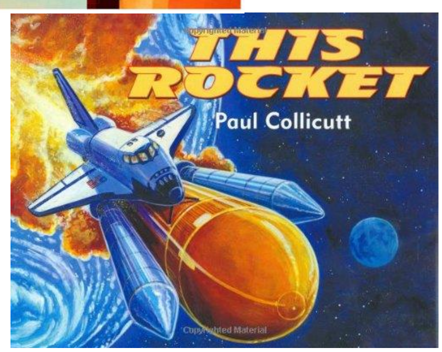
It Really IS Rocket Science!
Part 1

Humanity has looked to the stars and dreamed of traveling to the far distant points of light in our night sky throughout time. Rockets have been written about in stories by famous writers and dreamed of by small children. It is only in the latter half of the twentieth century, however, that humans have actually left the Earth and set foot on the Moon or sent robotic spacecraft throughout the solar system.

The vehicle that has made such travel possible is the rocket. Today's rockets are remarkable collections of human ingenuity that have their roots in the science and technology of the past. They are natural outgrowths of literally thousands of years of experimentation and research on rockets and rocket propulsion.

Access prior knowledge with appropriate books such as the beautifully illustrated *This Rocket* by Paul Collicutt and/or watch the fun (and funny!) animated short *Pigeon: Impossible:* by Lucas Martell to introduce the topic of rockets at https://www.youtube.com/watch?v=jEjUAnPc2VA . or http://martellanimation.com/pigeonimpossible/ And/or the extraordinary and gorgeously animated short film *Countdown*

http://vimeo.com/28760604 by Céline Desrumaux.



300 B.C.: Steam Powered Rockets

One of the first devices to successfully employ the principles essential to rocket flight was a model pigeon made of wood and suspended from the end of a pivot bar on wires. The writings of **Aulus Gellius**, a Roman, tell the story of a Greek named **Archytas** who lived in the city of Tarentum, now a part of southern Italy. (**H** who lived in Damascus (**have students locate and mark it on a world map using cardinal directions, latitude/longitude, or other grade level appropriate technique ave students locate and mark it on a world map using cardinal directions, latitude/longitude, or other grade level appropriate technique**).Somewhere around the year 300 B.C., Archytas mystified and amused the citizens of Tarentum by flying a model pigeon. Escaping steam propelled the bird, which was suspended on wires. The pigeon used the same action-reaction principle as the rocket does, which was not stated as a scientific law until the 17th century.

About three hundred years later, 600 BC, Almost two millennia before the rest of humanity entered the industrial age, the Greek inventor Hero invented the steam engine, wind-powered machinery, and theories of light that couldn't be improved for centuries. And then he invented some really crazy stuff.

Scientific geniuses have to pull off a tricky balancing act before they're even born. Great minds like Albert Einstein (helped to prove the existence of atoms and molecules, found the link between mass and energy, helped lead to the formation of nuclear bombs—which he later very much regretted, a new kind of refrigerator, and much more.) or Isaac Newton (His endless curiosity led him to tackle problems as minuscule as rug-peeing cats (legend says he invented the cat door) and as grandiose as humanity's ultimate purpose in the cosmos. He laid the foundation of our understanding of gravity and beautiful in their simplicity, Newton's three laws enable scientists to understand the movement of everything from subatomic particles to spiraling galaxies.) were born at precisely the right time for their ideas to be really revolutionary - just far enough ahead of their time to be trailblazers, but not so far ahead that people had no idea what they were talking about and wanted to lock them away. **Hero** of Alexandria, invented a rocket-like device called an **aeolipile** (which translates to the Ball of Aeolus (the Greek god of wind)). It, too, used steam as a propulsive gas.

Hero mounted a sphere on top of a water basin. A fire below the basin turned the water to steam, which traveled through pipes and into the sphere. Two L-shaped tubes on opposite sides of the sphere allowed the steam to escape and provided a thrust that caused the sphere to rotate. This steam escaped through the nozzles at high speed, generating thrust according to Newton's 2nd and 3rd laws of motion, causing the sphere to rotate on its axis.


Hero Engine

When you heat a gas like air or steam, the molecules in the gas move around faster. The faster they move, the harder they hit anything that is in the way. If we put something in the way, such as a ping-pong ball, a propeller or a pinwheel, we can make them spin (this is how turbine generators spin to create electricity). If we confine the gas in a container with a lid, we can pop the lid off (this is how the engine in a car works).

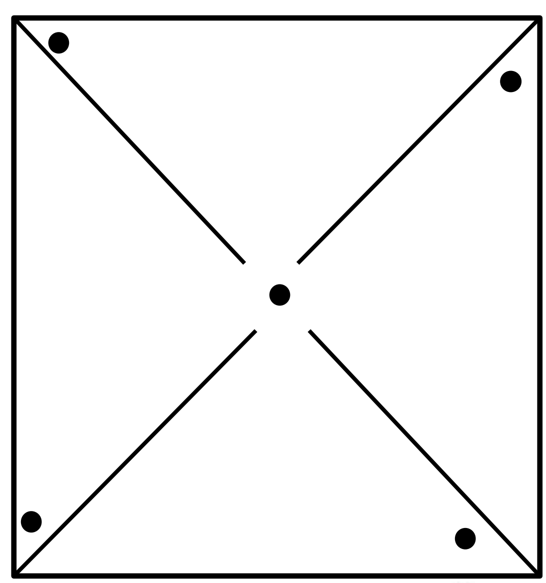
Making Pinwheels

To get a clear idea of what spin fins (and pinwheels are like) and the affect they'll have on our rockets, let's build some!

Materials:

- Lightweight paper (Tip: double-sided paper designs are fun for pinwheels)
- Scissors
- Tacks
- Pencils or straws

To get started making their own pinwheel, have students measure and cut a 4-inch x 4-inch square out of a piece of paper.

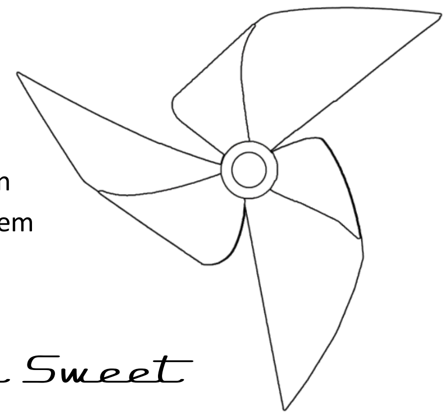


To make their pattern: Draw diagonal lines across their square to join up the corners. Then, mark the center of the square with a dot, and draw an additional dot at each of the corners. (Refer to the picture for an example)

Have students use a pair of scissors to cut along the diagonal lines. Then, use a hole punch or pin to punch a hole through each of their dots.

Line the dots on the outer edge of your pinwheel up with the dot in the center. Push a tack through the dots to hold everything together. Then, push the pin into the side of a pencil eraser or straw. Your pinwheel is now ready to use! Have students test their pinwheel. What effect do they think fins like those on a pinwheel might have on their rockets? Can they think of any other shape for the fins? Have them test their ideas.

Students can also experiment with motion by drawing large (1-inch squares around the pinwheel) and see what shapes they get when the wheel turns. Students can also experiment with color. Have them draw red stars alternating with blue stars in a line all the way around the wheel. See what colors they get when the wheel turns.



Set up a fan and put it on the lowest setting. Have the students hold their pinwheels in front of it and observe. Turn up the fan and ask the students to observe. Did the pin wheels blow faster? Slower? What can you conclude from this? You can also blow on the pinwheels or take them outside to test the wind.

Pop, Pop, Fizz Fizz…Oh, What a Sweet Rocket It Is!

 How to fuel a film canister rocket with that famous bubbling tablet -fThis concept is easy and fun to demonstrate with a film canister, an Alka-Seltzer tablet, and some water. Warning: It's impossible to do this activity just once. It is addicting and habit-forming. Proceed at your own risk!

Materials

- Film canister with a snap-on lid. Look for a clear film canister, if possible. (Fuji brand works best)
- Soda
- Alka-Seltzer tablets
- Paper towels for cleanup- or do it outside! (you already know that this one is going to be good!)
- Water
- Watch or timer
- Notebook
- Adult helper
- Safety glasses
- Option: Cardboard paper towel roll

- Option: duct tape

EXPERIMENT

IMPORTANT: This experiment requires you to wear protective safety glasses.

Pre-Flight Testing

Put on those safety glasses.

Fill the film canister three-fourths full with soda. To avoid a sticky mess, seltzer water can be used, which is simply carbonated, sugarless water.

Quickly seal the canister with the lid and shake the thunder out of the canister! Be careful to aim it away from your eyes. If you're lucky, the lid will pop off and fly into the air at warp speed.

What are you waiting for? Do it again!

The Amazing Alka-Seltzer Rocket

Put on your safety glasses.

Divide an Alka-Seltzer tablet into four equal pieces.

Fill the film canister one-half full with water.

Get ready to time the reaction of Alka-Seltzer and water. Place one of the pieces of Alka-Seltzer tablet in the film canister. What happens?

Time the reaction and write down the time. How long does the chemical reaction last? In other words, how long does the liquid keep bubbling? Why do you think the liquid stops bubbling? Empty the liquid in the film canister into the trash can.

Repeat the experiment, but this time place the lid on the container right after you drop in the piece of Alka-Seltzer. Remember to start timing the reaction as soon as you drop the tablet into the water. Stand back! If you're lucky, the lid will pop off and fly into the air at warp speed! Write down your observations.

If you really want to see the rocket fly, start by sealing the end of the cardboard tube with several pieces of duct tape or use a plastic tube with one end sealed. Divide the Alka-Seltzer into four equal pieces. Fill the film canister one-half full with water. Place one of the pieces of Alka-Seltzer tablet in the film canister and quickly snap the lid on the container. Turn the film canister upside down and slide it (lid first) into the tube. Point the open end of the tube AWAY from yourself and others and wait for the pop. Instead of the lid flying off, the bottom of the film canister shoots out of the tube and flies across the room.

