Jet Propulsion Laboratory
California Institute of Technology

Education

CLASSROOM ACTIVITY

Stomp Rockets

DIY Space: Stomp Rockets - Make the Rocket (Part 1). Credit: NASA/JPL-Caltech

Details

GINEERING,
CS

SROOM
MILY ACTIVITY ,
OOL ACTIVITY

s: 4 - 9

c: THE DESIGN

pics:
CTION,
ND PROBABILITY
MEASUREMENT
MOTION AND FORCES
NUMBER AND OPERATIONS
SOLAR SYSTEM

Time Required: 1hr - 2hrs

Next Generation Science Standards (Website)
3-5-ETS1-2
3-5-ETS1-3
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4
5-PS2-1

Overview

In this activity, students will:

- Work individually or in teams of two to construct and launch paper rockets using a teacher-built PVC-pipe launcher.
- Following the flight of their rocket, calculate the altitude their rocket achieved.
- Based on the flight performance of their rockets, analyze their rocket designs, modify or rebuild them, launch again, and calculate the altitude achieved to determine if their changes

affected the performance of the rocket.
- Conclude the activity by writing a post-flight mission report.

Materials

- Paper rocket (per rocket):
- - Student Instruction Sheet (optional) - Download PDF
- - 2 sheets of 8.5 x 11-inch paper (white or color) OR custom skins - Download PDF
- - Cellophane tape OR masking tape
- - Scissors
- - Markers for decorating/naming rockets
- - 24-inch length of 1/2-inch PVC pipe (for the rocket form)
- Stomp rocket launcher (per launcher):
- - Stomp Rocket Assembly Instructions - Download PDF
- - 5-foot length of 1/2-inch PVC pipe cut into various lengths (see assembly instructions for lengths)
- - 2 PVC 45-degree elbow slip connectors
- - 2 PVC tee slip connectors
- - 2 PVC slip caps
- - Duct tape
- - Empty 2-liter bottle (plus spares if available)
- Altitude tracker (per tracker):
- - Altitude Tracker (printed on cardstock) - Download PDF
- - String OR thread
- - Penny OR similar weight
- - Paper clip
- Additional materials:

Common Core State Standards for Mathematics (Website)
7.G.A.1
HSG.CO.D.12
7.G.A.2
4.MD.C.6
6.SP.B.5.C

Keywords: MARS, ROCKETS, JOURNEY TO MARS, DIY SPACE, INFORMAL EDUCATION, AFTER-SCHOOL ACTIVITY, OUT-OF-SCHOOL ACTIVITY, MAY THE FOURTH, VIDEO, TEACHABLE MOMENTS

- Data Sheets - Download PDF (printout) OR XLSX (digital)

- 2 clipboards (each with a pencil) OR a mobile device linked to the digital Data Sheet

- Graph paper

- Protractor

- Ruler with metric measure

- Long measuring tape

Management

Preparation:

- Prepare for the lesson by watching the "Do It Yourself Space: Stomp Rockets" videos available at the top of this page.

- Prior to launch day, construct at least one rocket launcher. Take the Stomp Rocket Launcher Assembly Instructions to a hardware store to make purchasing the right pieces easy. While at the hardware store, purchase enough 1/2-inch PVC pipe to make the launchers *and* the rocket forms. If you do not own a PVC cutter, it's a good idea to purchase one or ask the hardware store to pre-cut the PVC pipe for you in the specified lengths. You may also use a fine-tooth saw to cut PVC.

- **Safety Note:** Use caution when cutting the PVC for the launcher and rocket forms.

Building the Rockets:

- Decide in advance if students will each build their own rocket or will work in teams. Working in pairs works best for younger students and can be useful for brainstorming between older students. Students may work in pairs to build more than one rocket to observe design differences.

- **Be sure that the rocket-body tubes that students roll are slightly loose.** They should slide freely along the PVC rocket form. If they are too tight, it will be difficult to slide the completed rockets over the launch tube.

- While students finalize their rockets, examine them to ensure that they are airtight.

