Build a Water Bottle Rocket Assembly!

In February of 2008 Leland flew aboard the Space Shuttle Atlantis for his first space mission, launching with two attached solid rocket boosters. Check out the experiment below for directions on how to build your own Water Bottle Rocket.

Leland launched into space for the first time in February 2008 aboard the Space Shuttle Atlantis. His mission was made possible by decades of research and experimentation in aeronautics, rocket design, and fuel systems. NASA and other private, commercial companies are constantly improving the design of rockets and vehicles used for space travel, missions to the International Space Station, and maybe one day, the journey to Mars.

This activity, *Water Bottle Rocket Assembly*, reinforces more advanced concepts associated with Newton's Laws of Motion such as the exertion of force to propel rockets upward, showing the connection between force, propulsion and acceleration.

The size of the rocket as well as the size, number and design of the fins can greatly impact stability and distance achieved. A rocket with no fins is much more difficult to control than a rocket with fins. The placement and size of the fins is critical to achieve adequate stability while not adding too much weight.

The activity includes instructions on how to test your rocket for stability and how to assemble a rocket launcher. It is recommended that you build the rocket launcher with adult assistance, as you will need to purchase items from a hardware or building supply store, as well as operate a drill. It is also recommended that you operate the rocket launcher with adult

For more detailed information on the science concepts demonstrated, as well as additional information on safety precautions and recording your results you can reference the *Adventures in Rocket Science* activity guide (http://www.nasa.gov/pdf/265386main_Adventures_In_Rocket_Science.pdf) or search educational resources available at NASA.gov.

The experiment has three stages:

- Construction of the Rocket
- Construction of and Performance of a Stability Test
- Construction of a Rocket Launcher.

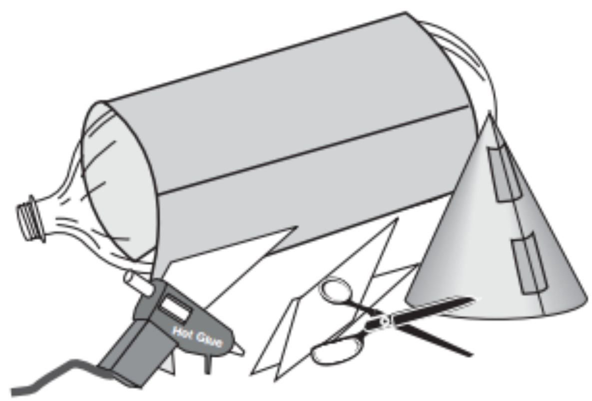
We recommend that you work with an adult or under adult supervision during each phase of the experiment, but especially as you build the Rocket Launcher. You may want to read ahead, before you begin Stage One, to prepare for each stage.

And remember, as always, Safety First! Wear properly fitting safety goggles and launch your rockets in a large outdoor area where there is space to safely observe the launch and record your flight results.

Stage One: Build the Water Bottle Rocket

Materials and Tools

- 2-liter plastic soft drink
- bottles
- Low-temperature glue
- guns
- Poster board
- Tape (masking and/or duct)
- Modeling clay
- Scissors
- Safety Glasses
- Decals
- Stickers
- Marker pens



Notes as you begin:

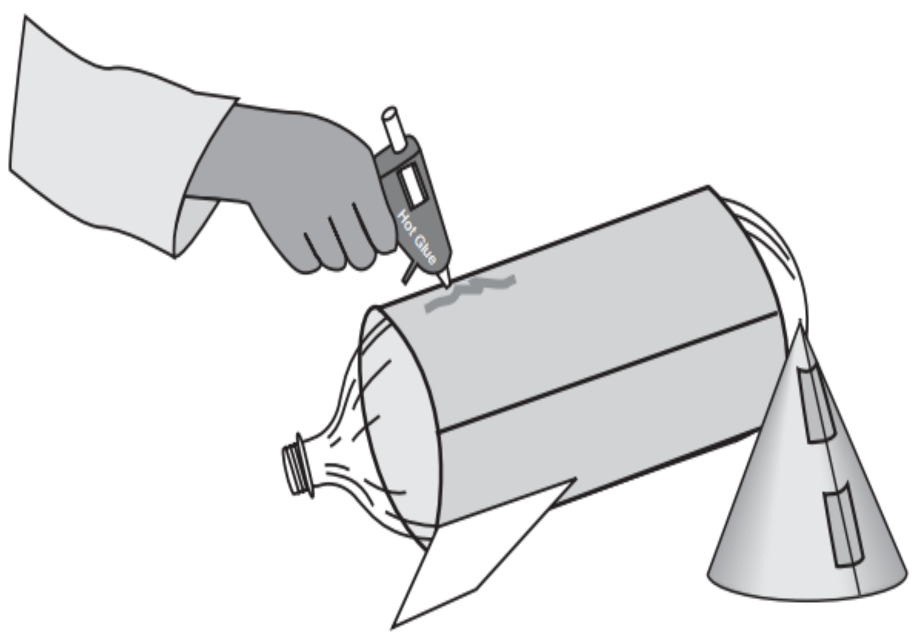
- Safety first! Always wear proper fitting goggles for experiments, especially as you launch your rockets. The rockets are projectiles so