If you're really creative, you can use construction paper to turn the bottom part of the film canister into a rocket. Wrap some paper around the canister, add some fins, top the whole thing off with a nose cone, and you've got an Alka-Seltzer powered rocket.

HOW DOES IT WORK?

The first part of this experiment is just a variation of the classic Alka-Seltzer film canister rocket. The same principle is at work here. In both cases, carbon dioxide gas builds up so much pressure the lid is forcibly launched. With an Alka-Seltzer tablet, the CO2 is produced as a result of a chemical reaction. With the soda, the CO2 is produced as a result of vigorous shaking. This provides a good contrast between a physical and chemical change.

The fizzing you see when you drop an Alka-Seltzer tablet in water is the same sort of fizzing that you see when you mix baking soda and vinegar. The acid mixes with the sodium bicarbonate (baking soda) to produce bubbles of carbon dioxide gas. If you look at the ingredients of Alka-Seltzer, you will find that it contains citric acid and sodium bicarbonate (baking soda). When you drop the tablet in water, the acid and the baking soda react to produce carbon dioxide gas. The gas keeps building up (the molecules push and push on each side) until finally the top (the weakest part) pops off. The lid of the canister is the path of least resistance for the gas pressure building up inside, so it pops off instead of the stronger sides or bottom of the canister bursting open.

We can thank Sir Isaac Newton for what happens next. When the build up of carbon dioxide gas is too great and the lid pops off, Newton's Third Law explains why the film canister flies across the room: for every action there is an equal and opposite reaction. The lid goes one way and the film canister shoots out of the tube in the opposite direction.

> **Thinking like a Hero**
>
> Launching Alka-Seltzer rockets is tons of fun, don't you think? So how can we make this simple and engaging activity even deeper & use the scientific method? The trick is to change a variable, create a new experiment, and then compare the results.
>
> Repeat the experiment using another of the pieces of Alka-Seltzer, but this time change the amount of water they put in the film canister.
>
> Once you've mastered the film canister rocket technique described above, it's time to measure how far the film canister rocket flies across the room. After each trial, write down the amount of water you used in the film canister (the variable), the size of the piece of Alka-Seltzer (this should not change because it is your control), and the distance the canister traveled. What amount of water mixed with a quarter piece of Alka-Seltzer produces the best rocket fuel?
>
> After you've determined the best amount of water to use, try changing the temperature of the water. How does temperature affect the speed of the reaction? Does warmer or colder water change the distance the film canister travels?

So, how does this apply to real rockets? If we let the fast moving molecules push on one side of a container, and escape through a small hole on the other side (so they are pushing on one side more than on the other) then we have a rocket or a jet, which moves in a direction away from the side with the hole. *Poke a hole or two in the lid of the film canister and try it again, what happens?*

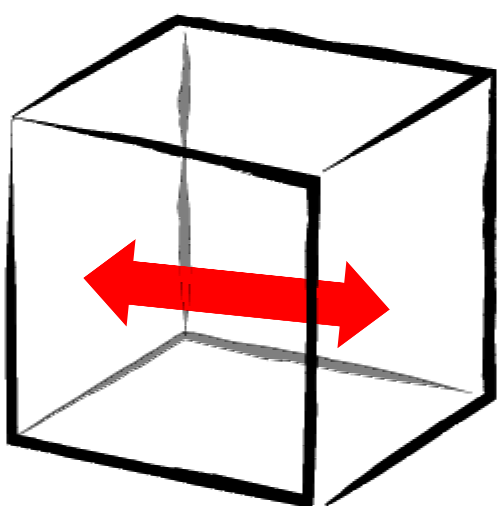
As the water heats up in Hero’s Engine, the molecules of water move faster. When the water boils, the molecules are moving too fast to stay stuck together as a liquid, and they move about freely as steam.

The fast moving water molecules are bouncing around in the can, hitting the walls of the can from all directions. Because they hit the top as often as they hit the bottom, the can neither moves up nor down.

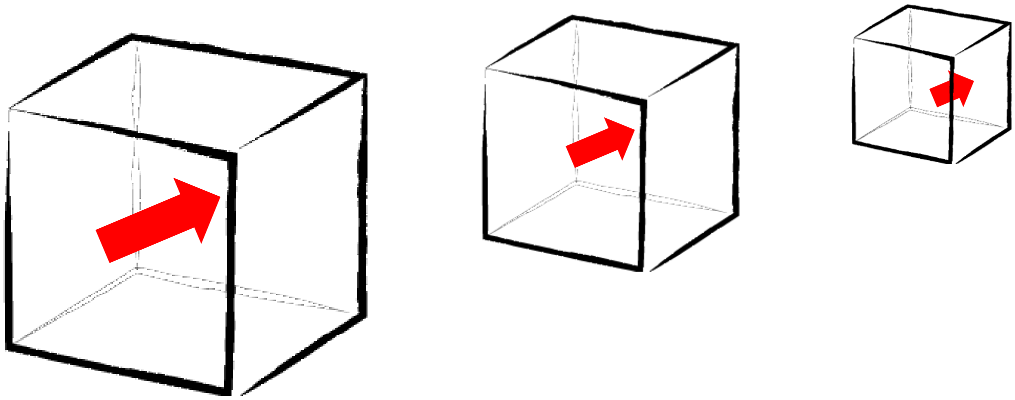
But there is one direction in which the molecules don't hit anything. This is the direction where the holes in the tubes are. Instead of hitting a wall of the can, the molecules hit nothing, and exit out into the air. The molecules in the can are pushing on all the walls the same amount, except where the holes are. Because nothing is pushing in that direction, there is nothing to hold the can back, and it moves away from the holes in the tubes.

Imagine a big box on the floor, with no top, no bottom, and one wall missing.

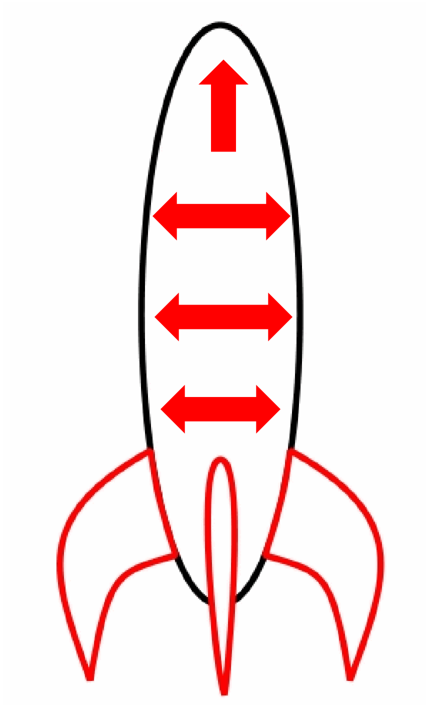
Imagine inside the box are ten little kids, all running in different directions. When a kid runs into the wall of the box, the box moves a little bit, and the kid bounces off the wall and runs in another direction. Let's call the walls the left wall, the right wall, and the front wall. The back wall is the one that is missing. Some kids will hit the left wall, and the box will move to the left. At the same time, some kids will hit the right wall, and the box will move to the right. These movements will **cancel each other out**, and the box will **stay** in the center of the room.



Each time a kid hits the front wall, the box will move towards the front. But since there is no back wall, no kids will ever hit one (a back wall) and move the box backwards and cancel out the forward hit. The result is a box that is moving across the room.



Rockets and jets move the same way the box moves. A rocket can work in outer space because it does not need to push against air or the ground. It works because the molecules inside the rocket are pushing with force in every direction, except out the back.



Our steam engine works because it has two rockets (the brass tubes) pushing the sides of the can in opposite directions, causing it to spin.

Today combustion engines, turbines, lawn sprinklers, and rockets are just some of the machines relying upon the principles shown by Hero.

Others before Hero had mentioned aeolipiles, but he was the first to actually describe in any sort of detail how to make one, and it's unclear whether his predecessors had actually been talking about the same device anyway. His inventions (like robots or automatons, pumping water hoses to fight fires, and a form of coin operated vending machine) were so far ahead of their time that many of them could be of little practical use and, in time, were forgotten. Now, over 2,000 years later, many are used in some form today!

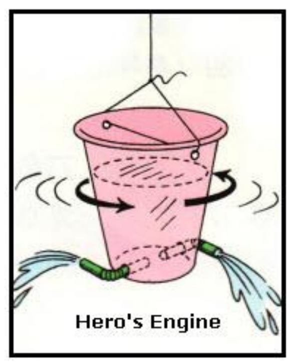
Now, Hero's aeolipile was more a interesting curio (curiosity) than an actual machine that could be used to do work, but we need to keep in mind just how far ahead of its time this machine was. And, though the aeolipile wasn't built to do useful work, it's worth remembering that there was no work it could actually do. There wasn't any real use for a steam engine in the pre-industrial world of ancient Alexandria.

Once Hero's aeolipile was forgotten, we don't know of any other person inventing a steam engine until the Ottoman inventor and all-around genius Taqi al-Din in 1577 who lived in Damascus (**have students locate and mark it on a world map using cardinal directions, latitude/longitude, or other grade level appropriate technique**- and he was considered the greatest scientist on Earth by his contemporaries. So if Taqi al-Din was the greatest mind of his time, what does it say about the man who invented basically the same thing 1,500 years before he did?

Whether it's steam engines, wind turbines, or vending machines, no inventor ever saw further into the future or innovated quite as boldly as Hero of Alexandria. If ever a scientist was well-named, Hero most definitely was.

Soda Pop Heros?

