wrap.



### Making a Sleeve

If you find that the chute area is too small to hold your parachute, you can increase the size of container by adding a section of chipboard around the girth of the bottle. Or you can use another 2-liter bottle. Remove the top and bottom of the 2nd 2-liter and tape the new cylinder into position. This tends to make your rocket more stable by increasing the distance between the Center of Pressure and the Center of Gravity.



### The "Bertha Cone Chute" (3 out of 5 Stars)

With this chute system, instead of taping the nose cone on, attach a safety cord to the **weighted** cone and apply a parachute to the top of the pressure cylinder. In theory, once the rocket reaches apogee (the highest point of travel), the weighted nose cone separates from the main body. The main body is creating enough drag to slow itself down. If everything works, the parachute deploys and the two pieces float gently back down to earth.

In practice, the nose cone can sometimes get jammed on the main body causing a failure. In addition, safety cord can be too short and the cone can't clear the body.

### Nose

The "Tug of the or tennis chute needs to unravel. Problems jams. Cone



### Cone Tug Chute (3 out of 5 Stars)

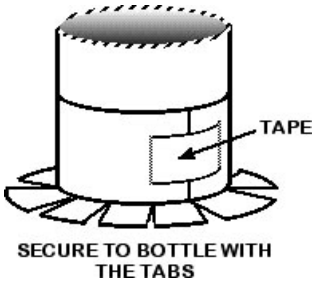
"Chute" uses the force of the lifting nose cone to pull the chute out sleeve or needle assembly. Attach a safety line to the nose cone ball. Attach a parachute close to the cone/ball assembly. The to be folded small enough to fit inside the needle yet not too tight

with this system include; not enough line and parachute packing style noses with a sleeve have more success with this system.





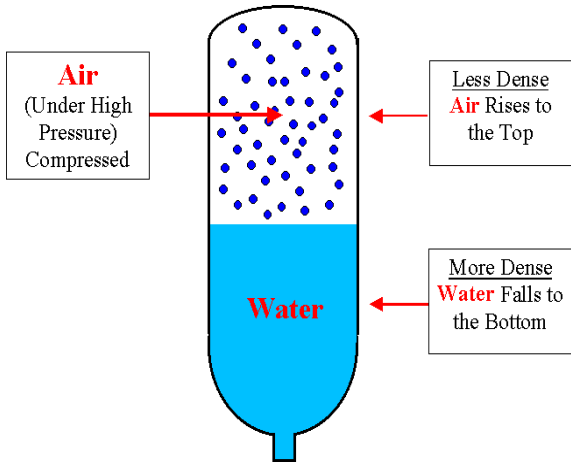
The "Space Needle" style of nose cone can be made from a **spare bottle, empty paper towel roll, and a tennis ball or racket ball**. This type of nose cone adds a great deal of inertial mass to the rocket and makes it really stable. Simply, attach the towel roll to the top of a single Bertha nose cone and then fix the tennis ball to the top of the roll. Take your time building this set up because you want the entire assembly to be straight as an arrow.



Cut tabs in an index card and glue or tape the card to the tube. This will hold the tube upright. Then tape the tabs onto the nose cone top.

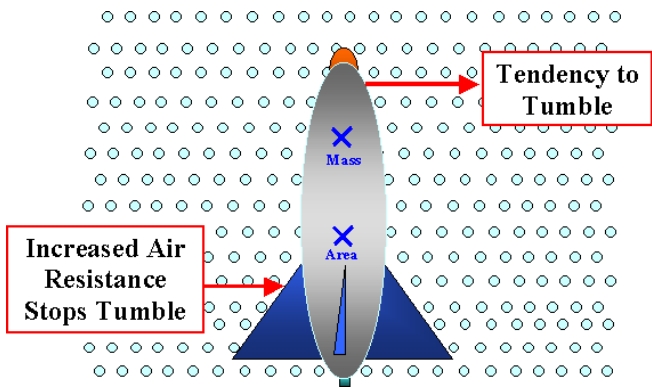
SECURE TO BOTTLE WITH  
THE TABS

# Concepts



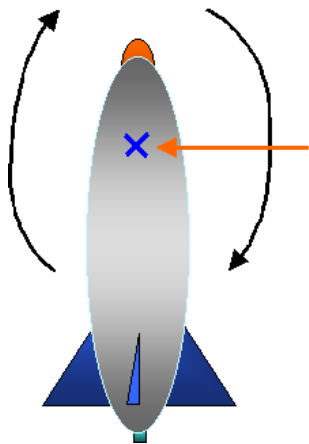
Air enters the pressurized vessel from the bottom and presses down on the water. When the pressure reaches a critical level, it pops the "cork" out of the nozzle and the pressurized air expels the water from the nozzle.

