Activity Three: Build a Multistage Balloon Rocket

Educator Notes

Challenge

Students will work together as a team to design and build multistage balloon-powered rockets to demonstrate how rockets can achieve greater distances using the technology of staging.

Suggested Time

120 minutes

Learning Objectives

Students will

- Apply the steps of the engineering design process to successfully complete a team challenge.
- Design and build their own multistage rocket and successfully launch it across the classroom.
- Improve their rockets based upon the results of the experiment.
- Demonstrate an understanding of Newton's laws of motion and their application in rocket launches.

Curriculum Connection

Science and Engineering (NGSS)	
Disciplinary Core Ideas • MS-PS2-2 Motion and Stability: Forces and Interactions: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. PS2.A: Forces and Motion. • MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. – ETS1.A: Defining and Delimiting Engineering Problems: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. • MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. – ETS1.B: Developing Possible Solutions: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. – ETS1.C: Optimizing the Design Solution: Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. • MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. – ETS1.B: Developing Possible Solutions: A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions.	*Disciplinary Core Ideas (continued)* – ETS1.C: Optimizing the Design Solution: The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *Crosscutting Concepts* • Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. • System and System Models: Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems. • Energy and Matter: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior. • Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. *Science and Engineering Practices* • Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. • Developing and Using Models: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. • Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. • Construct Explanations and Design Solutions
Technology (ISTE)	
Standards for Students • Computational Thinker: Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions. – 5c: Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem solving. • Innovative Designer: Students use a variety of technologies within a design process to identify and solve problems by creating new, useful, or imaginative solutions.	*Standards for Students (continued)* – 4a: Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts, or solving authentic problems. – 4c: Students develop, test, and refine prototypes as part of a cyclical design process. • Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally. – 7c: Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.
Mathematics (CCSS)	
Content Standards by Domain • CCSS.MATH.CONTENT.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by: – CCSS.MATH.CONTENT.6.SP.B.5.A: Reporting the number of observations. – CCSS.MATH.CONTENT.6.SP.B.5.B: Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.	*Mathematical Practices* • CCSS.MATH.PRACTICE.MP1: Make sense of problems and persevere in solving them. • CCSS.MATH.CONTENT.MP3: Construct viable arguments and critique the reasoning of others. • CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically.

Preparation Time

30 minutes

- Read the Introduction and Background, Educator Notes, and Student Handout to become familiar with the activity.
- Gather and prepare all supplies listed on the materials list.
- Print copies of the Student Handout for each team.
- If presenting videos or web-based resources, test the links and the classroom technology ahead of time.
- Prepare the classroom by setting up "launch pads" consisting of fishing line running across the classroom parallel to the floor but high enough so students are able to walk underneath them or near the walls. If you set up two launch pads side by side, students can launch simultaneously to race their rockets across the classroom.

Materials

- ☐ Foam coffee cups
- ☐ Fishing line or smooth string
- ☐ Long balloons (5- by 25-in. balloons work best)
- ☐ Straight drinking straws
- ☐ Scissors
- ☐ Copies of Student Handout and blank paper
- ☐ Masking tape
- ☐ Balloon hand pumps (optional)
- ☐ Wooden spring-type clothespins or large binder clips
- ☐ Paper/pencil for brainstorming

Introduce the Challenge

- Provide context for this activity using the Introduction and Background information in this guide. Discuss how NASA uses rocket stages for deep space exploration.
- Explain the role of engineers in designing technology to solve problems. Share the NASA video Intro to Engineering and introduce the engineering design process.
- Introduce any new terminology (e.g., first stage, second stage, and thrust).
- Distribute the Student Handout and blank paper and explain the challenge and constraints.

Design Constraints

1. Each team will receive the same materials to construct a multistage balloon-powered rocket that can travel across the classroom along fishing line.
2. The balloon rocket must be securely attached to straws on the fishing line to provide guidance, navigation, and flight control during the launch.

Demonstration

Use the following instructions to demonstrate how to set up a two-stage rocket using two balloons and a foam cup.

1. Thread the fishing line through the two straws. Stretch the fishing line snugly across a room and secure its ends. Make sure the line is just high enough for people to pass safely underneath or near a wall to avoid people walking into it.
2. Cut the coffee cup in half so that the lip of the cup forms a continuous ring.
3. Stretch the balloons by pre-inflating them. Inflate the first balloon about three-quarters full of air and squeeze its nozzle tight. Pull the nozzle through the ring. Twist the nozzle and

Share With Students

Brain Booster

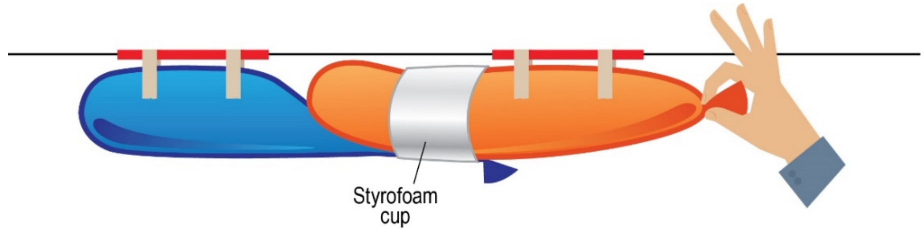
Johann Schmidlap was a German fireworks maker and rocket pioneer. He invented the step rocket, a multistaged transport system for lifting fireworks to higher altitudes. A large skyrocket (first stage) carried a smaller skyrocket (second stage). When the large rocket burned out, the smaller one continued to a higher altitude before showering the sky with glowing cinders. Schmidlap's idea is basic to all of today's multistage rockets that travel to space.