- Collect a variety of decorative materials or decals before construction so you can customize the rockets.
- Use tape or a low-temperature electric glue gun (available from craft stores) to attach the paper and decorations. High- temperature glue guns will melt the plastic bottles.
- Build your rockets on a surface where glue guns can be used safely, or put down a protective layer (such as flattened cardboard) over your workspace.
- When launching rockets, it is important that others stand back. Use a Countdown to help inform everyone as to lift off!
- Be sure to conduct your experiment in a large area with enough space to allow for the rockets to fly.
- Once you create and launch your first rocket, think about how to modify or improve your design and try it again!
- Be sure to measure how far your rocket travels with each launch and track your data!

Procedure:

For this experiment the first step is to construct your rocket according to the diagram instructions provided. Test and launch the rockets using the Rocket Launcher in a large outdoor space.

1. Wrap poster board around the bottle to form the main tube of your rocket. Glue or tape it securely. The bottom of the plastic bottle will be the top of your



2. Design and cut out several fins of any size or shape and glue/tape them to the tube. The fins should align to the "bottom" of your rocket (which is the top opening of the plastic bottle)

3. Form a nose cone out of poster board and secure it with tape or glue.

4. Press a small round ball or modeling clay into the top of the nose cone.

5. Glue or tape the nose cone to the upper end of your rocket (the bottom of the bottle) so that it may be easily removed. Performing the stage two stability test will tell you if you need to add weight to your nose cone for stability.

6. Decorate your rocket.

Once you have constructed your rocket, evaluate its quality of construction and design:

- Observe how well fins align and how well they are spaced
- Observe how smoothly the fins and nose cone attach to the bottle.
- Observe how straight the nose cone is at the top of the rocket.
- Observe how heavy your Rocket is and how stable it seems to be as it sits on the table.

Stability is an important factor in determining a rocket's ability to fly well. The next step in our experiment is to construct and perform the Stability test.

Stage Two: Perform the String-Swing Stability Test

A rocket that flies straight through the air is said to be a stable rocket. A rocket that veers off course or tumbles wildly is said to be an unstable rocket. The difference between the flight of a stable rocket and an unstable rocket depends upon its design.

All rockets have two distinct centers. The first is the center of mass (CM). This is a point about which the rocket balances. If you could place a ruler edge under this point, the rocket would balance horizontally like a seesaw. What this means is that half of the mass (weight) of the rocket is on one side of the ruler edge, and half is on the other. The CM should be towards the rocket's nose.

The other center in a rocket is the center of pressure (CP). This is a point where half of the surface area of a rocket is on one side and half is on straight, as the fins and tail have more surface area. (To learn more about center of mass and center of pressure consult the *Adventures in Rocket Science* pdf after your experiment is complete!)

Materials and Tools

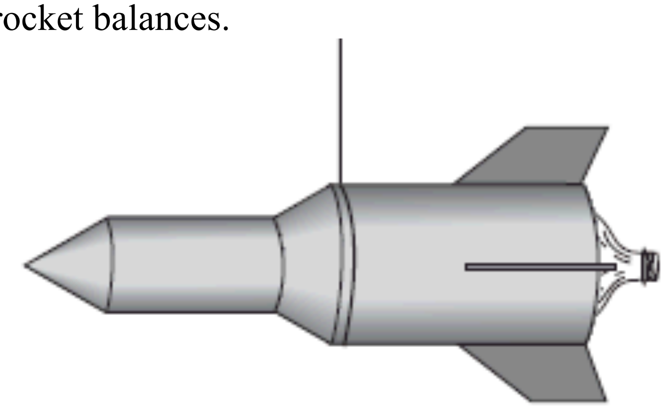
- A spool of medium weight string (like a kite string)
- Graph paper
- Straight edge ruler or yardstick
- Measuring tape
- Straight piece of cardboard
- Scissors
- Pen or marker