NOTE: Hero's Engine was actually powered by steam, making it the first Steam Engine. We are using water because it is much safer than steam.



Rocket Activity

Pop Can "Hero Engine"

Objective

To investigate Newton's third law of motion using thrust produced by falling water.

Description

Small student teams will construct water-propelled engines out of soft drink cans and investigate ways to increase the action-reaction thrust produced by water shooting out of holes punched in the can sides.

Materials

- 4 empty aluminum soft drink cans per team, with pull tabs intact
- Carpenter's nails of different sizes (6,12, 16D, etc.)
- String (about 50 cm)
- Water tub (large plastic storage tub, small kiddy pool, sink, etc.)
- Water
- Towels
- Rulers
- Stickers or bright permanent marker

Management

Divide your students into small groups. Set up one or more water tubs around your classroom and fill the tubs with about 20 cm of water. Have no more than one or two teams test their engines at one time. Discuss the importance of keeping the water in the tubs. When engines are filled, they should not be raised any higher than the rim of the tub. This will keep water coming out of the holes from falling on the surrounding floor. Be sure to recycle the cans at the conclusion of the activity.

> **Tip** Ask students to bring undented and washed soft drink cans from home. You will need at least three cans per student team.

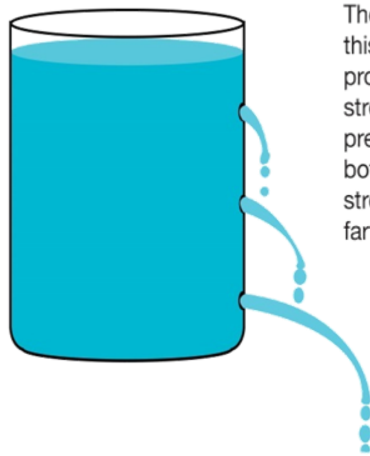
Background

This activity simulates the operation of the classic aleoliphile engine invented by Hero of Alexandria more than 2,000 years ago. (See page 2.) Hero's engine was a spinning copper sphere that was propelled by a thrust produced by a jet of steam. The engine was an early demonstration of the action-reaction principle (third law of motion) stated by Sir Isaac Newton 1,700 years later. (See page 4.) Steam, shooting out through two L-shaped holes, creates an action force that is accompanied by an equal reaction force in the opposite direction.

Hero's invention was not self-contained and therefore, not a true rocket device. Heat to generate the steam had to be applied externally. Rockets are completely self-contained.

In this activity, a Hero engine-like device is created by the students. Holes are punched in the side of a soft drink can. The holes are angled pinwheel fashion. A string, tied to the pull tab, supports the can and permits it to rotate. The can is immersed in water and pulled out. Gravity draws the water through the angled holes, and streams shoot out in either a clockwise or counterclockwise direction. The streams produce an action force that is accompanied by a reaction force. The can spins in the opposite direction.

There are many potential variables with the Pop Can Hero engine. Hole size, hole angle, number of holes, and the placement of the hole above the base of the can all affect the thrust produced. The most significant of these variables is the hole placement. The greatest thrust occurs when the holes are punched just above the bottom of the can. This is a gravity effect. The strength of the water stream (thrust) is based on the pressure. Water pressure in a container is the greatest at the bottom. The pressure at the top of the water in the container is zero (ignoring air pressure in this example). Water dribbles out of a hole near the top of the column. The water stream gets stronger the closer the hole is to the container bottom. Thrust stops when water drains out to the level of the holes. Holes at the bottom of the container produce thrust for a longer time. However, the magnitude of the thrust diminishes as the water column lowers (pressure drops with column height).



The three holes in this container each produce a water stream. Greater pressure at the bottom makes the stream shoot out farther.

The effects of the other variables are many. For example, more holes means more water streams out of the can, but the water drains from the can more quickly. Large holes drain water more quickly than small holes. Holes angled in different directions counteract each other. Holes that are not angled produce water streams that leave the can perpendicular and no rotation occurs. (The object is to have students discover the effects of the different variables themselves.)

Procedure Making the Pop Can "Hero Engine"

1. Divide your students into small teams of two or three members.
2. Demonstrate the procedure for punching holes in the cans. The idea is to punch the hole without crushing the can sides. Place the nail point near the bottom rim of the can. Apply pressure with the nail, turning it, if necessary, to make the hole.
3. When the hole is punched, push the nail head to the right or to the left. This will angle the hole so that water will stream out on a

tangent to produce thrust.

4. Rotate the can 1/4 turn and punch a second hole. Again angle the hole (in the same direction as before).
5. Repeat the procedure two more times to make four holes in total. (Cans may have different numbers of holes.)
6. Tie a string to the pop tab.
7. Place a sticker or a dot with a permanent marker near the top of the can. (The sticker or dot helps students count the rotations.)
8. Immerse the can in the tub of water.
9. When the can is full of water, lift it out by the string and observe the rotational motion.

Procedure Student Team Experiment

1. Provide each team with copies of the "Pop Can Hero Engine" experiment sheet.
2. Review the instructions on the page and discuss the objective. ("Design an experiment to find a way to increase the number of rotations the Pop Can Hero Engine makes.")
3. Make a list of student ideas for variables to test (hole size, number of holes, etc.). Discuss the importance of changing only one thing at a time. The first Hero engine they create will serve as the baseline experiment. The second and third engines will vary just one thing (e.g., Can 1 - medium size holes, Can 2 - smaller holes, Can 3 - larger holes)

5\. Discuss ideas for keeping track of the number of rotations the cans make. (Place a large bright mark on one side, etc.)

4\. Give teams time to pick their experiment, devise their hypothesis, and write the procedures they will follow on their experiment page.

5\. Distribute the materials to the teams and have them begin their investigation.

Discussion

- *What provides the force that causes the cans to rotate?*
  Actually, there are a combination of factors that contribute to the force that causes the cans to rotate. The most important is the force of gravity. It attracts the water

Tip Make sure the nails used for punching holes have good points on them. They do not have to be needle sharp, just not blunt.

in the can and causes it to stream out the holes. The shape of the hole directs the water streams. The diameter of the hole determines how fast the water streams out, etc.

- *Which of Newton's laws of motion explains why the can rotates in the opposite direction from the direction of the water streams?*
  Newton's third law of motion
- *Based on the results of the individual team experiments, what could you do to maximize the number of rotations of the Pop Can Hero Engines?*
  Individual answers: combine best hole size with the right number of holes, best placement, etc.

Assessment

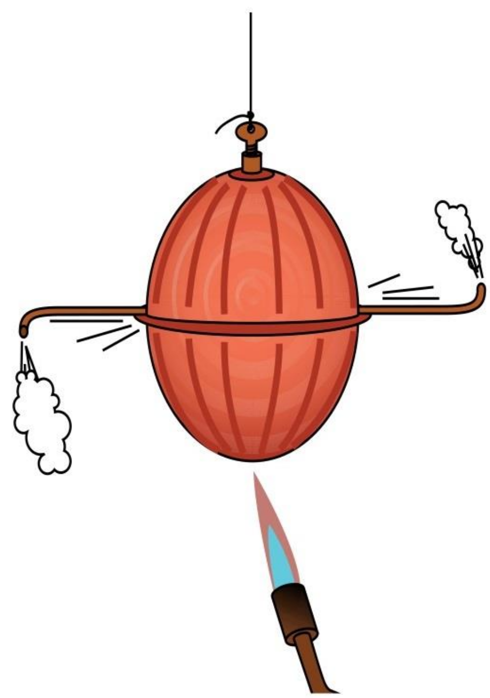
- Ask teams to state their experiment hypotheses, explain their procedures, and present their results. Make a list of the different ways one can increase the number of rotations the Hero engine makes.
- Have teams submit their completed data sheet with their written conclusion based on their results.

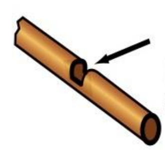
Extensions

- Construct an actual steam-powered hero engine and use it as a demonstration device. Although not difficult to construct, the engine will require some basic construction skills, principally soldering. You will need the following materials:

  - Copper toilet tank float (available from plumbing supply stores and from on-line plumbing supply stores - search "copper toilet tank floats."
  - 12" copper tube, 3/16" diameter (from hobby shops)
  - Thumbscrew to fit threads for float arm attachment
  - Metal file
  - 3/16" drill
  - solder
  - propane torch
  - pliers
  - string
  - water
  - eye protection

1. File a notch in the center of the tube. Do not file all the way through. In Instruction 3, the tube will be inserted completely through the sphere. This supports the tube while it is being soldered. (See diagram to the right.)
2. Drill 3/16th" holes through opposite sides of the float just above the "equator" joint.
3. Insert the tube through the holes. Lightly heat the place where the tubes contact the sphere. Touch solder to the contact point to seal the tube to the float.
4. Apply heat to soften the opposite ends of the tube until they bend easily. Using pliers to grasp the ends, bend the tube ends into an L shape. Be careful not to overheat or bend too forcefully, or the tube may flatten on the bend.
5. Drill through the center of the threads for the attachment point for the float arm. This will open a water-filling hole into the float.
6. Drill a hole through the flat side of the thumb screw to permit tying of the string.
7. Pour about 30 milliliters of water (about 1 tablespoon) into the float through the filling hole.
8. Thread the thumbscrew into the hole and attach the string.
9. Suspend the engine from above and gently heat the bottom of the engine with a torch. Be sure to wear eye protection. When the water boils, steam will be produced that will jet out of the two nozzles and propel the engine.





Filing produces an opening in the tube through which the steam can pass.

Tip Before using your steam Hero engine, confirm the tubes are not blocked by blowing through them. If air comes out the opposite tube, the engine is safe to use.

Pop Can Hero Engine

Team Member Names:

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Design an experiment to find a way to increase the number of rotations the Pop Can Hero Engine makes.

