Rockets

How to Get From Here to Out There

NGSS Standards (Core ideas related to the activity):

5-PS2.B - The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center

MS-PS1.B3 - Some chemical reactions release energy, others store energy

MS-PS2.A - For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction

MS-PS2.B - Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have a large mass

MS-PS3.C - When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the subject

ETS1.A – Defining and delimiting engineering problems

ETS1.B – Developing possible solutions

ETS1.C – Optimizing the solution

Objectives: The student will:

- Discuss the roles of Newton's laws in understanding how rockets work.
- Apply the principles of center of mass and pressure as they design a rocket to launch.
- Demonstrate that the thrust of a rocket is a force that can counteract and overcome gravitational force.

Background:

Space is considered anything over 63 miles high. It doesn't seem like it is very far, but getting there is hard work. Scientists and engineers work together to determine the most efficient **fuels** to burn, design the most powerful **motors** and **engines**, and build the most aerodynamic **rockets** to fly. In addition, all of this happens while keeping **payload** safety in the forefront.

NASA is building the next great rocket called the SLS, or Space Launch System, that will take us to the Moon, Mars and beyond. This rocket is 322 feet tall and will safely launch up to 4 astronauts at a time using both Solid Rocket Boosters and RS-25 Engines for power. This combination produces over 8 million pounds of **thrust.**

Thrust is the force that allows the rocket to overcome Earth's gravity and enter **orbit**. Part of the scientific principles that explain how thrust works are found in **Newton's 3 Laws of Motion.** Other theories of aerodynamics, such as **Bernoulli's principle,** explain why control surfaces like **fins** and **nosecones** affect the way a rocket behaves. In addition, concepts of physics, including **center of mass** and **center of pressure** must be taken into consideration to ensure rocket **stability.**

Vocabulary:

- Rocket – a vehicle whose motor or engine does not need oxygen to work – its propellants include fuel and oxidizer.
- Space – the region beyond the thickest part of Earth's atmosphere, generally defined as above 63 miles or 100KM.
- Solid Rocket Fuel – rocket fuel and oxidizer mixed, packed into a cylinder and stored in a solid form.
- Liquid Rocket Fuel – rocket fuel and oxidizer, kept separate until combustion and in a liquid state.
- Payload – things that are carried on a spacecraft
- Thrust - the forward or upward force produced by the engines of a plane or rocket.
- Orbit - The curved path that a planet, satellite, or spacecraft moves as it circles around another object.
- Newton's 1st Law - Every body continues in a state of uniform motion in a straight line unless acted upon by some external force.
- Newton's 2nd Law - Force = mass x acceleration or F = ma
- Newton's 3rd Law -To every force or action, there is always an equal and opposite reaction.
- Rocket Fin - fins are engaged to steer or direct the air flow for flight stability.
- Rocket Nosecone – leading part of the rocket designed aerodynamically to reduce drag.
- Center of Mass – center point of the rocket around which all of the weight of the rocket is balanced.
- Center of Pressure – Single point through which all of the aerodynamic forces on a rocket act.
- Stability – the ability of a rocket to fly in safe, controlled manner.

Supplies:

For Straw Launched Rockets:

- Sheet of 8.5 x 11 paper (white or colored)

- Cellophane tape
- Scissors
- Ruler
- Meter stick or tape measure
- Round pencil or dowel
- Eye protection
- Drinking straws
- Copy of the SLS paper rocket plans
- Digital Student Lab Book

For Fizzy Tablet Rockets:

- Film Canisters
- Safety goggles
- Card stock or construction paper
- Scissors
- Cellophane Tape
- Fizzy anti-acid tablets
- Water
- Paper Towels
- Digital Student Lab Book

For Paper Rockets:

- PVC pipe (1-inch diameter, 12 inches long) (need 2, one for launcher, one for template)
- Empty and rinsed 2 Liter Soda Bottle
- Bicycle tire inner tube (1-inch diameter)
- Duct tape
- Colored Paper
- Markers
- Scissors
- Cellophane Tape
- Fin and nose cone templates

Procedures:

There are three rocket options to try, each with a different focus.

Straw Launched Rockets: Stability

Stability means making sure the rocket follows a smooth path in flight. If it wobbles, the ride will be rough and extra fuel will be burned to get back on course. If it tumbles, it's time to abort the mission! An unstable rocket is dangerous.