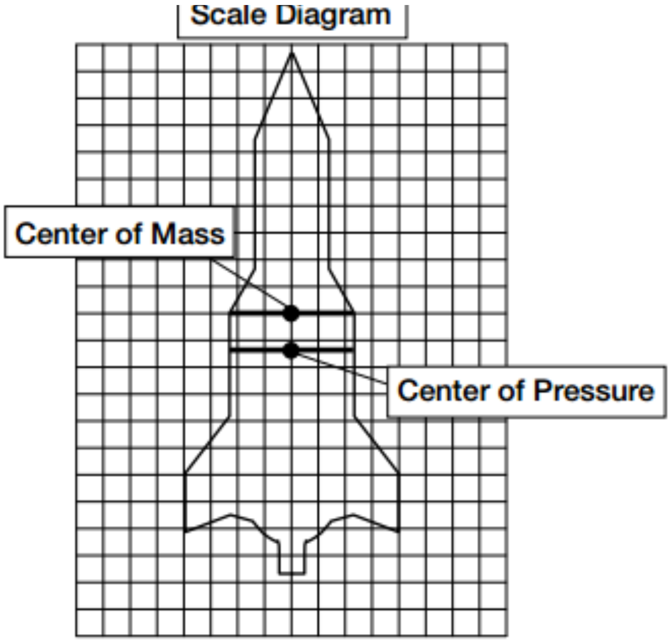
Stability Determination

Using graph paper, draw out the top view of your rocket, to scale (1 square = 1 inch), based on the measurements of your rocket. You can also draw a side and bottom view to have a complete record of your rocket's shape and size.

Then carefully place your rocket on the piece of cardboard and trace around it, as closely as you can. Cut out the trace of the rocket.

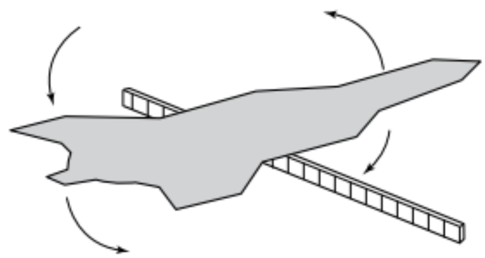
Tie a string loop around the middle of your rocket, but keep it loose enough to move along the rocket body as you find the center of mass (CM) for balance. Tie a second string to the first so that you can pick it up. Hold the rocket up in the air and slide the string loop to a position where the rocket balances.





Keeping the string in place, measure how far it is from the nose cone (or bottom) of the Rocket. Find the corresponding place on your scale image and mark it with a straight line across the body of the rocket and a dot in the center of the rocket body.

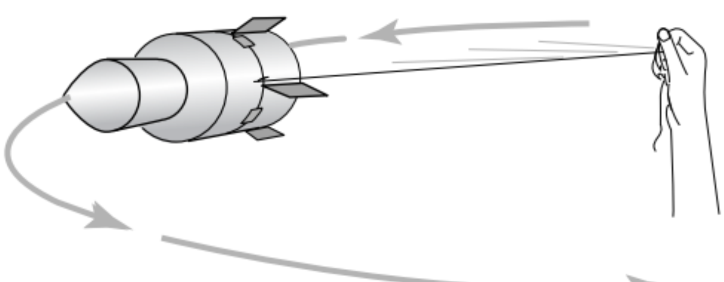
Lay the cardboard silhouette you just cut out on the ruler edge and balance it. Mark the placement of the ruler on your cardboard cutout, measure and mark your graph paper diagram in the corresponding point. The center is the CP of the rocket.



If your CM is in front of the CP, (closer to the nose cone) your rocket should be stable. Proceed to the swing test. If the two centers are next to or on top of each other, add more clay to the nose cone of the rocket. This will move the CM forward. Repeat steps 2 and 3, and then proceed to the swing test.

Swing Test

Tape the string loop you tied around your rocket in the previous set of instructions so that it does not slip.