Write your experiment hypothesis below.

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Briefly explain your experiment procedures below.

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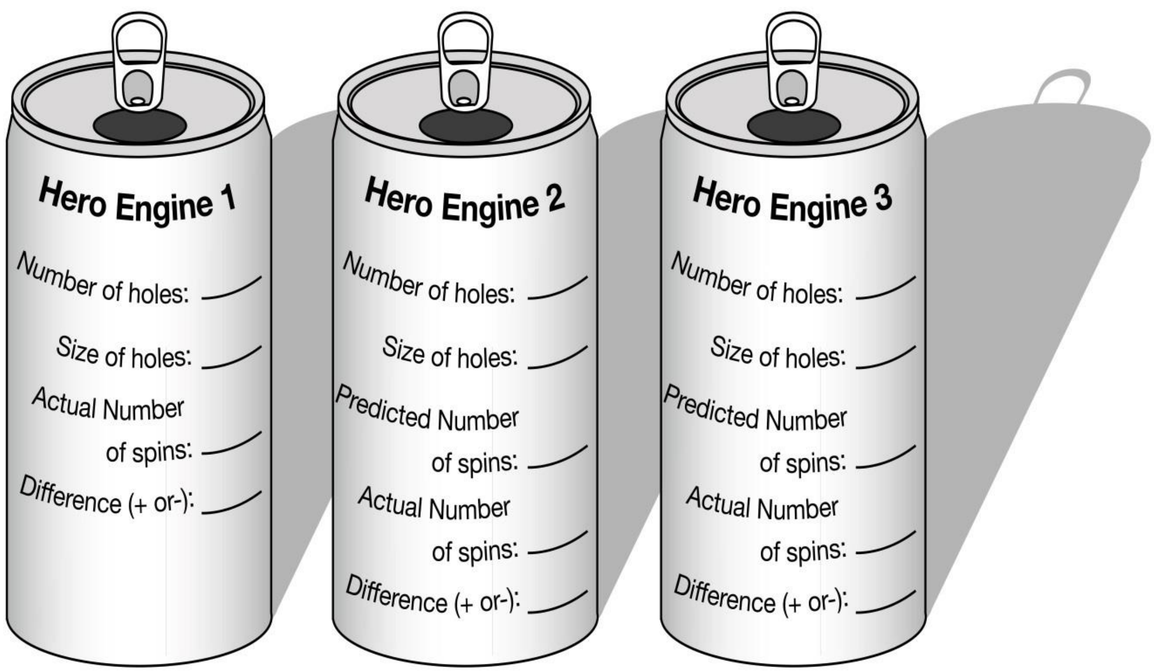

Based on your results, was your hypothesis correct? ______________

Why?

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Pop Can Hero Engine

Design and build a new Hero Engine that maximizes rotation rate.

What things did you learn from your experiment and the experiments of others for increasing the Hero engine rotation rate?

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Briefly describe your new Hero Engine (hole size, number of holes, placement, etc.)

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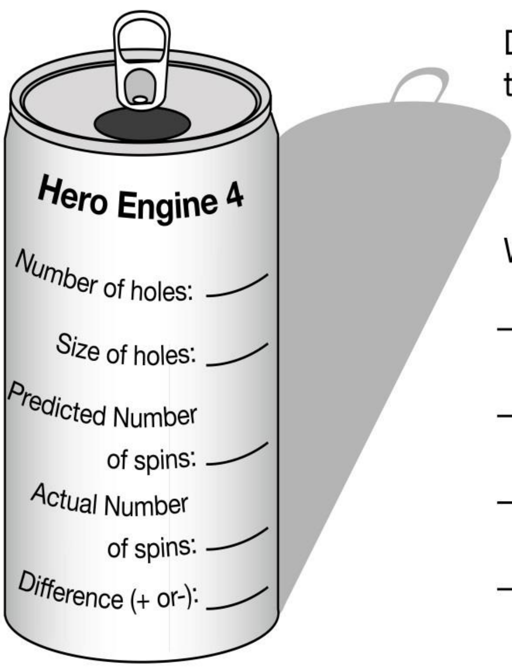

Did your new Hero engine out-perform the original engines you built? ______________

Why or why not?

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What did you learn about Newton's laws of motion by building and testing Hero engines?

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100 A.D.: First True Rockets

Just when the first true rockets appeared is unclear. Stories of early rocket-like devices appear sporadically throughout the historical records of many cultures. It is likely that the first true rocket flights were the result of accidents. In the third century B.C., the Chinese **(have students find and mark China on the map)** reportedly developed a simple form of gunpowder made from saltpeter, sulfur, and charcoal dust (by weight measure, black powder is made of seventy-five parts saltpeter finely ground, fifteen parts charcoal, and ten parts sulfur.) Then, some makers added just enough water or stale urine to make the batch bunch about like biscuit dough. The urine, substituted for water, "gives the powder more oxygen and higher performance."

Sulfur can be bought at a store these days, but it also be found in pure deposits around volcanoes, and in early times, because it was found where molten lava issued from the earth, the sulfur condensed around the rims of the volcanoes was called brimstone.

charcoal is produced from wood by heating it in a reducing atmosphere, i.e. one low in oxygen. Charcoal is almost pure carbon, but the mechanical properties of charcoal, grain size, shape, and structure, depend somewhat on the wood used to make it. Willow is the traditional wood of choice, followed by grapevine, hazelwood, elder, laurel, and pine cones.

The powder was used to create explosions during religious festivals in order to frighten away evil spirits. Bamboo tubes were filled with the powder and tossed into fires. It may be that some of the tubes failed to explode and, instead, skittered out of the flames and along the ground, propelled by hot, leaking gases.

Chinese Fire-Arrows

Early observations of such phenomena almost certainly led to more coordinated activity. The Chinese are known to have experimented with gunpowder-filled tubes of different designs, trying to create control over where the rockets went. Among other things, they attached bamboo tubes to arrows and launched them with bows, creating a device called the **fire arrow**. Fire arrows, having better range than ordinary arrows, eventually found their

What is Saltpeter?

Pure saltpeter or potassium nitrate is a white crystalline solid, usually encountered as a powder. Today most potassium nitrate is produced using chemical reaction of nitric acid and potassium salts, but bat and bird guano was an important historical natural source. (Until World War I, before people learned to reliably synthetically produce niter, urine, guano, and manure were all collected to produce gunpowder.)

Initially, saltpeter was scraped from the walls of stables, but this source quickly proved to be insufficient, so people started collecting urine and dung to access the valuable nitrates. The saltpeter supplier would send out teams of collectors who would locate promising places to dig (abandoned privies and dungheaps) by tasting the soil before digging it out and carting it off to be boiled, strained and evaporated to produce saltpeter of the required purity. It is said that throughout Europe no privy, stable, or dovecote was safe from saltpeter collectors or "petermen". That's why caves in Peru and islands in the Pacific full of a seemingly endless supply of bat or bird guano were so popular for trade and profit.! (The first American overseas territories--59 islands--were uninhabited islands covered in guano.)

Potassium nitrate was isolated from guano by soaking it in water, filtering it, and harvesting the pure crystals that grow. It may be produced in a similar manner from urine or manure. Even human has been used. People were paid to collect it from outhouse owners (keeping those outhouses clean), harvested it, stored it, and collected the saltpeter later.

Today saltpeter is a common food preservative and additive, fertilizer, and oxidizer for fireworks and rockets. It is one of the principle ingredients in gunpowder. Potassium nitrate is used to treat asthma and in topical formulations for sensitive teeth. It was once a popular medication for lowering blood pressure. Saltpeter is a component of condensed aerosol fire suppression systems, salt bridges in electrochemistry, heat treatment of metals, and for thermal storage in power generators.

applications in battle. The Chinese also discovered that gunpowder tubes could be launched by simply igniting the powder and releasing the tube. The bow was not essential to getting the fire arrow aloft! Thus, the first true rockets were born.

Control systems for rockets are intended to keep a rocket stable in flight and to steer it. Small rockets usually require only a stabilizing control system. Large rockets, such as the ones that launch satellites into orbit, require a system that not only stabilizes the rocket, but also enable it to change course while in flight.

Controls on rockets can either be active or passive. Passive controls are fixed devices that keep rockets stabilized by their very presence on the rocket's exterior. Active controls can be moved while the rocket is in flight to stabilize and steer the craft.

The simplest of all passive controls is a stick. The Chinese fire-arrows were simple rockets mounted on the ends of sticks. The stick kept the center of pressure behind the center of mass. In spite of this, fire-arrows were notoriously inaccurate. Before the center of pressure could take effect, air had to be flowing past the rocket. While still on the ground and immobile, the arrow might lurch and fire the wrong way.

Years later, the accuracy of fire-arrows was improved considerably by mounting them in a trough aimed in the proper direction. The trough guided the arrow in the right direction until it was moving fast enough to be stable on its own.

The first recorded use of fire arrows occurred in 1045 A.D. An official named Tseng Kung-Liang wrote a complete account of the Chinese use of gunpowder called ***The Wu-ching Tsung-yao*** (***Complete Compendium of Military Classics***).

By the 13th century the secret of gunpowder had spread to Islamic Asia **(have students find and mark Southeast Asia on the map)** where it was used against Europeans **(have students find and mark Europe on the map)**. Ever since, gunpowder has been a staple of the military and political establishments.