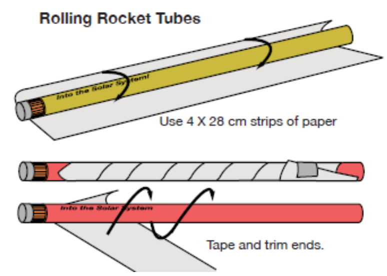
Fortunately, it is relatively easy to ensure stability when traveling through the atmosphere if two things are kept in mind. These two things are *center of mass* and *center of pressure*.

Center of mass (COM) is easy to demonstrate. It is the balance point of a rocket. Think of it like balancing a meter stick on an outstretched finger. If the stick rests horizontally, the

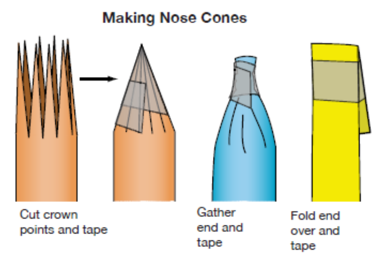
COM is directly over your finger. If the COM is to the right of your finger, the stick will tip to the right. If to the left of your finger, the stick will tip to the left.

An object, tossed into the air, rotates around its COM. Rockets also try to rotate around their COM while in flight. If this rotation is allowed to happen, the rocket becomes unstable. This is where center of pressure (COP) comes to the rescue.

COP is also a balance point. It is the balance point of the pressure exerted on the rocket surface by air molecules striking it as it flies through the air. Like COM, there is a midpoint for the air pressure on the rocket body. This is the COP. For a stable rocket, the COP is located to the rear of the rocket and the COM is to the front. To understand why the rocket is stable, let’s take a look at a couple of devices that also depend upon the placement of COM and COP.

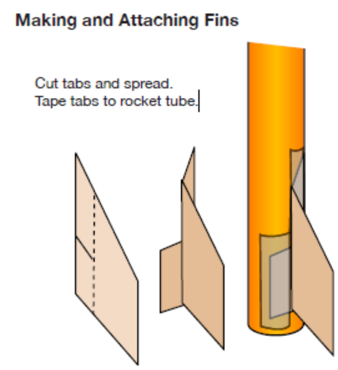


For Example: A weather vane pivots on a vertical axle (COM) when the wind blows. One end of the vane is pointed and the other end has a broad surface. When the wind blows, the broad end of the vane catches more air (more air pressure) and is blown downwind. The narrow end of the vane has less pressure exerted on it and points into the wind. One end of an arrow is long, narrow, and pointed while the other end has large feathers (or plastic fins). In flight, greater air pressure is exerted on the feathers than on the narrow end. This keeps the arrow from tumbling around its COM and on course to its target.

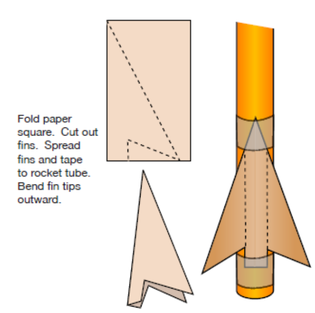


Talk over ideas for safety. Discuss wearing safety glasses. Ask students what should or should not be done while launching. Also discuss what should be done when they retrieve their rockets for another launch.

To build the rocket:



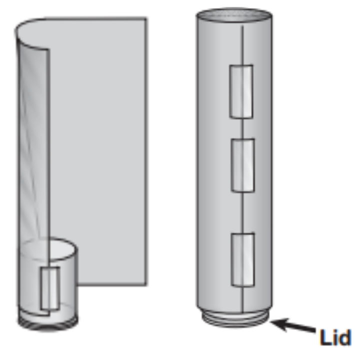
1. Cut a strip of paper for the rocket body (about 4 cm wide by 28 cm long). (If you would like to use the SLS template, it is included at the end of the lesson plan)
2. Use a round pencil as a form and roll the strip around the pencil.
3. Tape the long seam, ensuring that it is completely sealed.
4. Close off one end to make a nose cone.
5. Cut out three or four fins.
6. Tape the fins to the open (lower) end of the rocket. Bend them outward and space them evenly around the base of the rocket.
7. Perform drop tests to check for stability: Hold the rocket horizontally at eye level and drop it to the floor. If the nose of the rocket hits the floor first, the rocket is stable and ready for flight. If the rocket falls horizontally or the fin end hits first, the rocket is unstable. Larger fins may be needed to stabilize the rocket.
8. Launch the rocket. Stand at one end of your launch range. Insert a straw into the rocket body. Aim the rocket down range and puff strongly into the straw. Liftoff!