Air is a mixture of gases that can be compressed. As more and more air is forced into the rocket "engine," air molecules are packed more and more tightly together. Pressure inside the container is very high. When the stopper is released, the compressed air in the container rushes out.

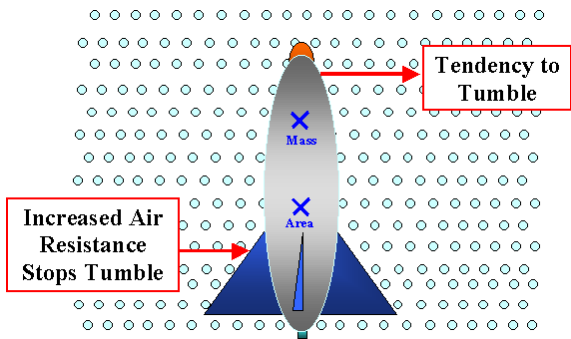


Shift Center of Mass Up

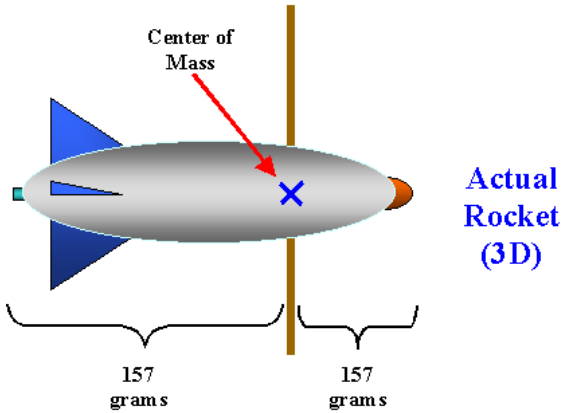
By placing a clay ball or weight in the nose cone the Center of Mass is moved high enough on the rocket so that it won't tumble on lift off.



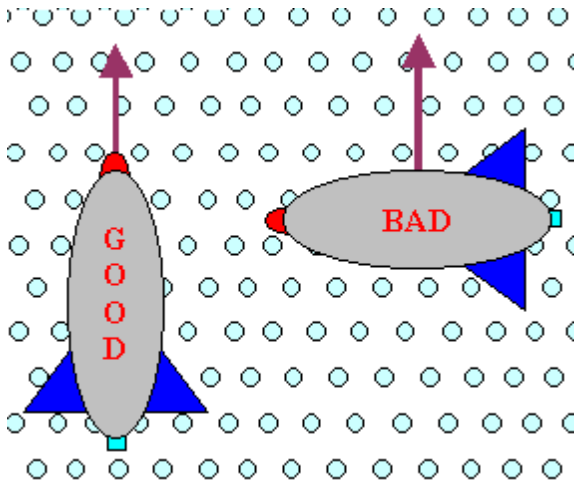
If the center of mass of your rocket is too close to the center of area, your rocket will cartwheel out of control. It will NOT fly straight! Moving the center of mass UP away from the midpoint of the rocket, will help to ensure that the rocket flies straight.



Here is a way to tell if your rocket will tumble. Measure the Center of Mass & mark this spot on your rocket. Now measure the Center of Area and mark this space as well. If the two marks are further apart than the width of your rocket body, you are probably in good shape.



The best way to determine Center of Mass is to balance your rocket on a yardstick.



Obviously, if your rocket behaves more like the one on the left it is more likely to fly straight. The rocket on the right will tumble out of control.

# Newton's Laws

You can use the water Bottle Rocket as part of the Webelo's Science badge and use the following to study Newton's Three Laws

## Preliminary Questions to consider:

- Why do bottle rockets fly?
- Why do we have to use water, or do we?
- Will it fly without water?
- If a little water works well, will a lot of water work better?
- Will it fly best when it is totally full?
- What volume of water works best?

These questions can be answered by demonstration using a bottle with no modifications and with various levels of water.

As with all good demonstrations more questions usually arise, such as:

Why did the rocket that was full of water barely take off?

It was too heavy or massive. This can be explained with **Newton's first law of motion; A body at rest tends to remain at rest and a body in motion tends to stay in motion.**

The rocket didn't have enough "oomph" (force) to make it take off. Why?

There was not enough force for the relatively huge mass. The more mass it has, the less it will accelerate using the same force. This can be explained using **Newton's second law of motion: Force equals Mass times Acceleration.**

Why did the water go one way and the rocket the other? There is an equal force in both directions.

This can be explained by **Newton's third law of motion: For every action there is an equal but opposite reaction**