Tracking Altitude:

- If your students will be measuring the altitude attained by their rockets, allow time to construct the Altitude Trackers. To obtain an accurate angle of elevation, you'll want several Altitude Trackers on each baseline, so have each student team make one.
- Be sure to print out a copy of the Data Sheet for each baseline (A and B) and have a student recorder for each baseline take the Data Sheet, along with a pencil and a clipboard, out to the launch area. Alternately, download the digital Data Sheet onto a mobile device that students can use to record the data.
- Younger students may make comparative altitude estimates using landmarks on buildings or flagpoles. If using this technique, consider building several launchers for the class so that multiple rockets may be launched simultaneously.

Launching the Rockets:

- When headed out to launch, always have spare empty 2-liter soda bottles and duct tape handy. Though some bottles will launch 20 to 40 rockets, bottles will eventually fail and will need to be replaced.
- Because of their lightweight design, stomp rockets perform best on non-windy days. If you are located in a windy location, try to orient your launch location behind a windbreak such as a gymnasium or other large building.
- Secure an outdoor location that is clear of overhead obstructions (trees, building roofs, power lines, etc.) and has a ground area of at least 100 meters by 25 meters for best altitude-tracking results. A shorter, 50-meter or 25-meter baseline may also be used.
- If calculating altitude using tracking stations A and B, place the rocket launcher at the midpoint of a 100-meter baseline. If estimating altitude using local markers such as marks on buildings, orient the rocket launchers and observers appropriately.

- **Stomping:** Be sure students stomp on the bottle across the bottle label, perpendicular to the body of the bottle. This is the most flexible zone of the bottle and allows for it to be reused numerous times. If students stomp on the bottom end of the bottle, it will often shatter, rendering the bottle unusable.

- **Aiming:** The PVC legs of the launcher are different lengths. This allows for adjustment on uneven ground and aiming the launch into the wind if you are launching on a windy day. (Launching into the wind will compensate for rocket drift and make rockets easier to track and retrieve.) Additionally, horizontal distance competitions can be held and launch angles adjusted. Place a basketball in the landing zone, have students imagine the ball is Mars, and launch their rocket to Mars! If performing horizontal launches, a large indoor space such as a cafeteria or gymnasium may be used.

- **Re-inflating the bottle:** Bottles can be easily re-inflated using air from your lungs. Place your hand in a fist around the open end of the launch tube and blow into your fist to re-inflate the bottle. Using your fist protects you from the unsanitary conditions that may exist on your rocket launcher.

- **Safety Note:** Use caution when launching the stomp rockets. Keep all students clear of the launch tube and the landing area. Allow only one student, the stomper, to be near the launcher, and be sure the launch tube is pointed away from the stomper. Only retrieve rockets once they have landed.

Background

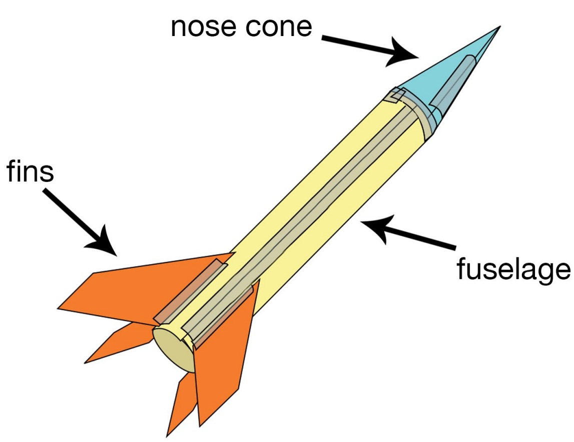
The mighty space rockets of today are the result of more than 2,000 years of invention, experimentation and discovery. Rockets have launched spacecraft to every planet in the solar system and even sent humans to the moon. Soon, they will take humans even farther to places such as Mars and beyond.