9. Have students improve their rocket design by holding distance trials. Students will launch their rocket three times and find the average distance the rocket travels. They will then try to improve their rocket design to get greater distance.

Fizzy Tablet Rockets: Newton’s Laws of Motion

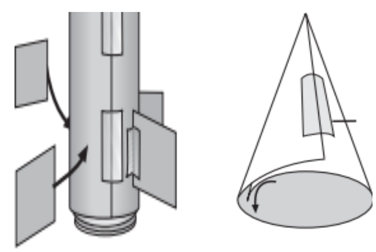
This rocket is a great demonstration of Newton’s Laws of Motion. The rocket lifts off because an unbalanced force acts upon it (First Law). This is the force produced when the lid blows off, caused by the gas that is formed in the canister. The amount of force is directly proportional to the mass of water and gas expelled from the canister and how fast it accelerates (Second Law).The rocket travels upward with a force that is equal and opposite to the downward force propelling the water, gas and lid (Third Law).



NOTE: This lesson can also be adapted to use in Chemistry, by breaking the tablet up you can affect the rate of reaction and the time needed to launch.

Building the Rockets:

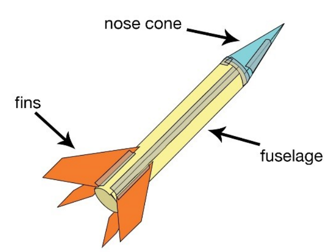
1. Cut a piece of cardstock or construction paper in half.
2. Wrap and tape the piece of paper around the film canister. The lid end of the canister goes down!
3. Use the other half of the paper to cut out and tape fins to your rocket.
4. Cut out and roll a cone of paper and tape it to the rocket's upper end.
5. Put on the safety goggles.
6. To launch the rocket, turn the rocket upside down and fill the canister one-third full of water.
7. Working quickly, drop in 1/2 tablet.
8. Snap lid on tight.
9. Stand rocket on launch platform.
10. Stand back.



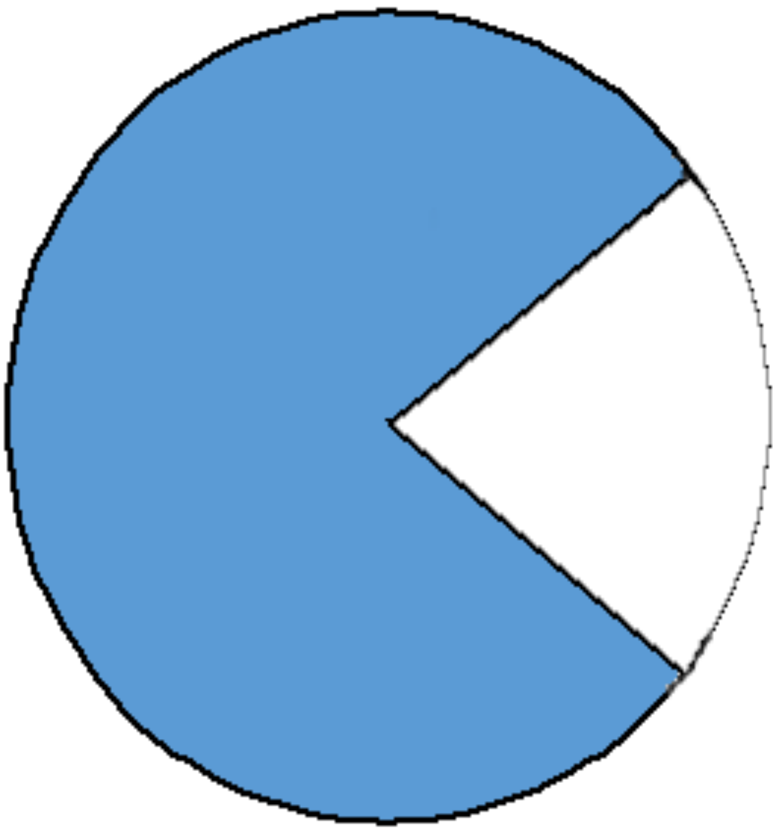
Air Rockets: Laws of Motion and Thrust

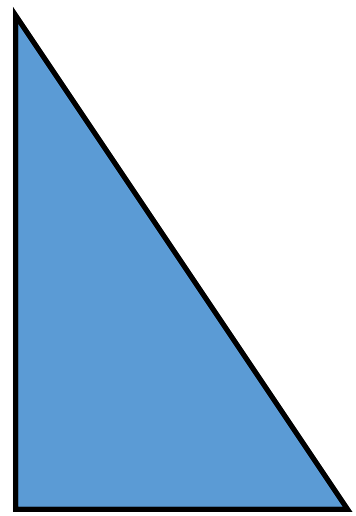
Building the Air Rockets:

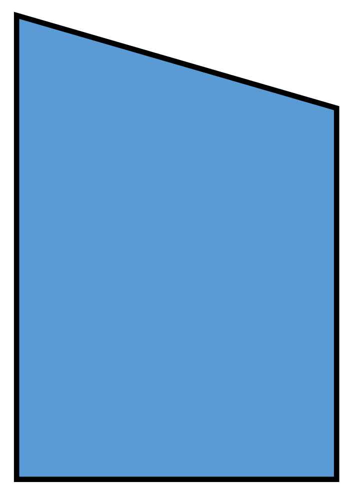
1. Wrap a piece of colored paper around the PVC pipe (long or short).
2. Make sure the paper tube you created fits, but is a little loose so that it doesn’t get stuck when you launch. Seal it with tape.
3. Construct a nose cone for the rocket. If desired, trace the pattern provided.



4. Attach the nose cone to one end of the body tube. Be certain there are no holes in the seam. One easy way to accomplish this is to gently blow into the open end of the rocket. Place one hand near the seam of the rocket to feel if any air is escaping. This is called the Leak Test.
5. Cut out fins. Allow the students to choose the shape and numbers of fins. Rockets at least need 3 fins to be stable. If desired, the students can trace patterns the patterns found below to create their fins.
6. Secure the fins to the rocket using the cellophane tape.
7. Templates for nosecones and fins are below.







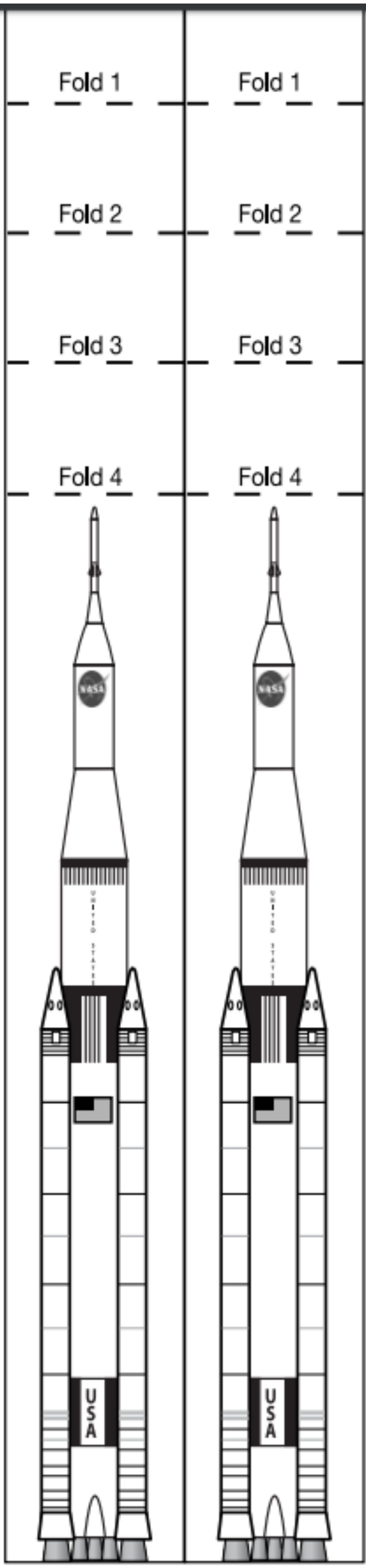
Building the Launcher:

There are several building plans on-line ranging from elaborate to simple. This is the simplest launcher.

1. Cut the bicycle innertube so that it is no longer a circle, but is one long tube open on each end.

2. Stretch one end of the tube over the opening of an empty 2 liter bottle. Secure with duct tape.
3. Stretch the other end onto the end of the PVC pipe. Secure with Duct tape.
4. To launch the rocket, slide it onto the PVC pipe. Make sure that the PVC pipe is pointed away from any one.
5. Stomp on the 2 Liter bottle. The air will launch the rocket.
6. Un-crush the bottle and repeat.
7. **Safety note 1** – students will want to blow into the PVC pipe to re-inflate the bottle. If you let them, they can use their hands to form the seal so that they are not actually putting their mouths on the PVC. Sanitize.
8. **Safety note 2 -** make sure that someone is holding the bottle off the ground to prevent anyone from stepping on it during re-inflation – this would be dangerous.