Chinese soldier launches fire-arrow

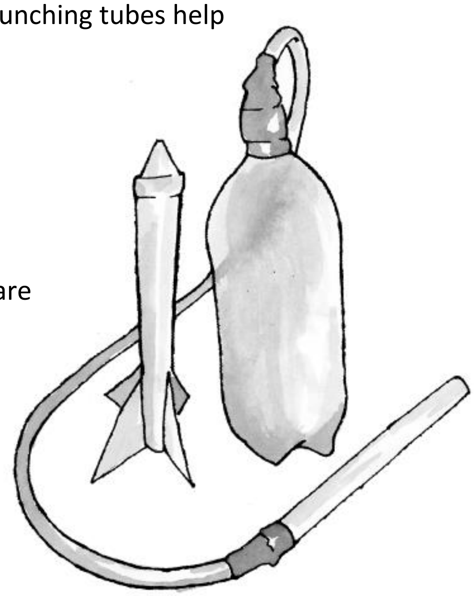
13th Through 16th Centuries: Rockets as Weapons

Rockets were first used as actual weapons in the battle of Kai-fung-fu in 1232 A.D. The Chinese attempted to repel Mongol invaders (**(have students find and mark Mongolia on the map)** with barrages of fire arrows and, possibly, gunpowder-launched grenades. The fire-arrows were a simple form of a solid-propellant rocket. A tube, capped at one end, contained gunpowder. The other end was left open (why do you think they did that?) and the tube was attached to a long stick. When the powder was ignited, the rapid burning of the powder produced fire, smoke, and gas that escaped through the open end and produced a thrust. The stick acted as a simple guidance system that kept the rocket headed in one general direction as it flew through the air. It is not clear how effective these arrows of flying fire were. But one source reported that one grenade could incinerate a 2,000 square foot area.

Let's test it and see if a stick or launching guide really works with Bottle Blast Off!

Bottle Blast-Off

In this activity from The Exploratorium (http://www.exploratorium.edu/afterschool/activities/docs/bottleblastoff.pdf), students get to make a rocket launcher and a rocket, and investigate how rockets fly and launching tubes help guide them.



What do I need?

For the launcher:

- 2-liter plastic bottle
- 1/2-inch inner diameter flexible vinyl tubing (available at a hardware store); about 2 feet (60 cm) long
- hair dryer (optional—to straighten out the vinyl tubing if it's too curled to work with)
- tape (vinyl tape, masking tape, duct tape, electrical tape)
- 1/2-inch inner diameter PVC pipe (also available at the hardware store); 1 foot (30 cm) long

For the rocket:

- 8 1/2" x 11" sheet of construction paper or card stock
- transparent tape
- scissors
- index card
- ruler
- pencil

What Do I Do?

Building the launcher

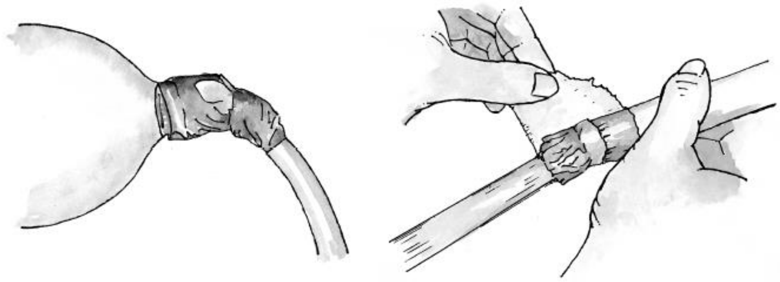
1. Remove the cap from bottle.

2. Cut about two feet of vinyl tubing.

(If the tubing is tightly curled, you can heat it with a hair dryer and straighten it out.)

3. Put the vinyl tubing into the neck of the bottle and create a tight seal with the tape so air can't escape. Use a generous amount of tape.

4. Put the other end of the vinyl tubing just up against the PVC pipe and, using tape, make an airtight seal.



Building the Rocket

1. Make a tube by wrapping the paper the long way loosely around the PVC pipe. Then slide the tube off, making sure not to tighten it.

2. Using transparent tape, tape the tube along the seam.

3. Make a point at the top of the rocket. First flatten the tube at one end. Then, using your scissors, cut the flattened part into a point. You could also cut it just shy of a sharp point.

4. Make a tight seal on the point with transparent tape to prevent air from escaping.

You can use the rocket as is, or add fins to the rocket.

The weight of the rocket is a critical factor in performance and range. Remember the fire-arrow? The stick added too much dead weight to the rocket, and therefore limited its range considerably.

An important improvement in rocketry came with the replacement of sticks by clusters of lightweight fins mounted around the lower end near the nozzle. Fins could be made out of lightweight materials and be streamlined in shape. They gave rockets a dart-like appearance. The large surface area of the fins easily kept the center of pressure behind the center of mass. Some experimenters even bent the lower tips of the fins in a pinwheel fashion to promote rapid spinning in flight. With these "spin fins," rockets become much more stable in flight. But this design also produces more drag and limits the rocket's range.

Did You Know?

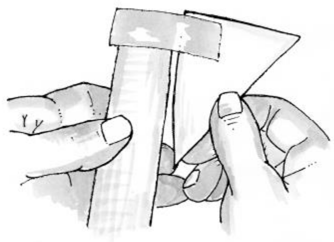
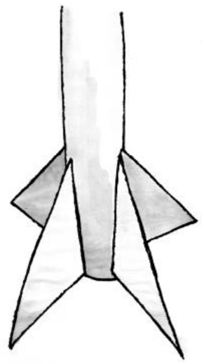
In space, only by spinning the rocket or by using active controls involving the engine exhaust can the rocket be stabilized or have its direction changed. Without air, fins have nothing to work upon. (Science fiction movies showing rockets in space with wings and fins are long on fiction and short on science.)

And Now…Back to Our Rockets: To add four fins

1. Take a 3 x 5 index card, fold it in half, open it at the fold, then cut it along the fold into two pieces.

2. Using the ruler, draw a diagonal line from corner to corner on each piece of the card, then cut along those lines to form four fins.

3. Tape the fins to the bottom of the rocket so that the distances between them are equal. Put a fin flat against the rocket and tape it, then bend it flat to the other side and tape it again.

Flying the Rocket

1. Slide your rocket about halfway down the PVC pipe.

2. Put the bottle on the ground.

3. Hold the PVC pipe with the rocket on it and point it upwards or away from people to guide its direction

4. Step on the bottle and watch your rocket fly!

Note: If the bottle flattens out, curve your hand around the top of the PVC pipe and, resting your lips against your hand (not the pipe) blow into it. This should re-inflate your bottle so you can blast off again. It's a good idea to have some extra bottles on hand, though, in case that doesn't work.

Stomp Rockets!

(Variation and instructions created by the very inventive "seamster")

http://www.instructables.com/id/Paper-Stomp-Rockets-Easy-and-Fun/.

There are many versions of paper stomp rockets and launchers out there. They all work essentially the same way: air is forced through a PVC contraption which launches a lightweight paper rocket up into the air. This particular launcher design is a combination of a handful of ideas and successful twists on the classic.

Step 1: Materials

This launcher design produces no waste, and should cost around $10. For one launcher, you will need:

- One 10-foot length of 1/2-inch PVC
- One 1/2" 90-degree elbow (all fittings are of the slip variety)
- One 1/2" four-way fitting

- Two 1/2" end caps
- One 1" coupling
- One 1" by 1/2" bushing
- One 2-liter soda bottle cap
- Lots of 2-liter soda bottles

Other supplies you will need for this project:

- PVC cement
- Hot glue
- White glue
- Cotton balls
- Tape
- Sheets of 8 1/2" by 11" paper
- Lots of copies of the PDF rocket template

Step 2: Cut the PVC

From the 10-foot length of PVC, cut (or have the hardware store cut) the following pieces:

- One 40" piece
- One 18" piece
- One 5" piece
- Two 12" pieces
- Three 11" pieces

Of all the pieces to be cut, accuracy is the most crucial on the three 11-inch pieces. These will be made into forming tubes which will be used to help make the actual rockets. Construction of the forming tubes is covered in step 5.

Step 3: Build the basic launcher assembly

The photos here, or at the link (http://www.instructables.com/id/Paper-Stomp-Rockets-Easy-and-Fun/), should provide enough detail on how to construct the basic launcher assembly.

1. Use PVC cement to put it all together (available at hardware stores.)
2. The 12-inch pieces are the side supports that make the base.

3. The 18-inch piece is the riser from which the rockets will launch. Use sand paper to quickly knock off the sharp edge of the launch-end of the 18-inch piece of PVC.
4. The 1" coupling and the 1" by 1/2" bushing go together to make the bottle end of the launcher.


1/2" CRESLINE

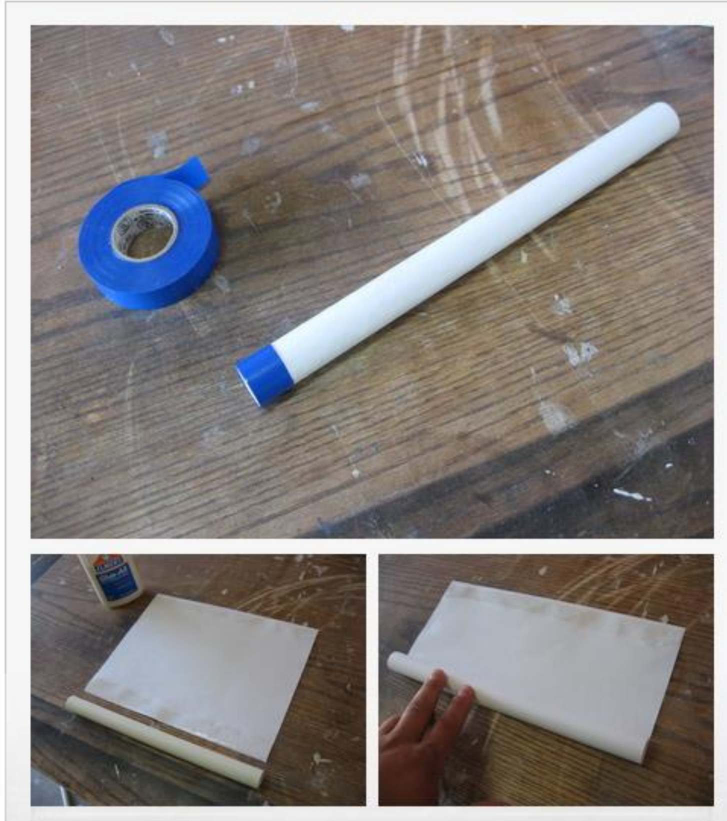
Step 4: Make the bottle-end of the launcher

2-liter bottles make great bladders for stomp rocket launchers because they're readily available and they're pretty durable. This set-up is especially nice because it allows you to quickly replace bottles when they've been completely worn out or cracked.