NASA's Space Launch System will be the most powerful rocket the agency has ever built. When completed, SLS will enable astronauts to begin their journey to explore destinations far into the solar system. Credit: NASA

Early rocket pioneers created what at the time seemed impossible – rocket-propelled devices for land, sea, air and space. When the scientific principles governing motion were discovered, rockets graduated from toys and novelties to serious devices for commerce, war, travel and research, and made some of the most amazing discoveries of our time possible.

Every space rocket ever built was constructed with a specific mission in mind. The Bumper Project in the 1950s combined a small WAC Corporal rocket with a V2 to test rocket staging, achieve altitude records and carry small payloads for investigating the space environment. The Redstone missile was designed for explosive warheads but later adapted to carrying the first American astronaut into space. The Saturn V was designed to carry astronauts and landing-craft to the moon. It, too, was modified and used to launch the first U.S. space station, Skylab. The space shuttle, perhaps the most versatile rocket ever designed, was nevertheless a payload and laboratory carrier for low-orbit missions and was used in assembly flights to the International Space Station . The myriad potential uses for NASA's future Space Launch System remain to be seen, but plans include carrying robotic spacecraft to places in our solar system that might harbor life, such as Jupiter's moon Europa and Saturn's moon Titan, and eventually carrying crew in the Orion spacecraft farther into the solar system than ever before – to an asteroid or even Mars.

Learn more about the history of rocketry and the inspirations that ultimately led to humankind's first journeys into outer space here.



Each rocket has a unique design that's dependent on the mission at hand, but they all have a few essential parts: the fuselage, the fins and the nose cone. The fuselage is the main body of the rocket. The fins provide stabilization and are placed symmetrically around the circumference of the fuselage near the tail. And the nose cone is secured to the top of the rocket to aid in aerodynamics by piercing the air.

The stomp rockets in this activity, while simple, can have a surprising amount of variability in the altitude they achieve. By eliminating drag and streamlining their designs, students can make their rockets fly higher. The rockets won't reach Mars, but if designed properly, they can reach more than 50 meters!

Procedures

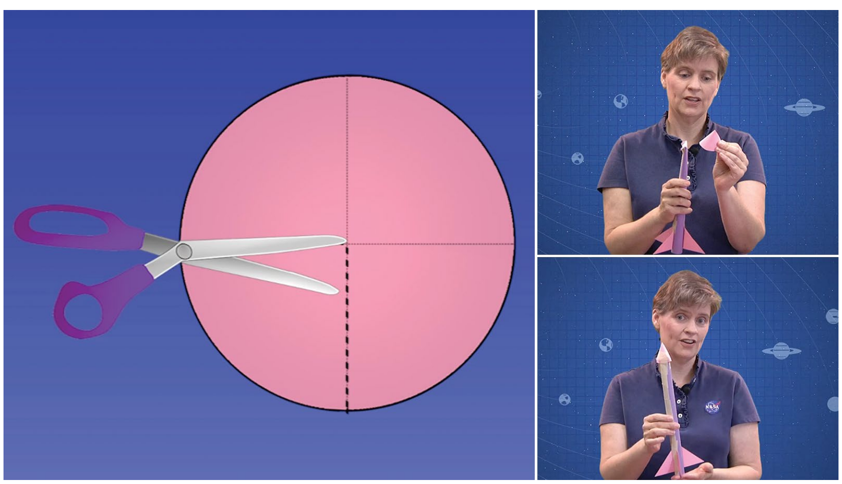
Build the Rocket:

1. Roll a piece of 8.5 x 11-inch paper snuggly (but not too tightly) around a 24-inch length of 1/2-inch PVC pipe. Optionally, use one of the custom skins.

2. Tape the paper to itself (but not to the PVC pipe). Use enough tape to completely seal the seam, making the seam airtight. This will be the body, or fuselage, of your rocket.