SLS Rocket Pattern for 1/4 or 5/16th inch dowel or standard pencils



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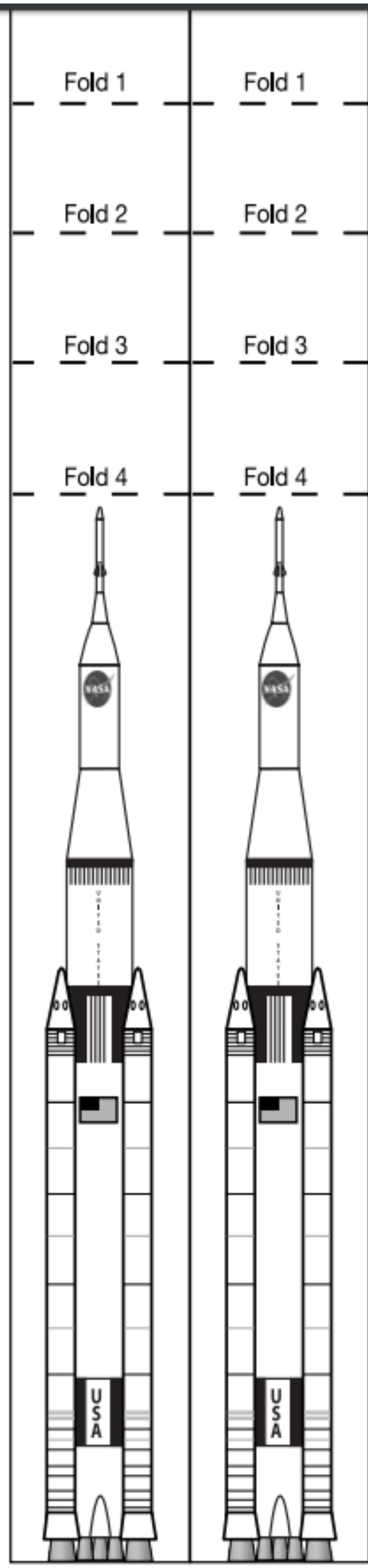

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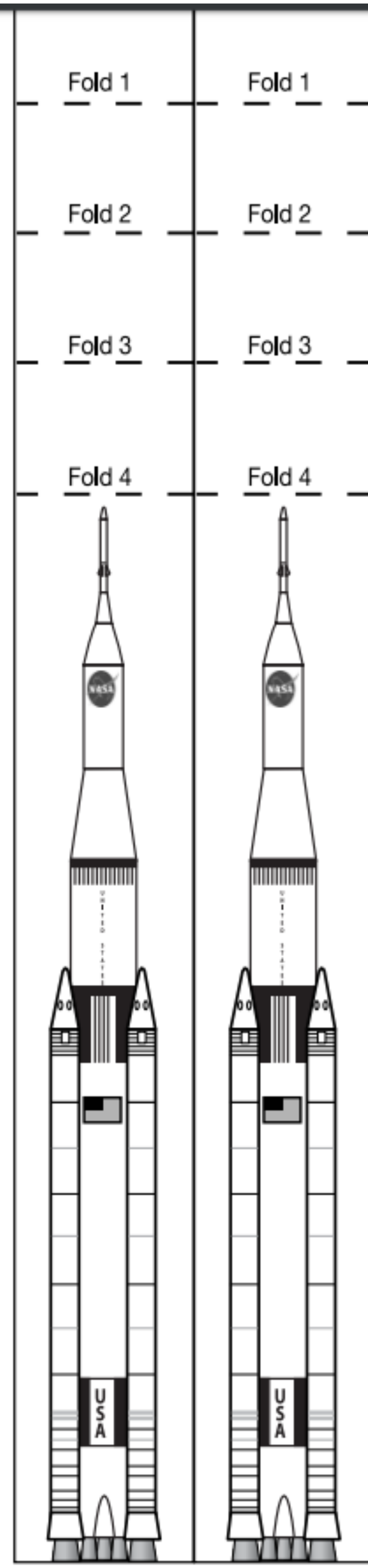

Resources:

https://www.nasa.gov/exploration/systems/sls/factsheets.html

Credits:

https://www.nasa.gov/stem-ed-resources/3-2-1-puff.html

https://www.instructables.com/id/DIY-Stomp-Rockets/

https://spaceplace.nasa.gov/glossary/en/

https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-rocket-58.html

https://www.grc.nasa.gov/www/k-12/airplane/srockth.html