While standing in an open place, slowly begin swinging your rocket in a circle. If the rocket points in the direction you are swinging it, the rocket is stable. If not, add more clay to the rocket nose cone or replace the rocket fins with larger ones. Repeat the stability determination instructions, and then repeat the swing test.

Once you determine your rocket is stable, securely glue or tape the nose cone in place for launch!

Stage Three: Construction of a Rocket Launcher.

Construct the launcher described below or obtain one from a science or technology education supply catalog or online.

Once you have the launcher ready, remember safety first! Wear properly fitting goggles when launching rockets, and stand back. If you create and launch your rockets in a group, you can create launch safety rules that everybody must follow and roles for each person in the group. Countdowns help everybody to know when the rocket will lift off.

Consult the materials and tools list below to determine what you will need to construct a single bottle rocket launcher. The launcher is inexpensive to construct, but it can also be purchased if you do not have access to the materials needed. We recommend adult assistance in constructing and using the launcher. Because the rockets are projectiles, safely using the launchers will require careful planning and possibly additional supervision. Please refer to the launch safety instructions in the *Adventures in Rocket Science* pdf for more detailed guidance.

Air pressure for the launch is provided by means of a hand-operated bicycle pump. The pump should have a pressure gauge for accurate comparisons between launches. Most needed parts are available from hardware stores. In addition, you will need a tire valve from an auto parts store and a rubber bottle stopper.

Materials and Tools

- Four 5 in corner irons with 12.75 in wood screws to fit
- One 5 in mounting plate
- Two 6 in spikes
- Two 10 in spikes or metal tent stakes

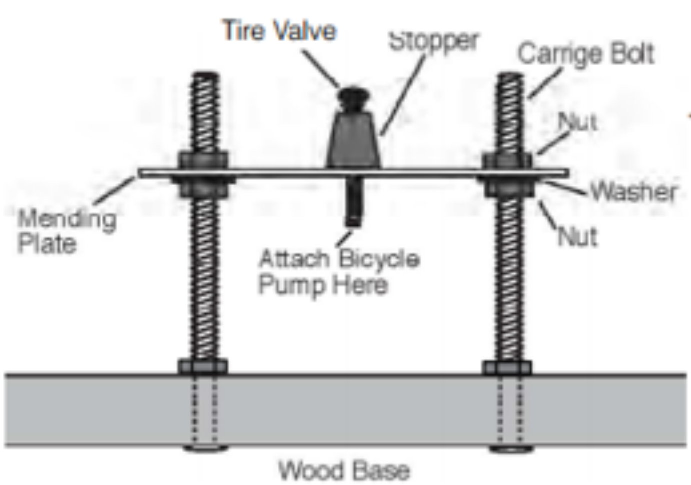
- One 3 in eyebolt with two nuts and washers
- 0.75 in diameter washers to fit bolts
- One number 3 rubber bottle stopper with a single hole
- One Snap-in Tubeless Tire Valve (small 0.453 in hole, 2 in long)
- Wood board 12 ×18 × 0.75 in
- One 2-liter plastic bottle
- Electric drill and bits including a 0.375 in bit
- Screwdriver
- Pliers or open-end wrench to fit nuts
- Vice
- 12 ft of 0.25 in cord
- Pencil
- Bicycle pump with pressure gauge

Procedure

1. Prepare the rubber stopper by enlarging the hole with a drill. Grip the stopper lightly with a vice and gently enlarge the hole with a 0.375 in bit and electric drill. The rubber will stretch during cutting, making the finished hole somewhat less than 0.375 in.

2. Remove the stopper from the vice and push the needle valve end of the tire stem through the stopper from the narrow end to the wide end.

3. Prepare the mounting plate by drilling a 0.375 in hole through the center of the plate. Hold the plate with a vice during drilling and put on eye protection. Enlarge the holes at the opposite ends of the plates, using a drill bit slightly larger than the holes to do this. The holes must be large enough to pass the carriage bolts through them.