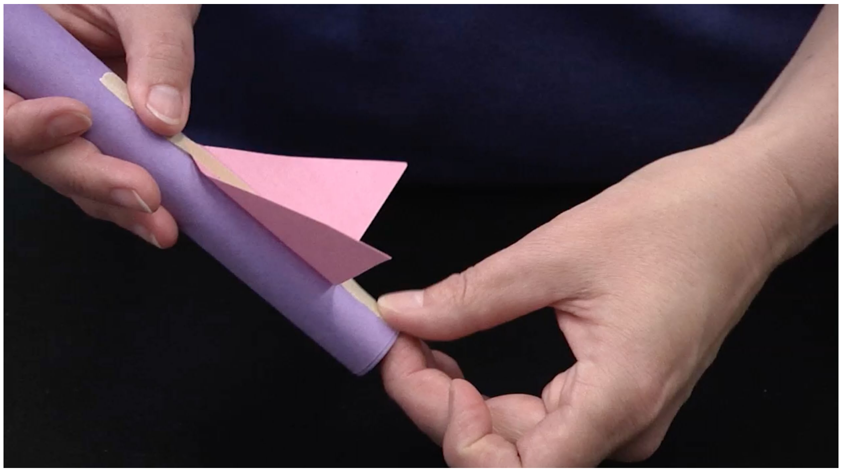
3. Slide the fuselage off the PVC form. Verify that the fuselage slips easily from the PVC form so that it will fit on the launch tube later.

4. Make a nose cone either by pinching one end of the fuselage, folding it over and taping it to the rocket body; or by cutting out a 3/4 circle, rolling it into a cone shape and taping it to the fuselage. Optionally, use the custom nose-cone template. Secure the nose cone using plenty of tape to make the rocket airtight. (Blow through the rocket from the bottom to check for leaks.)



5. Cut out fins (of any shape) and attach them symmetrically to the lower part of the fuselage (opposite the nose cone), leaving the opening at the bottom of the fuselage open and clear of tape.
Allow students to experiment with the size and shape of their rocket fins. Through repeated flights, students will discover that proportional, firm fins will provide the most stabilization to their

rocket and eliminate drag.



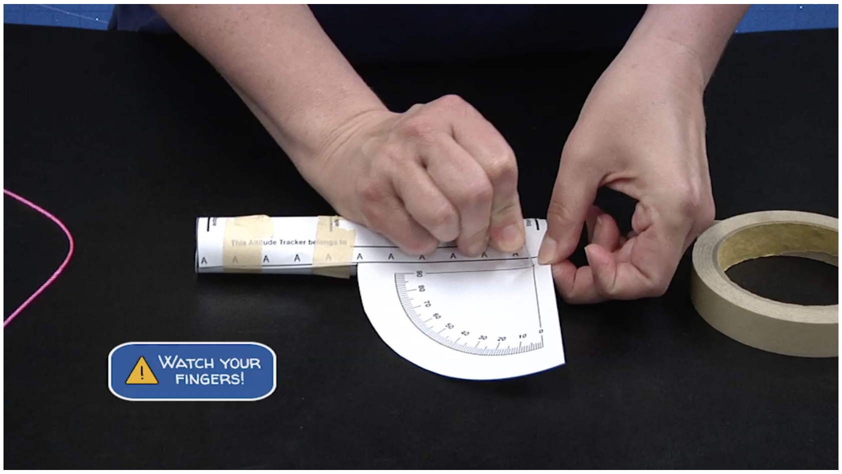
6. Have students color and name their rockets to differentiate them from other rockets in the group.

Build the Altitude Tracker:

1. Cut out the Altitude Tracker (copied on card stock), following the outer outline.

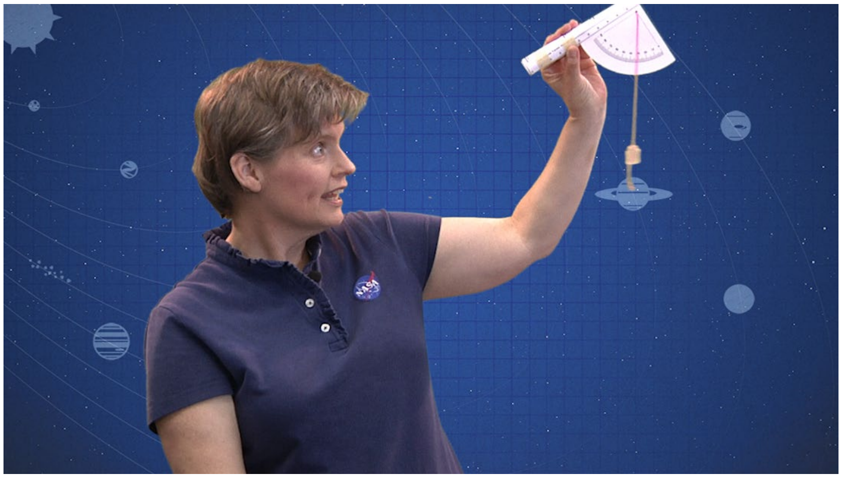
2. Roll the sighting tube so that the line of As and the line of Bs are together, then staple or tape it to form a tube.

3. Use a paper clip or sharp pencil to poke a hole through the apex of the protractor quadrant on the template.



4. Slip a thread or piece of string through the hole and tape the small end to the back of the tracker.

5. Complete the tracker by taping a penny to the other end of the string so the string hangs weighted in front of the protractor.

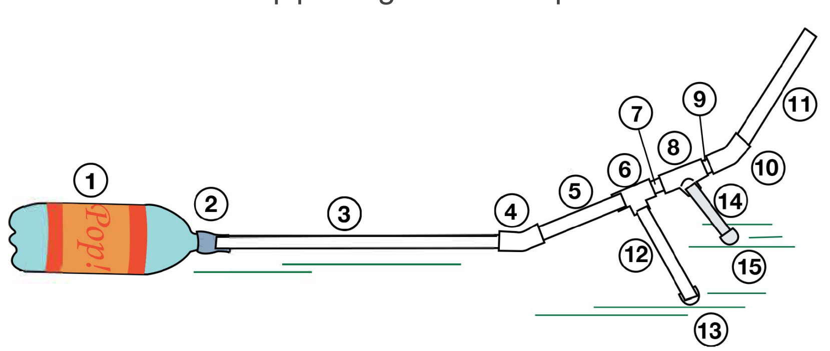


Build the Launcher:
This should be done by the instructor prior to launch day.

1. Cut the PVC pipe into the following lengths. (The part numbers indicate where each piece is placed in the assembled launcher diagram):
    - #3 - 50 cm
    - #5 - 18 cm
    - #7 - 4 cm
    - #9 - 4 cm
    - #11 - 25 cm
    - #12 - 20 cm
    - #14 - 25 cm

2. Insert the end of part #3 into the neck of the bottle and tape it securely with duct tape.

3. Follow the construction diagram below to assemble the launcher. Match the pipe lengths with the part numbers.



4. Swing the two legs outward or inward until each touches the ground to form the tripod. The launcher is ready for use.

Launch and Track the Rocket:
Safety Note: Use caution when launching the stomp rockets. Keep all students clear of the launch tube and the landing area. Allow only

one student, the stomper, to be near the launcher, and be sure the launch tube is pointed away from the stomper. Only retrieve rockets once they have landed.

1. Locate a safe spot to launch the rockets (clear of vertical and horizontal obstructions).

2. Place the stomp-rocket launcher half way between Baseline A and Baseline B.

3. Measure and record the distance between Baseline A and Baseline B.

4. Have several students with Altitude Trackers on each baseline along with a student who can read and record the results from the trackers.

5. Have a student place their rocket on the launch tube, sliding it down as far as it will easily go.

6. Instruct the student to note the wind direction and aim their rocket into the wind as needed by turning the rocket launcher or tube. Make sure the launcher is stable on the ground, adjusting the legs as necessary.

7. **Clear the launch area of all people and be sure the rocket is aimed away from people.**

8. Have students do a 3, 2, 1 countdown. On "launch," the student whose rocket is launching should stomp on the bottle perpendicular to the long axis of the bottle.

