Pre-Conference Activities

Activity #1

DISCOVER NASA AND YOU: A TIMELINE ACTIVITY

Teacher Sheet(s)

Objective: The learner will exercise and expand their knowledge on NASA history by:

- Utilizing research skills to collect information on NASA historical figures and events;
- Sequence events in chronological order on a timeline

Grade Level: 9-12
Subject(s): Social Studies – History; Language Arts – Comprehension, Sequencing
Duration: 1 class period, or at the teacher's discretion

Materials:

- List of important people and events (share a list with each student or write on board)
- Research materials, i.e.:
    1. computers with internet access
    2. encyclopedias
- Writing utensils
- Paper
- Blank timeline (optional)

Important People and Events

Alan Shepard
Apollo 11
Apollo Program
Edward White
Gemini Program
International Space Station
John Glenn
Launch of Explorer I
Launch of Sputnik
Mercury Program
President Kennedy speaks at Rice University
President Kennedy speaks to Congress
Proposed date for NASA’s return to the Moon
Robert Goddard
Space Shuttle Program
Skylab Program
US government establishes NASA
US launches “Ham” the chimpanzee
Wernher von Braun
World War II
Yuri Gagarin

NOTE: This activity may be used during the video conference event to enhance the student’s learning experience.

Procedure:

1. Provide students with a list of *important people and events.*

2. Allow students time to research each event and person, paying special attention to the date, location, and country represented.

3. Once research is complete, students (either individually or in groups) will organize information in chronological order on a sheet of paper.

4. On a separate sheet of paper, students will construct a timeline that will best organize the information.

5. Complete the timeline by placing the people and events in the correct place.

This lesson may be done as an individual, small group, or large group activity. For more ideas, please refer to “Activity Extension”.

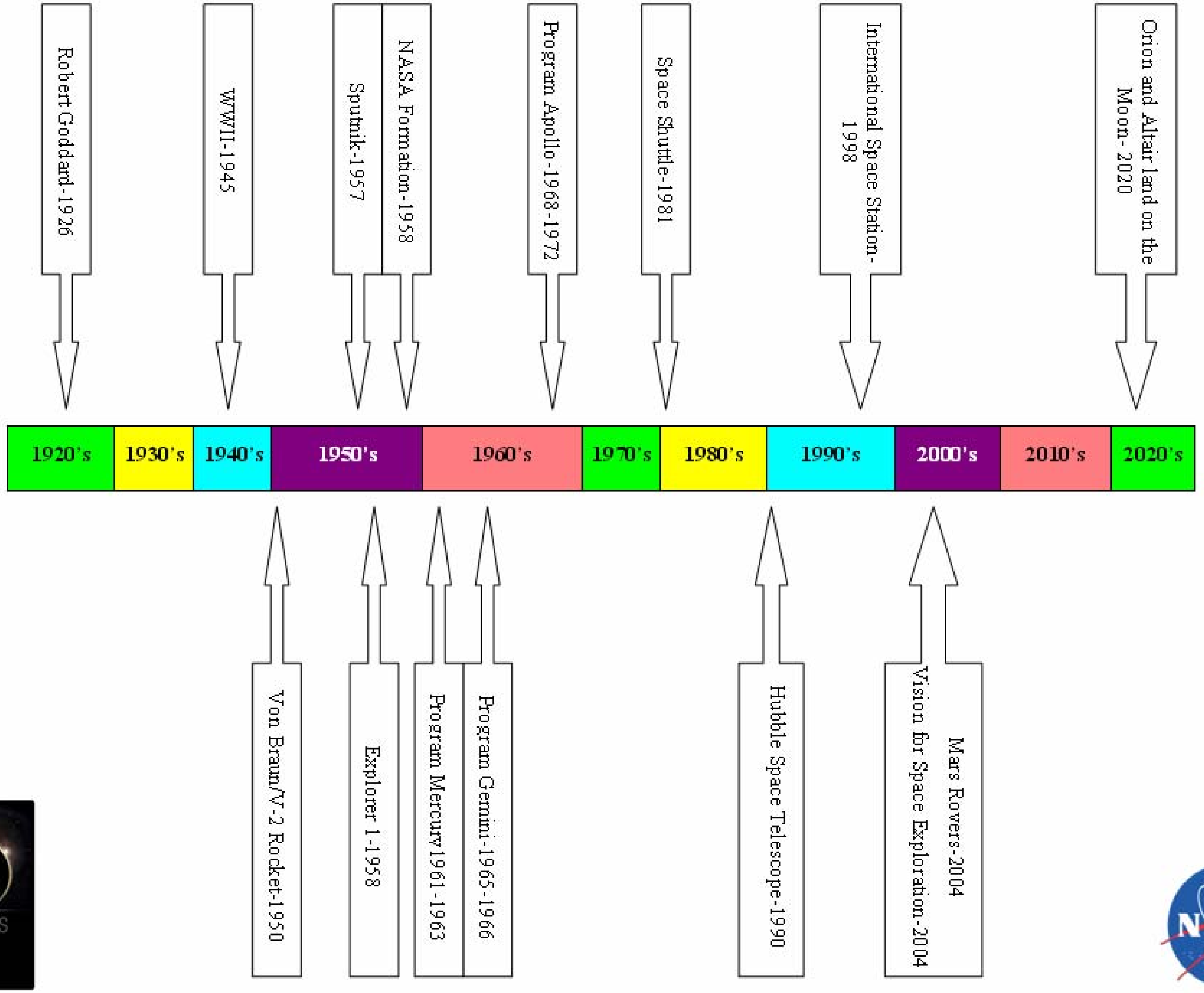
Feel free to use the provided timelines below. The filled in timeline is the teacher’s version and may be used as a guide for what information may be entered into the blank student version.