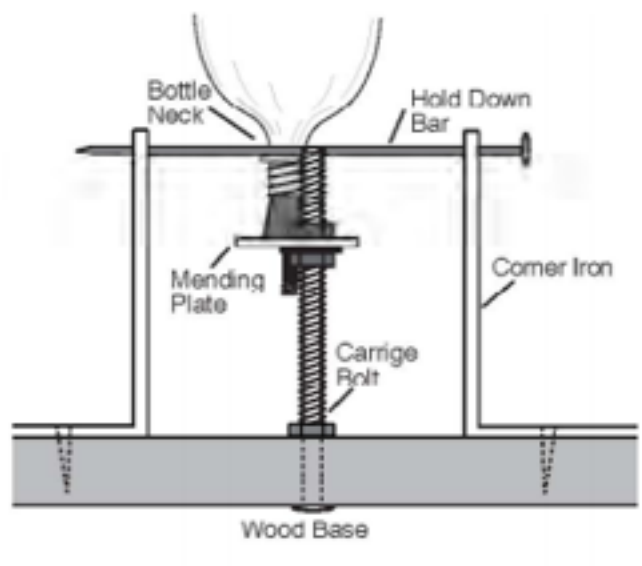
4. Lay the mending plate in the center of the wood base and mark the centers of the two outside holes that you enlarged. Drill holes through the wood big enough to pass the carriage bolts through.

5. Push and twist the tire stem into the hole you drilled in the center of the mounting plate. The fat end of the stopper should rest on the plate.

6. Insert the carriage bolts through the wood base from the bottom up. Place a hex nut over each bolt and tighten the nut so that the bolt head pulls into the wood.

7.Screw a second nut over each bolt and spin it about half way down the bolt. Place a washer over each nut, and then slip the mounting plate over the two bolts.

8. Press the neck of a 2-liter plastic bottle over the stopper. You will be using the bottle's wide neck lip for measuring in the next step.



Positioning Corner Irons

9. Set up two corner irons so they look like book ends. Insert a spike through the top hole of each iron. Slide the irons near the bottle's neck so that the spike rests immediately above the wide neck lip. The spike will hold the bottle in place while you pump up the rocket. If the bottle is too low, adjust the nuts beneath the mounting plate on both sides to raise it.

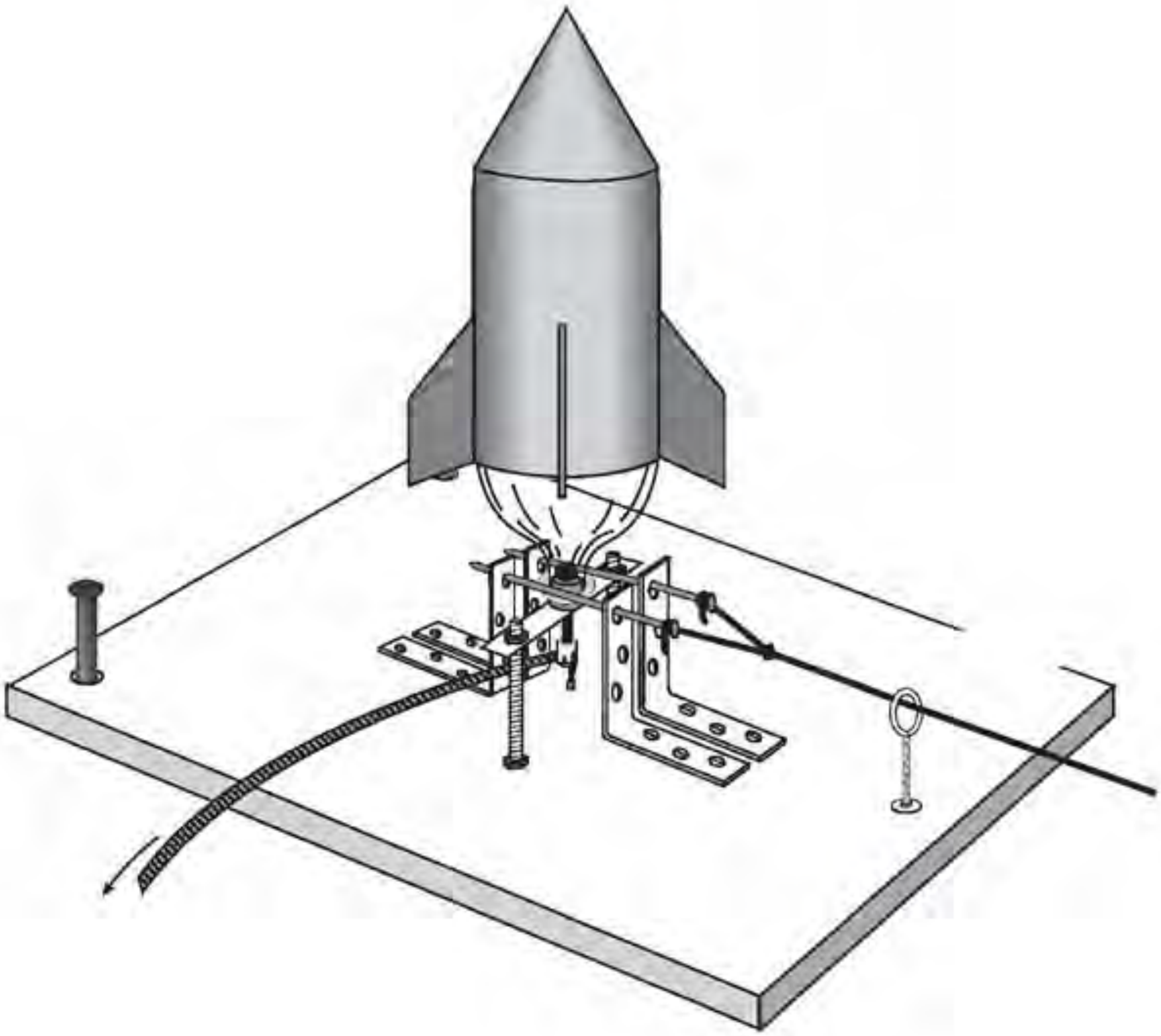
10. Set up the other two corner irons as you did in the previous step. Place them on the opposite side of the bottle. When you have the irons aligned so that the spikes rest above and hold the bottle lip, mark the centers of the holes on the wood base. For more precise screwing, drill small pilot holes for each screw, and then screw the corner irons tightly to the base.