9. As the rocket is in flight, have students with the Altitude Trackers follow the rocket to its highest altitude and hold the trackers in place while a partner reads the angle.

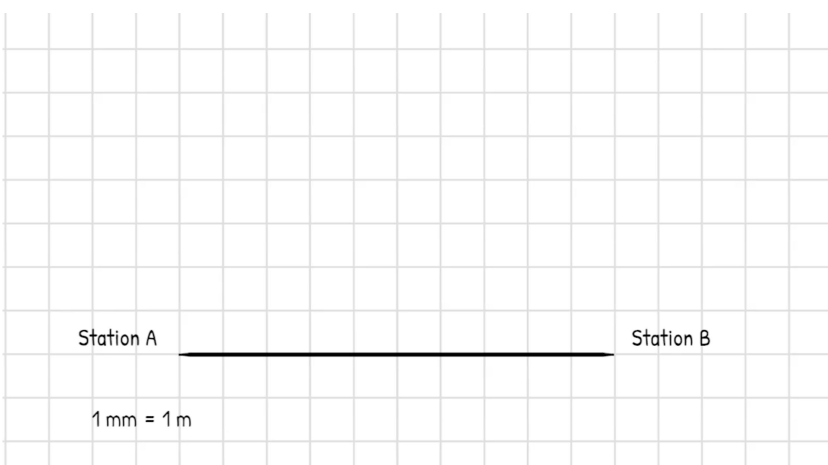
10. A data logger for each baseline should record the altitude angles that each tracker measured for the rocket.

11. Repeat Steps 1 through 10 for each rocket.

Calculate the Rocket's Altitude:

1. Have students determine a scale to use for their scale drawings. The scale should be small enough that the measurement between Baseline A and Baseline B will fit on a sheet of the graph paper.

2. They should then draw a horizontal line on the graph paper that represents the distance between Baseline A and Baseline B.

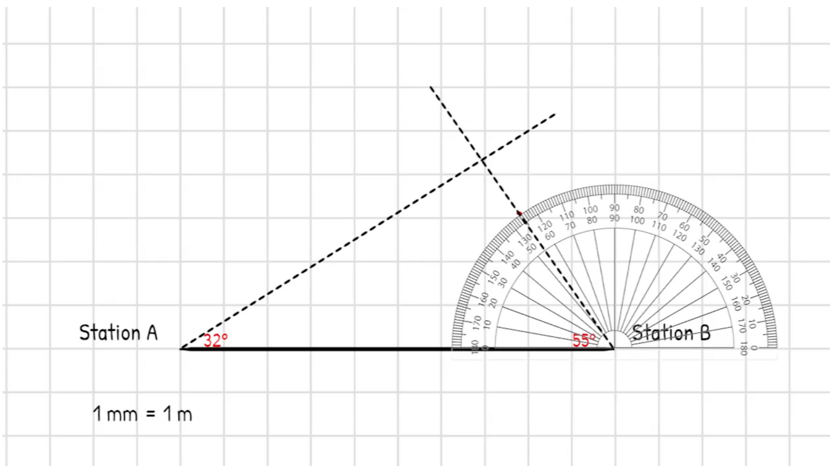


3. Obtain the angle data recorded for their rocket from Baseline A and Baseline B.

4. Find the average angle of elevation of their rocket from Baseline A and Baseline B.

5. Use a protractor to construct the angle of elevation from Baseline A on one end of the line, extending the angle line across the paper.