Activity Extension:

- Individual Activity: Describe the impact each event or person had on US and/or World history in written annotations for each entry.
- Class Activity: Find images of the important people and events, and create an illustrated timeline

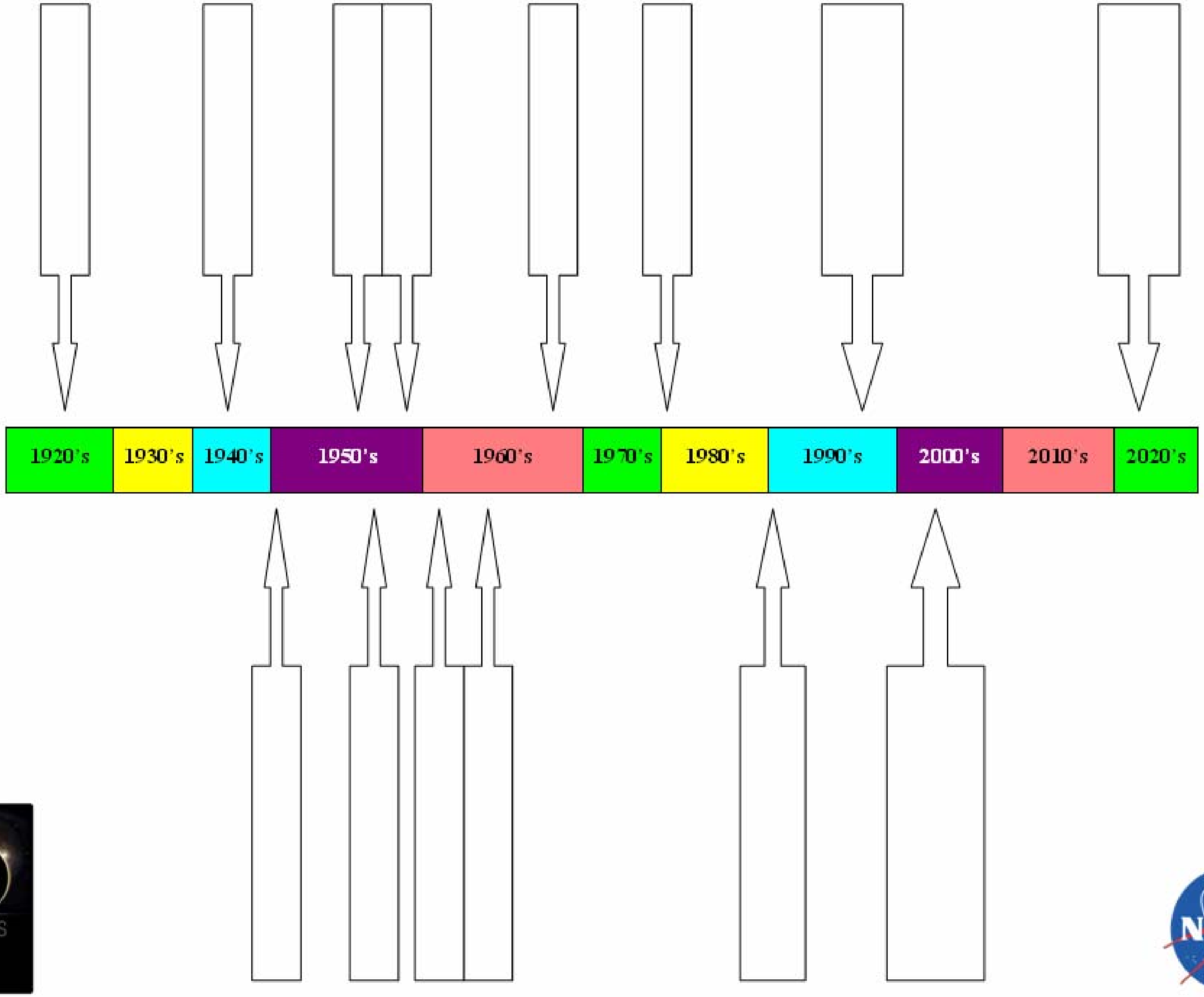
NASA History

Teacher Sheet



NASA History

Student Sheet



Activity #2

ESSAY QUESTIONS

* Students must carry out some research on their own to properly answer most of these essay questions.

1. How do you think the world would have been different if the Soviets continued their domination of space exploration during the 1950s and 1960s?

2. Make a poster that would encourage companies to invest in the exploration of space. Entice them by informing them that there are many resources in outer space that humans could potentially utilize on Earth.

3. Explain the pros and cons of a manned space flight program to a NASA administrator. Your final report should mention if you support or do not support a manned space flight program.

4. Give a NASA accountant your recommendation as to where funds should be allocated for the next 5 years (or 10, 15, or 25 years). (I.e. What portion of the NASA budget should be used to fund human and robotic space exploration?)

5. Design a healthy diet and exercise plan for an astronaut that would be living in microgravity for 6 months. Be sure that you list the amount of food the astronaut is supposed to eat as well as which exercises and for how long the astronaut must do them everyday. Include as much variety in your plan as you want to make sure the astronaut stays as healthy as possible.