Begin by drilling or hammering (with a nail) a hole through a 2-liter bottle cap. This is easiest to do while the cap is screwed onto an old bottle.

Hot glue is preferred to glue the bottle cap into the opening of the 1" coupling. Hot glue is quick, fills the gap between the bottle cap and coupling nicely, and it's only semi-permanent.
When the bottle cap itself begins to wear out and the threads are stripped, you can just grab it with a pair of pliers and yank it out to replace it with a new one.

Step 5: Make rocket forming tubes

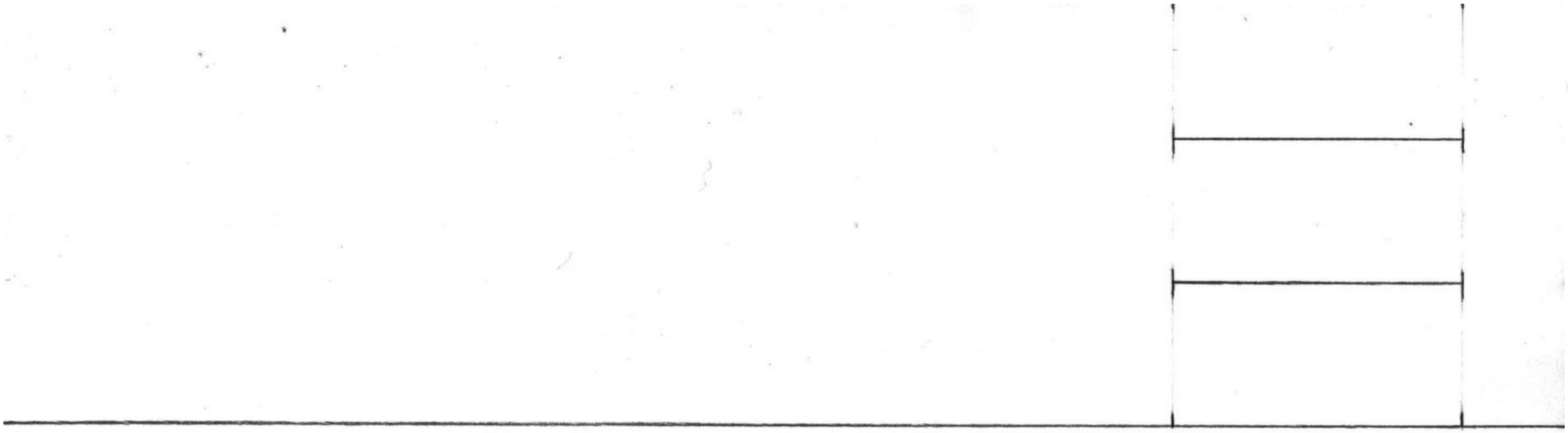


The three 11-inch pieces of PVC will be used to make three separate rocket forming tubes. These will help you make perfect rockets every time. It's nice to have a few on hand so more than one student can be working on a rocket at the same time.
The forming tubes need to be slightly bigger than the tube that the rockets get launched from. This is accomplished by gluing a sheet of 8 1/2" by 11" paper around each forming tube. Use white glue and glue each sheet directly to the tube, and then to itself after rolling it on tight.
A piece of tape (ex. electrical tape) was wrapped around one end of each paper-covered tube. This is to aid in the construction of the rocket, as detailed in the next step.

Step 6: Make Some Rockets

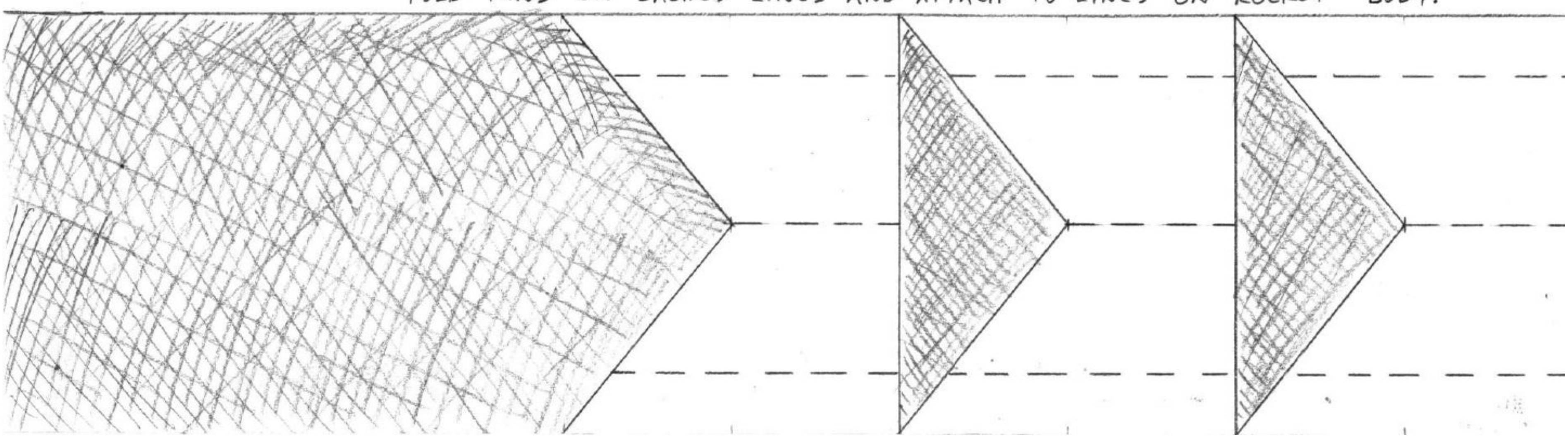
Print out and make plenty of copies of the included rocket template by seamster
There are basic building instructions on the rocket template. Decorate and cut out areas as directed.
Roll the rocket body section onto forming tube, with the bottom of rocket (where the fin placement lines are located) just above the tape at the end of the forming tube. This creates an open space at the top of the tube, where the cotton balls will go.
Have students tape the body tube together, but NOT to the forming tube. Fold the fins and tape them in place on the fin placement lines.
Place two cotton balls into the open area at the top of the paper tube, and cover with a couple of pieces of tape. Remove rocket from forming tube.

PDF at http://www.instructables.com/id/Paper-Stomp-Rockets-Easy-and-Fun/step6/Make-some-rockets/



DECORATE AREA ON OTHER SIDE OF THIS LINE.
DO NOT CUT!

DECORATE FINS AND CUT OUT ON SOLID LINES.
DISCARD SHADED AREAS.
FOLD FINS ON DASHED LINES AND ATTACH TO LINES ON ROCKET BODY.



Step 7: *LAUNCH!*

Before you launch your rockets, be sure to explain some safety rules to everyone involved so nobody gets shot in the eye.

After each launch, students will have to refill the bottle with air. Tell the kids to hold the top of the launch tube with their hand and blow through their hand to fill up the bottle. This way germ-passing is somewhat minimized.

Paper Stomp Jets!

Hey, if students like paper stomp rockets maybe they should test out a fun variable, Paper Stomp Jets and compare and contrast them to how the rockets fly and to test out changes that wings make and changing the angle of the launch tube! (Also created by seamster, http://www.instructables.com/id/Paper-Stomp-Jets/)
The launch assembly is exactly the same as above for the stomp rockets, except for the change to the 45-degree elbow, which is especially fun.

The launcher is made from 1/2" PVC. Each launcher will need the following fittings, along with some used 2-liter bottles:

- One 1/2" four-way fitting (all fittings are of the slip variety)
- Two 1/2" end caps
- One 1" coupling
- One 1" by 1/2" bushing
- One 1/2" **45-degree elbow**

The assembly **is exactly the same** as the steps for the stomp rockets, except for the change to the 45-degree elbow. Please see the directions above, or that instructable itself (http://www.instructables.com/id/Paper-Stomp-Rockets-Easy-and-Fun/), for additional details on building a launcher.

Step 2: Jet tube PVC form

In order to make the jet tubes, students will need a blank form. This form will allow them make jet tubes that will slip nicely over the launch tube, and will also help when finishing the nose section of the jet, as will be seen in step 4.

To make a jet form, cut (or have the hardware store cut) a piece of 1/2" PVC exactly 11 inches. Take a regular sheet of 8.5" by 11" paper and roll it onto the tube, using white glue to glue it tightly in place, flush with the PVC on either end.

Take a 3-inch piece of electrical tape and wrap it neatly around one end of the tube, flush with the end. That's it. Tip: You might want to make a few of these if you plan on having more than one student making jets at a time.

Step 3: Roll jet tube

Students should begin making a paper jet plane by rolling an 8.5" by 11" sheet of paper tightly around the form made in the last step. Roll the paper so it is butted up against the tape, but not covering it. The paper roll should extend beyond the end of the PVC form that does not have the tape on it, leaving a small open space inside.

Then have them smear a thin bead of white glue along the edge of the roll, and glue the paper down. Quickly roll the tube back and forth on the table to roll out any air bubbles. The tube should be able to slide on and off of the form freely, and not be glued to the form. Leave it in place on the PVC form for the remainder of the steps.