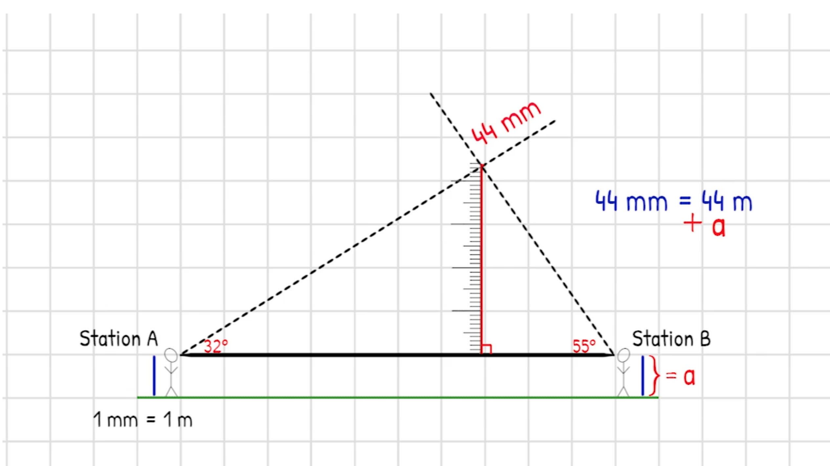
6. Use a protractor to construct the angle of elevation from Baseline B on the other end of the line, extend the angle line across the paper until it crosses the line constructed for Baseline A.



7. Using geometric construction techniques or aligning a ruler with gridlines on the graph paper, draw the altitude (perpendicular) from the intersection of the constructed lines to the horizontal line.

8. Measure the length of this altitude. This is the altitude their rocket reached.

9. For a more accurate altitude measurement, add the average eye-level height of the trackers on each baseline.



Build a Better Rocket:

1. Have students examine their rocket and analyze its flight performance, then compare the designs and flight performance of their classmates' rockets.

2. Have students discuss various criteria for good flight performance. What, besides or in addition to altitude achievement, constitutes good flight performance? *Stability in flight, smooth trajectory, etc.*

3. Based on their observations, have students hypothesize about the links between the specifics of rocket design and performance. Note such things as fin number, placement and design, nosecone design and fuselage length. Also examine materials used.

4. Have students aggregate class design and performance data to identify the best characteristics of high performing rockets.

5. Have students discuss how to best assess design changes and control variables. *One strategy is to change only one thing at a time and validate performance; another strategy is to completely rebuild a poorly performing rocket given the new information from class rockets.*

6. Instruct students to use what they learned from the first round of launches to brainstorm ideas to optimize their design and build a better rocket.

7. Repeat the steps under "Launch and Track the Rocket" and "Calculate the Rocket's Altitude."

8. Re-evaluate the rocket's flight performance and determine if the changes in design improved the rocket. Continue optimizing design elements and retesting until students believe they have achieved the best performing rocket they can.

Write a Post-Flight Mission Report:

1. Conclude the rocket engineering design experiment by having students write a short report that incorporates the various materials used, rocket design sketches and descriptions, redesigns, methods and reasoning used and outcomes. Have them include suggestions for future flights should they have an opportunity to conduct them.

Discussion

- Discuss various flight results and student designs. Ask students to hypothesize about the connection between design and performance.
- Ask students to devise a method of testing their theories of performance-linked design and then test their theories.
- Discuss construction variables: type and amount of paper used, tape vs. glue, etc. If these things change, will performance be enhanced?
- Have students describe what other variables existed during launch? (wind, interference, human error in angle measurement, etc.)

Assessment

- Have younger students submit drawings of their rocket(s) and illustrations of their flight paths. Ask them to comment on the design of each rocket and reflect on how various design aspects impacted flight and altitude achieved.
- Have older students submit a more sophisticated version of what younger students are expected to do, including scale drawings and mathematical calculations for altitude.
- Have students discuss how they might improve on their design should they have the opportunity to build and launch another rocket.

Extensions

- Compare rockets to an arrow, a weather vane, or a dart. Bring one or more of these objects to class and compare them to the shape of the students' rockets.
- Show pictures of different rockets and compare them to students' rockets.
- Use a mobile device to record slow-motion/high-frame-rate

video of the launch to be watched later. Analyze the flight of the rocket to assist in generating ideas for redesign.

- Consider hosting a family rocket-launch event, during which families work together to build rockets. The knowledgeable student in each family will be the team captain and instructor.

Explore More

- NASA's Space Launch System
- NASA's Space Launch System: Meet the Rocket
- NASA's Sounding Rockets

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