6. Imagine yourself as a PR representative for NASA. How would you increase public interest about space exploration? Create promotional material (posters, brochures, etc) and give a presentation that explains why the public should increase their knowledge of space exploration.

7. Imagine yourself an astronaut that is about to be trained to live aboard the ISS for 3 months. The astronauts that you will be living with are from various countries. At your first meeting, you must explain yourself to your crew and help them understand American culture. Give them a quick U.S. history lesson and explain to your fellow astronauts what the U.S. is looking to get out of its space program. *As a group activity, you may assign single students to the various countries that contribute to the ISS. Have them also give a quick history lesson of their country and what they are looking to get out of their own space program.*

Activity #3

Article: Recreating History

To celebrate the Centennial of Flight anniversary, a group of NASA rocket scientists are taking a small step into the past to explore a giant leap in mankind's history. For the 100th anniversary of the Wright Brothers' first powered flight, engineers at NASA's Marshall Space Flight Center (MSFC) are trying to replicate a historic flight of a different kind—Robert Goddard's first liquid-fuel rocket launch.

Robert H. Goddard (1882-1945) is considered by many to be the father of modern rocketry, and, together with Hermann Oberth of Germany and Konstantin Tsiolkovsky of Russia, one of the three fathers of space exploration. In 1913, he developed the mathematical theory of rocket propulsion, and, in 1915, proved that a rocket engine could produce thrust in a vacuum, thus making spaceflight a realistic goal. In 1920, he outlined how a rocket could reach the Moon, a notion that was widely ridiculed in the press at the time.