Step 4: Jet tube nose

For this step students will need two cotton balls and a penny.

The cotton balls block the end of the jet tube so air can't escape when you launch their jets. The penny adds a little bit of needed weight to the nose so the jets fly better.

Have students insert the two cotton balls into the open space in their paper tube, just above where the PVC form ends. Don't insert them into the PVC. Place the penny on top of the cotton balls, and tape down the paper over the cotton balls and penny with masking tape as shown in the photos.

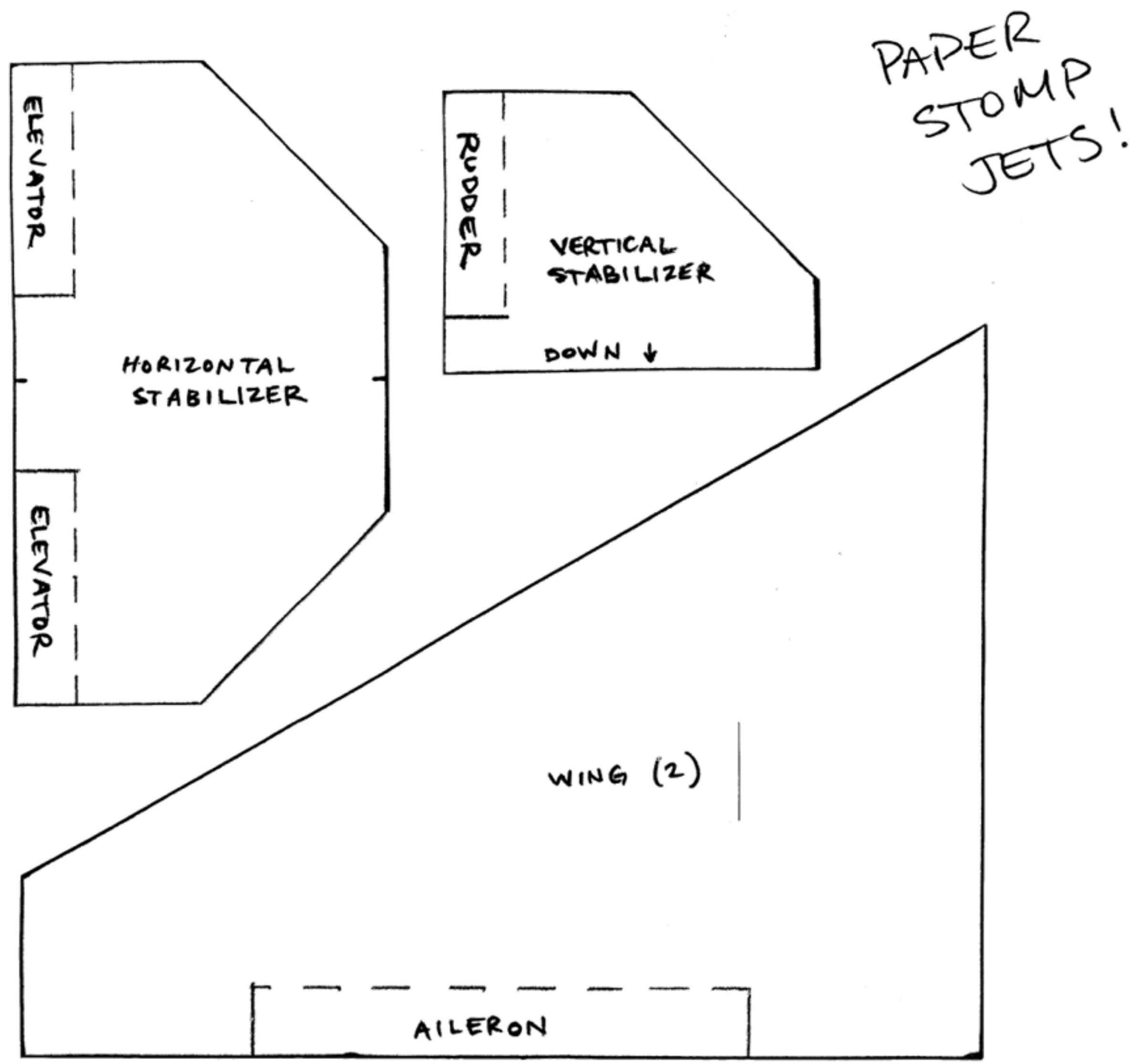
Step 5: Wings and tail pieces

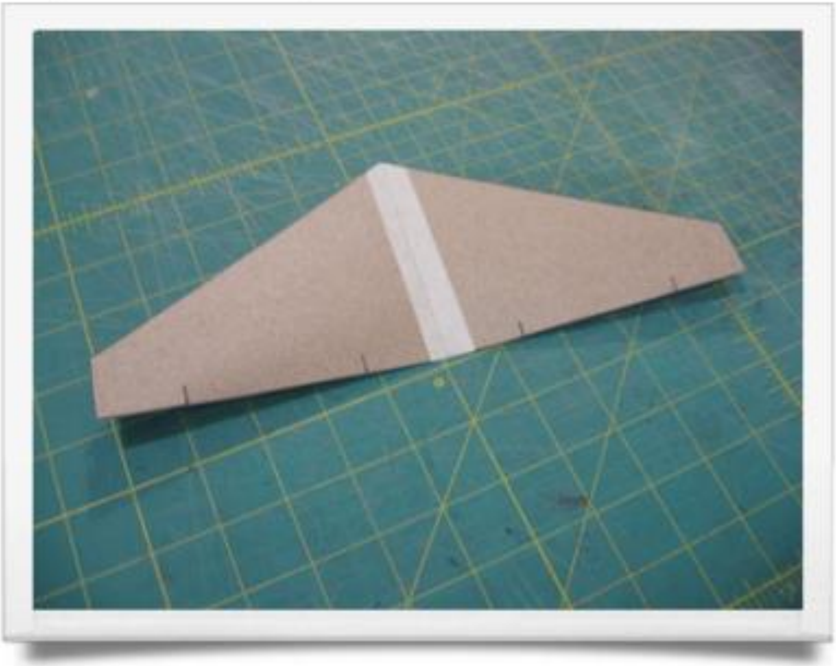
For the wings and tail section, print out the attached stomp jet template created by seamster, or print it from http://www.instructables.com/id/Paper-Stomp-Jets/step5/Wings-and-tail-pieces/

Thin cardboard, ex. from an old cereal box is perfect for making the wings and tail section of these jet planes. It's lightweight but still stiff enough to be able to bend and keep its shape for adjusting the control surfaces of the planes (ailerons, elevator, rudder).

Have students cut out the pattern pieces and trace them onto cardboard. Transfer the various marks on the patterns to their cardboard pieces, and cut them out. The solid lines are where they cut, and the dotted lines are where they fold.

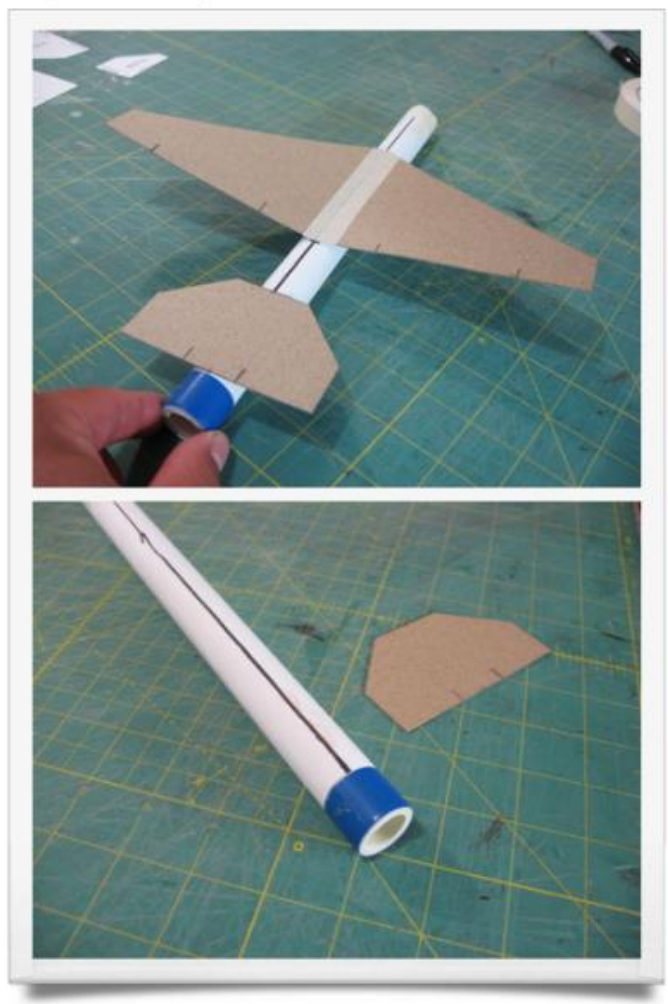
Students shouldn't worry about folding the control surfaces now. They can do this when the plane is completed, and even then they only need to be adjusted a tiny bit to really effect the movement of the planes.


PAPER STOMP JETS!
ELEVATOR
ELEVATOR
HORIZONTAL STABILIZER
RUDDER
VERTICAL STABILIZER
DOWN ↓
WING (2)
AILERON



Step 6: Assemble wings

Have students use masking tape to attach the two wing halves. If they bend them up just a bit at the taped joint, this will create a small amount of dihedral, or upward angle of the wings. This helps stabilize the jets, keeping them belly-down in flight.



Step 7: Attach wings and tail section

Use a single bead of hot glue to attach the horizontal stabilizer to the plane, flush with the back of the jet tube, just in front of the tape on the form.

Use a single bead of hot glue to attach the wings to the jet tube 1 3/4" in front of the horizontal stabilizer.