11. Install an eyebolt to the edge of the opposite holes for the hold down spikes. Drill a hole, and hold the bolt in place with washers and nuts on top and bottom.

12. Attach the launch pull cord to the head end of each spike. Run the cord through the eyebolt.

13. Make final adjustments to the launcher by attaching the pump to the tire stem and pumping up the bottle. Refer to the launching safety instructions for safety notes. If the air seeps out around the stopper, the stopper is too loose. Use a pair of pliers or a wrench to raise each side of the mounting plate in turn to press the stopper with slightly more force to the bottle's neck. When satisfied with the position, thread the remaining hex nuts over the mounting plate and tighten them to hold the plate in position.

14. Drill two holes through the wood base along one side. The holes should be large enough for large spikes or metal tent stakes to pass through. When the launch pad is set up on a grassy field, the stakes will hold the launcher in place when you yank the pull cord. The launcher is now complete!



Questions to Investigate:

- *How would a 2-liter bottle fly differently from a half-liter bottle?*
- *What if you just put air in the bottle?*
- *What happens if I add water to the rocket?*
- *How does adding modeling clay to the nose cone affect the rocket's flight?*

As you investigate your new questions, make a hypothesis and then build and launch rockets made from smaller/larger bottles, or change other variables.

The paper rocket was launched with just air pressure applied in a pulse. Your bottle rocket can be launched this way but can also employ extra pressure expelling water.

You can increase the force further by adding a small amount of water to the rocket. Adding a small amount of water to the bottle increases the action force. The water expels from the bottle before the air does, turning the bottle rocket into a bigger version of a water rocket toy available in toy stores.

Placing 1.75–3.53 oz (50–100 g) of clay into the cone helps to stabilize the rocket by moving the center of mass farther from the center of pressure.

You can explore what relative amounts of air and water propel the rocket better, or make design adjustments to the shape of the fins or nose cone, adding weight or surface area to see how it affects the launch and flight. Observing the flight of various lengths and weights of rockets will add to the inquiry experience.

1. If you make multiple rockets with a group, have some bottles filled one-fourth, one-third and one-half full of water.
2. Pump each rocket with the same amount of air (same number of pumps). Then, launch them to see which ones go the highest or furthest.

As you change the design of your rocket to investigate the effect of an individual variable, keep track of your changes and results so you can compare and analyze them.

Ideas for extra fun!

You can conduct spectacular nighttime launches of your bottle rockets. Make the rockets visible in flight by taping a small-size chemical light stick near the nose cone of each rocket. (Light sticks are available at toy and camping stores and can be used for many flights.)

For more experiments involving rockets, information on Newton's Laws of Motion or to learn how you can participate in NASA's rocket design challenge check out the activities in http://www.nasa.gov/pdf/265386main_Adventures_In_Rocket_Science.pdf