On March 16, 1926, at Auburn, Massachusetts, Goddard successfully tested the first liquid-fueled rocket, which he designed and built himself, and which was relatively simple by today's standards. The combustion chamber and nozzle were at the top of the rocket, and liquid oxygen and gasoline flowed up to that chamber from tanks at the bottom of the rocket through two-asbestos-wrapped aluminum tubes. An asbestos-coated cone protected the fuel tanks, located underneath the rocket engine.   The first flight lasted only 2.5 seconds, reached an altitude of 12.5 meters (41 feet), and landed 56 meters (184 feet) from the launch pad. While the flight may not sound all that impressive today, many people consider it to mark the beginning of the space age, and to be a feat on par with the Wright Brothers' first flight.

That launch was just one facet of an amazingly productive career. Goddard's research yielded hundreds of patents, and he was instrumental in the creation of such things as gyroscopic guidance, solar energy collectors, and bazookas. Many of the technologies he patented are still in use today in the Space Shuttle and International Space Station. Goddard went on to have 35 successful launches of liquid-fueled rockets, many several times larger than that first one, one of which reached an altitude of 2.7 kilometers (1.7 miles). However, it is that first flight in 1926 for which he is perhaps best remembered, and it is that flight that the engineers at MSFC hope to replicate.

Replicating the Goddard rocket is an appropriate way for Marshall Space Flight Center to celebrate the centennial of powered flight, since MSFC has been one of the nation's premier centers for research and development of rocketry and space propulsion systems for 43 years. Already, the team has created a replica of the rocket, which is as historically accurate as possible, both inside and out, and which contains accurate reproductions of the launch structure, injector assembly, combustion chamber, valves, control mechanisms, and nozzle. The task is made more challenging because Goddard left behind no detailed drawings of his rocket. Lacking details from the creator himself, the team has used drawings and photographs done by others at the time.

Now, the team faces a larger challenge—recreating a version of Goddard's first liquid-fueled rocket that can be considered flight-worthy in today's more safety-conscious era. Some things have to be changed, such as the asbestos heat shielding. Also being changed is the ignition system Goddard used for his rocket—a blowtorch on a stick lit the match-head-filled stub on the igniter, not quite up to par with today's safety standards. Step one is working backwards to figure out just how, exactly, Goddard's rocket did work. As components are built, they are tested using NASA's modern equipment, allowing an in-depth analysis of the technology that was not possible in Goddard's day. This will the first time anybody has really benchmarked what he did in a modern way. It's no small task, either—while Goddard's first rocket was a small-group operation, the team recreating it includes over two dozen contributors, each lending his or her own area of expertise.

One of Robert Goddard's most famous quotes is, "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow." One wonders what the rocketry pioneer would have thought of the fact that, through the ongoing fascination in his research, the reality of yesterday has become the dream of tomorrow.

Courtesy of NASA's Aeronautics Mission Directorate

Three Ways to Change Your Altitude

Teacher Sheet(s)

Objective:	To determine the altitude of a launched rocket using multiple techniques.

Level:	9-12
Subjects(s):	Trigonometry, Science, Technology
Prep Time:	10-30 minutes
Duration:	One to two class periods
Materials Category:	Common Household

National Standards:

Science:	1b, 2a, 3d
Math:	13a, 21c
Technology (ISTE):	11
Technology (ITEA):	2d, 13a,13c

Materials:

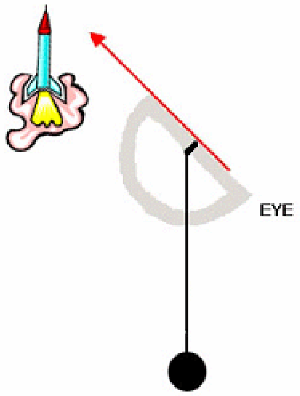
- Student sheets
- Stopwatch
- Protractor
- String
- Washer or small weight
- Calculator
- Meter Stick
- Materials from one of the lessons in the Related Lessons section

Pre-Lesson Instructions:

- Duplicate the Student Sheets (one per group):
- You will need a launch-able rocket. You can use of any of the three lessons in the Related Lessons section. Two of them are water-related, and the other is air-related. Each has different material lists and set-up times. You can use any of them for this activity. Depending on which rocket you choose, you will need a large, outdoor area to launch them. Follow the instructions from the Related Lesson that you picked to build the rocket. This can be done the same day as the activity, or it can be done at an earlier time.
    - Divide the class into groups of three or four.
    - Each group will need a protractor, a washer or a small weight, and a stopwatch.