Learn more: https://www.grc.nasa.gov/www/k-12/TRC/Rockets/history_of_rockets.html

On Location

As NASA's mission and requirements have evolved, the Marshall Space Flight Center in Huntsville, Alabama, has evolved to support them. Marshall has developed world-class capabilities in areas such as propulsion, materials, space environments, avionics, advanced manufacturing, life support, testing, and systems integration.

Learn more: https://www.nasa.gov/centers/marshall/home/index.html hold it shut with a clothespin or binder clip. Inflate the second balloon. While doing so, make sure the front end of the second balloon extends through the ring a short distance. As the second balloon inflates, it will press against the nozzle of the first balloon and take over the clip's job of holding it shut. It may take a bit of practice to achieve this. Clip the nozzle of the second balloon shut also.



4. Take the balloons to one end of the fishing line and tape each balloon to a straw with masking tape. The length of the balloons should be parallel to the fishing line, allowing the thrust to propel the balloons along the string.
5. Remove the clip from the first balloon and untwist the nozzle. Remove the clip from the nozzle of the second balloon as well, but continue holding it shut with your fingers.
6. Conduct a launch countdown. As you release the balloon you are holding, the escaping gas will propel both balloons along the fishing line. As the balloon you released expels air, it will separate from and release the nozzle of the other balloon, which will then provide thrust to continue to propel the balloon rocket across the string.

Facilitate the Challenge

Ask, Imagine, and Plan

Engage the students with the following discussion questions:

- What is the benefit of a multistage rocket?
- What factors could slow your rocket down as it moves across the string?
- What problems do you anticipate encountering?

Create, Test, and Improve

- Each team will build multistage rockets using only the materials supplied.
- Each team will test their design and make observations for systematic improvements to their rockets throughout the activity.

Share

Engage the students with the following discussion questions:

- What problems did your team encounter? How did you solve these problems?
- What forces prevented the rocket from reaching its destination?
- What configuration of balloons was the most successful?
- How do the experiment results compare or contrast to what you know of modern rocketry?
- What was the most innovative solution in the class?

Extensions

- Encourage students to try other launch arrangements, such as side-by-side balloons, three-stage rockets, or multistage heavy lift (vertical) rockets. (Resource: Heavy Lifting Rocket Activity. https://www.nasa.gov/sites/default/files/atoms/files/sls_heavy_lifting_508.pdf)
- Brainstorm ideas for flying a two-stage balloon rocket without the fishing line as a guide. How could the balloons be modified to make this possible?

Reference

Modified from Balloon Staging: https://www.grc.nasa.gov/www/k-12/rocket/TRCRocket/balloon_staging.html

Additional Resources

- Rocket Science in 60 Seconds Video Series. https://www.nasa.gov/exploration/systems/sls/multimedia/rocket_science_in_60_seconds
- Digital Badging: Online NASA STEM Learning. https://www.txstate-epdc.net/digital-badging/

Activity Three: Build a Multistage Balloon Rocket

Student Handout

Your Challenge

Design and build a multistage balloon-powered rocket to demonstrate how rockets can achieve greater distances using the technology of staging.

Design Constraints

1. You are only allowed to use the supplies provided by your teacher.
2. Your balloon rocket must be securely attached to straws on the fishing line to provide guidance, navigation, and flight control during the launch.

Ask, Imagine, and Plan

Discuss ways to configure two or more balloons in stages to design a rocket with enough thrust to travel across the room.

- How many balloons will your team use?
- How and where will the balloons be attached to the straws?
- What problems do you anticipate encountering?
- Sketch and label your ideas and design on the paper provided by your teacher.

Create, Test, and Improve

1. Assemble your multistage rocket design and attach it to the straws on the fishing line.
2. On a sheet of paper, create a data table like the example below.
3. Launch your rocket and record the distance traveled in your data table.
4. Your team must conduct flight tests during construction and systematically improve the design after each test. Record observations during the flight tests that will help you modify your design.
5. Redesign your rocket and balloon configuration to improve the thrust of the rocket and increase the distance traveled.

Share

Write a summary of your launch vehicle using correct science and technology terms. Describe the improvements made to your vehicle after each test and the resulting change in the rocket's performance.

- What was the greatest challenge for your team today?
- What problems did your team encounter? How did you solve these problems?
- What forces prevented the rocket from reaching its destination?
- What configuration of balloons was the most successful?
- How do the experiment results compare or contrast with what you know of modern rocketry?

Flight Test	Distance Traveled
1	
2	
3	
4	
5	
6	
7	
8	

Fun Fact

The power generated by four RS–25 engines is equivalent to the output of 16 Hoover Dams!

Learn more: https://www.youtube.com/watch?v=MLgYJh6OFbY&feature=youtu.be

Career Corner

Testing 1, 2, 3… Researchers use wind tunnels to learn more about how an aircraft will fly. Aerodynamic testing for the SLS is a critical component to mission success. Discover a career as a research engineer and test scale models of aircraft and spacecraft of the future.

Learn more: https://www.youtube.com/watch?v=_ChkbjRQq28&list=PLBEXDPatoWBmX3yrpEObbUoNF5rbbNcgX&index=27