Use the line where the paper roll ends to help students line up the stabilizer and wings as you glue them on. (In the photos, seamster traced this line with a pen to help it show up better.)

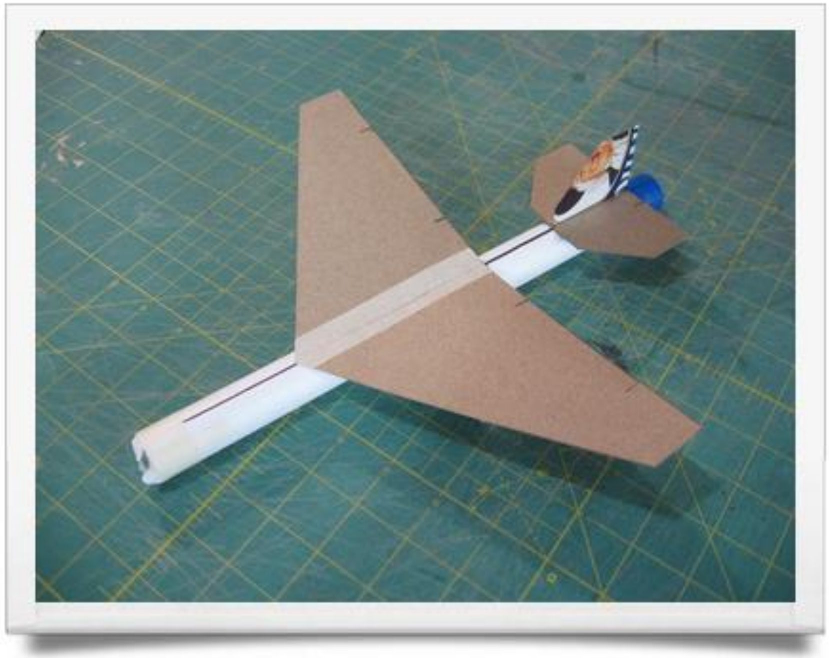
The vertical stabilizer is glued in place, also with just a single bead of hot glue.

Alright, that's it! The last step is just a few words on how to fly these amazing jets from seamster.

Step 8: Final Thoughts

“Here's the basics of control surfaces, just so you know. (Pardon me if I don't state any of this completely correctly, but you'll get the idea well enough to know how to manipulate your little jet plane.)

The ailerons generally move in opposite directions, one up, the other down, which turns the plane left or right. The elevators always move together, up or down, to make the plane go up or down. The rudder swings the tail of the plane left or right. I wouldn't mess with the rudder on this, because it really doesn't do much to these as far as I can tell.



To begin, try to get your plane to do a straight, level glide when launched by hand. To do this, I suggest keeping the ailerons in the neutral position and the elevator tabs bent up equally about 1/8".

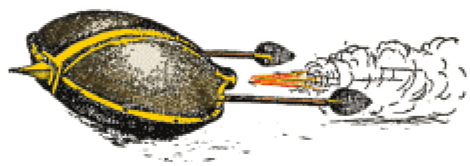
Once you have a decent glide, experiment with your plane to see what you can get it to do. Wild loops and barrel rolls are easy to make happen, but slow sweeping rolls turns and steady glides are much more tricky! We found that throwing the planes was almost as much fun as launching them.

This was a fun little project, and I suspect my kids and I will be building and flying these for a while."- seamster

Tip: Can students make the design more efficient or stable? Let's hypothesize and then test! Ex. As the rudder "doesn't do much" students could also simply make the rear wing slightly larger and put about a 30 degree bend in it. This would still give their jet a certain amount of directional stability and keep them from stressing about trying to tweak the rudder about.

Mongols Rock It!

Following the battle of Kai-Keng, the Mongols produced rockets of their own. During the 13th to the 15th centuries, the Mongols used rockets in their attacks on Japan and Baghdad **(have students find and mark these location on the map**) and may have been responsible for the spread of rockets to Europe. In England, **(have students find and mark it on the map)** a monk named **Roger Bacon** worked on improved forms of gunpowder that greatly increased the range of rockets. In France **(have students find and mark it on the map)**, **Jean Froissart** found that more accurate flights could be achieved by launching rockets through tubes. Froissart's idea was the forerunner of the modern bazooka. **Joanes de Fontana** of Italy **(have students find and mark it on the map)** designed a surface-running rocket-powered torpedo for setting enemy ships on fire.


Surface-Running Torpedo

By the 16th century rockets fell into a time of relative disuse as weapons of war, though they were still used extensively in fireworks displays. A German **(have students find and mark it on the map)** fireworks maker, **Johann Schmidlap**, invented the first "**step rocket**," a multi-staged vehicle for lifting fireworks to higher altitudes. A large rocket was ignited initially and carried one or more smaller rockets. When the large rocket burned out, the smaller rockets ignited and continued to a higher altitude before showering the sky with glowing cinders. Schmidlap's idea, known today as staging, is basic to all modern rocketry.

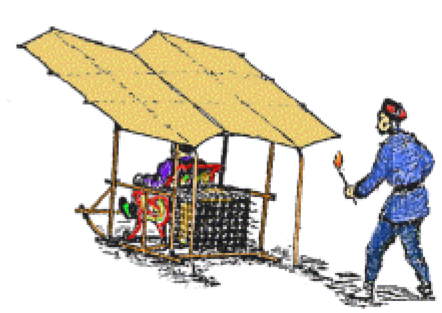
FYI

Until the 19th century (1800s), fireworks lacked a major aesthetically essential characteristic: color. Pyrotechnicians began to use a combination of potassium chlorate and various metallic salts to make brilliant colors. The salts of these metals produce the different colors: strontium burns red; copper makes blue; barium glows green; and sodium, yellow. Magnesium, aluminum, and titanium were found to give off white sparkles or a flash. Secondary colors (purple, orange, etc) are made by mixing these.

Wa-hoo Wan-hu!

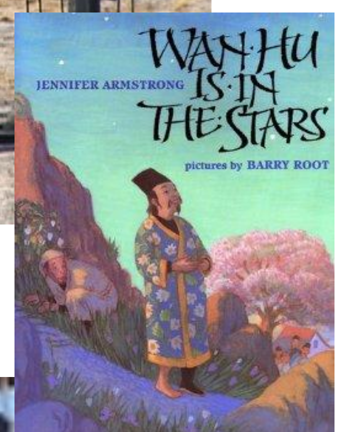
Nearly all uses of rockets up to this time were for warfare or fireworks; but there is an interesting old Chinese legend that reports the use of rockets as a means of transportation. It may be legendary or it may be true-- there is no way of telling. The story, however, is so charming that Wan-Hoo, fictional or not, has had a lunar crater named for him. With the help of many assistants, an otherwise unknown Chinese official named **Wan-Hu** assembled a rocket-powered flying chair. The chair was mounted between two wooden stakes. Attached to the chair were two large kites, and fixed to the kites were forty-seven fire-arrow rockets.

On the day of the flight, Wan-Hu sat in the chair and gave the command to light the rockets. Forty-seven assistants, each armed with torches, rushed forward to light the rockets. In a moment, there was a tremendous roar accompanied by


Legendary Chinese official Wan Hu braces himself for "liftoff"

billowing clouds of smoke. When the smoke cleared, Wan-Hu and his flying chair were gone. No one knows for sure what happened to Wan-Hu, but it is probable that the event really did take place. Now, the fact that there is a crater named after him on the far side of the moon might hint that he was successful, but even today, fire-arrows are still as apt to explode as to fly! What do students think? Trivia: Some people have claimed that the expression "WAH-HOO!" came from this event!

Compare this version of the ancient legend with the story as told in Wan Hu Is in the Stars by Jennifer Armstrong. *Oblivious to the stares and name-calling of the people in his ancient Chinese village, absent-minded poet Wan Hu embarks on a series of adventures in an attempt to satisfy his "only hope and one desire to be among the stars and learn the secret of their majesty."*



Modern Science: Busting the myth of Wan-hu: Ming Dynasty Astronaut

The Mythbusters team decided to try to recreate the Wan-hu rocket chair using the same sort of materials available to Wan-hu. They used a crash test dummy instead of a human.

For the experiment in the Mojave desert, they built two elaborate rocket chair thrones: one to be launched according to myth, one to be launched with more modern rockets that had 50 pounds of thrust each.

To reconstruct the rockets of that time, they found some 3/4" bamboo poles to build 1' rockets. The rockets were filled with homebrewed gunpowder (charcoal/sulfur/saltpeter) mimicking the historical ingredients. The bamboo was also wrapped in twine for strength. The first chair with these 'authentic' rockets pretty much reproduced the myth. There was a big explosion of smoke leaving a void where there was once Buster and throne, except the throne was blown to smithereens and Buster was a smoking heap on the ground, instead of in space (they may need to find him new skin now). The heat from the adjacent rockets was too much and the rockets exploded.

The second chair produced different results. After getting a couple feet of liftoff, the throne flipped over and the rockets proceeded to push Buster into the ground (breaking a leg). Even with the nozzles, the Chinese rockets acted more like roman candles, only reaching 5 pounds (2.3 kilograms) of thrust. Nevertheless, the team strapped test dummy Buster into the hot seat and ignited their 47 homemade rockets.

As suspected, the busted myth went down in a cloud of smoke, burning Buster to a crisp before the chair could barely get airborne. The team concluded that rockets cannot supply enough force to lift a rocket chair very far away from the Earth's surface. The Chinese achieved a lot of firsts, but the MythBusters' 2 failed rocket launches proved that a moon landing wasn't one of them. Or did it? What do students think?

Option: Map Markers

Place: _______________
Person: _____________
Date: _________

Place: _______________
Person: _____________
Date: _________

Place: _______________
Person: _____________
Date: _________

Place: _______________
Person: _____________
Date: _________

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Samples of Sources and Resources

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