Background Information:

Launching rockets can be fun and exciting. One of the first questions you may be asked is: “How high did it go?” Today’s activity will give you three ways of measuring that height. Even without special equipment, you can make a pretty good measurement of a rocket’s altitude.



Method one will be using a landmark of a known height to reference. This method, called eyeball, will be guess of how high the rocket went in reference to the landmark. Knowing that each floor of a building is about 3 meters (10 feet) will help.

Method two will be using a stopwatch to time the rocket’s ascent. Start the timer at launch, and stop it when the rocket is no longer going up. Alternatively, you can time the launch from start to finish and divide the time by two. From there, you can solve for the height reached by the rocket.

Method three will be using a protractor, a string, and a small weight. Tie the small weight to one end of the string. Tie the other end to the middle of the protractor. Holding the protractor upside down, the string should be held taut by the weight as it sweeps out the angles on the protractor. Holding the protractor to your eye, you can find the angle made by the rocket at its highest point. Standing a known distance from the launch, you can use trigonometry to find the height of the rocket above the ground.

Guidelines:

1. Read aloud, or have students read to themselves the article “Recreating History.”
2. Divide the class into groups.
3. Distribute the Students Sheets.
4. If building the rocket is a part of this activity, spend the first part of the class doing that.
5. Each group will be determining the altitude their rocket flies. There are three methods: eyeball, time, and triangle.
6. Go outside, have each group launch its rocket, and tell them to determine its altitude. Repeat two more times.
7. Answer the questions and fill in the chart.

Discussion/Wrap-Up:

- Discuss the motion of a launched rocket.
- Discuss how each of the three methods will work. Ask the students, “Which method do you think will be more accurate?”
- Answers to the questions will vary from group to group. They are designed to get them to think critically about this experiment. Check to be sure their logic is correct.

Student Sheet(s)

Background Information

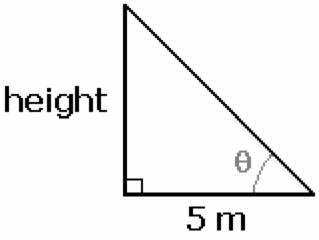
Note to Teacher: The background information can be found in the Teacher Sheet.

Materials

1. Stopwatch
2. Protractor
3. String
4. Washer or small weight
5. Calculator
6. Meter stick

Procedure:

1. Using your rocket, your group will find its maximum height after launch. Each group member will responsible for a different height measurement for each launch.



2. Here are the three methods you will use.

   a. Eyeball—using a landmark near the launch sight, guess how high the rocket went in reference to it.
   b. Time—use a stop watch to measure the time for the rocket to reach its maximum height.
   c. Triangle—using a protractor and plumb line, stand 5 meters (m) from the launch, and find the greatest angle made by the rocket in flight.

3. Write the eyeball amount in the chart.

4. Using the following equation, plug in the time you measured and solve for the distance. Record this number in the chart.

- $h = \frac{1}{2} g t^2$
- where h is the height in m or feet (ft), g is the acceleration of gravity (9.8 meters per second squared [m/s^2] or 32 feet per second squared [ft/s^2]), and t is the time you measured for the ascent in seconds (s).

5. Using the angle you measured and your distance (5 m) from the launch, solve for the height. Knowing the bottom of the triangle and the angle, use tangent to find the vertical height.

6. Launch your rocket three times, and record the height for each launch using the three different techniques. You can use feet or meters for the height, whichever your teacher chooses.

Maximum Height Of Rocket During Launch			
Method	**Launch 1**	**Launch 2**	**Launch 3**
Eyeball			
Time			
Triangle			

7. Answer the following questions:
    a. How close are your results for each method?
    b. Which one do you think is the most accurate? Explain.
    c. Which one do you think is the least accurate? Explain.
    d. Is there another method that you could use? Explain.

Related Lesson: Paper Rockets

Article: Souped-Up Shuttle Engine

Notice anything new about the Space Shuttle engines pictured to the left? You probably wouldn't unless you were a NASA scientist with a specific interest, but the ones in the picture feature the new and improved Block II main engines. This photo shows the engines awaiting their first trip to space aboard Space Shuttle mission STS-104 in July 2001.

That July mission sent just one Block II engine into space—it's a NASA safeguard when using new equipment, just in case there's an unanticipated problem. Shuttle launch STS-105, set to launch August 9, sends three of the new-and-improved engines blasting into space. This will mark the Block II's transition to full use in the Shuttle program.

What's so special about the Shuttle's improved engine system? The Block II engine has two primary changes from the original Block I engine, and those changes are safety upgrades, says George Hopson, manager of the Space Shuttle Main Engine Project office at NASA's Marshall Space Flight Center in Alabama. "This engine is on the cutting edge of technology, and is the most advanced combustion engine for this job. It meets our goals of efficiency, economy, safety and performance." If you could compare a Saturn V engine to a family car, the Block II engine would be a high-performance, souped-up Ferrari.

You could also compare the Shuttle engines to a Corvette. The three main engines plus the two solid rocket motors deliver the horsepower of about 120,000 Corvettes. With all that power and all that fuel consumption, having a safe, reliable engine is of paramount importance.

Safety Upgrades to the Engine

The two changes made to the Shuttle engine are a large-throat main combustion chamber and a new fuel pump.

During combustion, hydrogen and oxygen are expelled through a nozzle to increase the velocity of the gases and to give thrust, Hopson says. The smaller the throat of that combustion chamber, the higher the pressure, and the more thrust is created. High pressure and high temperature are the most severe environments an engine faces, and if both temperature and pressure can be lowered, that makes a more reliable system that is less apt to fail. The new engine has a larger throat opening, which costs the Shuttle a bit in performance, but the tradeoff is that the engine itself is safer. To everyone at NASA, safety is the top priority.

The Space Shuttle engine's fuel pump rotates at 35,000 revolutions per minute (rpm) as it sends fuel throughout the engine, and all that rotation means that it wears down quickly. The old pump needed to be pulled off and inspected after every flight, and was rebuilt after every seven missions. The new pump can go 10 flights before an inspection, so the cost and timesavings are obvious. "If you had to remove your car's engine every time you take a trip, that would be quite a chore," says Hopson. "The same applies to the Space Shuttle's engine." The new pump is beefed up structurally, and the bearings have an increased load-carrying capability. The old Block I pump was a welded model, whereas the Block II is built with bolts. A welded pump is lighter, but flaws can pass undetected. An internal crack in a weld would be disastrous, but a bolted pump can be disassembled for more detailed inspections. Once again, safety comes first in space travel.

The Block II engines operate for only about 8.5 minutes during liftoff and ascent, and then shut down just before the Shuttle reaches low-Earth orbit. Those 8 minutes are crucial, though. They provide thrust to assist the solid rockets in propelling the Shuttle up through the Earth's atmosphere and into orbit.

"The speed of liftoff is controlled by a ratio of weight and thrust," Hopson says. "Saturn 5 took 9 seconds to clear the tower. The Shuttle requires only about half that time. Both engines had similar thrust, but the Shuttle weighs far less. Of course, the Shuttle has a shorter distance to travel. Saturn had to propel the Apollo modules out of Earth's orbit and to the Moon."

The Block II engine has been in the works for 10 years and is the result of concentrated efforts to create a more efficient product, says Hopson.

When the Block II engine launched for its first actual mission in July of 2001, the development team was pleased to see that it met every goal and functioned perfectly. Television viewers who saw the Shuttle lift off uneventfully didn't see anything different—and that's exactly what the NASA folks wanted.

Courtesy of NASA's Aeronautics Mission Directorate

Paper Rockets

Teacher Sheet(s)

Objective: To design, construct, and fly paper rockets that will travel the greatest distance possible.

Level:	5-8
Subjects(s):	Science
Prep Time:	Less than 10 minutes
Duration:	50 minutes
Materials Category:	General Classroom

National Education Standards
Science: 2a, 3b
Math:
Technology (ISTE):
Technology (ITEA):
NGS Geography Standards:

Materials:

- Scrap bond paper
- Cellophane tape
- Scissors
- Sharpened fat pencil
- Milkshake straw (slightly thinner than pencil)
- Eye protection
- Metric ruler
- Masking tape
- Student Sheets

Related Links:

Lesson adapted from the following NASA site:
NASA Quest-Space Team Online

Supporting Article(s):
Souped-Up Shuttle Engine

Pre-Lesson Instructions:

- Prepare a paper rocket prior to teaching this lesson to show as an example to the students.
- Students may work individually or in pairs for this activity.
- Because the rockets are projectiles, make sure students wear eye protection.
- Select a location for flying the rockets. A room with open floor space or a hallway is preferable. Prepare the floor by marking a 10-meter test range with tape measures or meter sticks laid end to end.

Background Information:

NASA has a new and improved engine system for the Space Shuttle. What's so special about this new engine system? The Block II engine has two primary changes from the original Block I engine. Those changes are safety upgrades, says George Hopson. He's the manager of the Space Shuttle Main Engine Project office at NASA's Marshall Space Flight Center in Alabama. "This engine is on the cutting edge of technology, and is the most advanced combustion engine for this job. It meets our goals of efficiency, economy, safety and performance." If you could compare a Saturn V engine to a family car, the Block II engine would be a high-performance, souped-up Ferrari.

You could also compare the Shuttle engines to a Corvette. The three main engines plus the two solid rocket motors deliver the horsepower of about 120,000 Corvettes. With all that power and all that fuel consumption, having a safe, reliable engine is of paramount importance.

In this lesson, students will build their own paper rockets, and predict how far they will fly. They will use lung-power for propulsion, and safety goggles for added safety parameters.

Guidelines:

1. Read the article "Souped-Up Shuttle Engine." Discuss the article as a class, and any questions the students may have.
2. Explain that the students are going to be constructing their own rockets. Show the pre-made rocket as an example to the class.
3. Hand out Student Sheets.
4. Distribute the materials, and construction tools to each student or group.
5. Each student should construct a rocket as shown in the instructions on the Student Sheets.
6. Tell students to predict how far their rockets will fly, and to record their estimates on the Student Sheets. After test flying the rocket and measure the distance it

reached, students should record the actual distance, and the difference between the predicted and actual distances on the Paper Rockets Test Report.

Discussion/Wrap-up:

- What makes on rocket perform better than another? (Do not forget to examine the weight of each rocket. Rockets made with extra tape and larger fins weigh more.)
- How small can the fins be and still stabilize the rocket?
- How many fins does a rocket need to stabilize it?
- What would happen if you placed the rocket fins near the rocket's nose?
- What will happen to the rocket if you bend the lower tips of the fins in pinwheel fashion?
- Are rocket fins necessary in outer space?

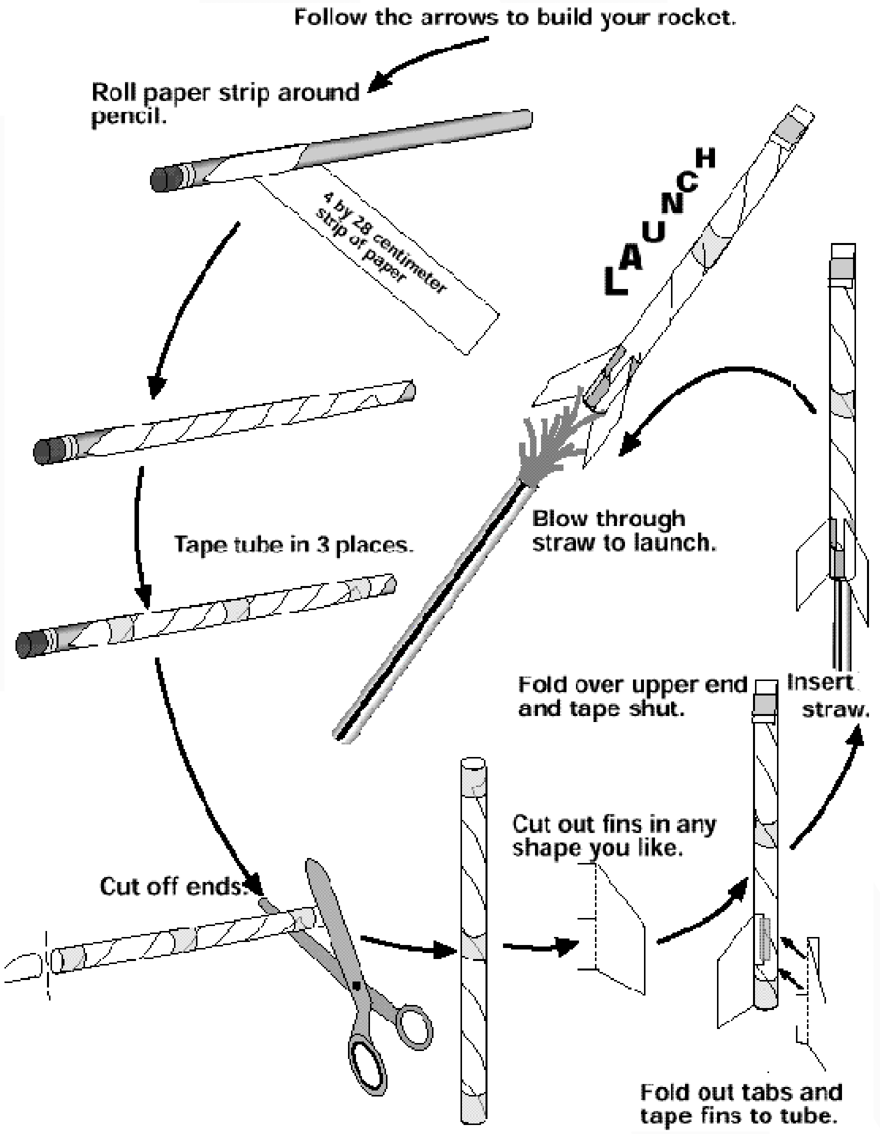
Extensions:

- Have students construct, and test two additional rockets of different sizes and fin designs.
- Try to determine how high the rockets fly. To do so, place masking tape markers on a wall at measured distances from the floor to the ceiling. While one student launches the rocket along the wall, another student compares the height the rocket reached with the tape markers. Be sure to have the students subtract the height from where the rocket was launched from the altitude reached. For example, if students held the rocket 1.5 meters from the floor to launch it, and it reached 4 meters above the floor, the actual altitude change was 2.5 meters.
- If time allowed for more than one rocket to be constructed, have students create a bar graph to show how far each of the rockets they constructed flew.
- Have students write a paragraph summarizing which rocket performed the best, and explain their ideas for why it performed as it did.

Paper Rockets

Student Sheet(s)

Name: ________________________



Follow the arrows to build your rocket.

Roll paper strip around pencil.

Tape tube in 3 places.

Cut off ends.

Cut out fins in any shape you like.

Fold out tabs and tape fins to tube.

Fold over upper end and tape shut.

Insert straw.

Blow through straw to launch.

Paper Rockets Launch Record Report

1. Launch your rocket three times. How far did it fly each time? What is the average distance your rocket flew? Write your answers in the spaces below.
2. In the space below, write a short paragraph describing the rocket you built and how it flew. Draw pictures of the rocket you constructed.

Rocket Launch

How far did it fly in centimeters?

1. _______________
2. _______________
3. _______________

Average distance in centimeters?

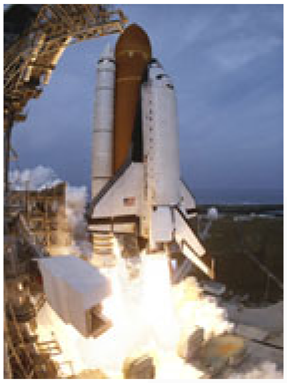
____

Make notes about the flight here:

Draw a sketch of your rocket here.

Related Lesson: Bottle Rocket

Article: Bolting it Down



Here's the situation: on the Space Shuttle launch pad, you need something really strong to hold things in place until liftoff, yet when it's time for parts to separate, you need them to let go right away. How do you accomplish such a task? The answer isn't in big steel structures; it's in little nuts and bolts. *Exploding* nuts and bolts.

"The two solid rocket boosters weigh 2.25 million pounds, and the orbiter with payload weighs less than .25 million pounds," says Greg Katnik, mechanical systems engineer at NASA Kennedy Space Center. "You really don't have to worry about the vehicle tipping over on the Mobile Launcher Platform. Nevertheless, we anchor the Space Shuttle to the launch pad with eight hold-downs, using inconel studs, which are a high-performance metal alloy."

The studs are 78.7 centimeters (31 inches) long and 9.1 centimeters (3.6 inches) in diameter, clamped with great force to the launch pad. There are two pyrotechnic charges in the nut, and when fired at launch, the nut splits in two pieces, the clamping force is released, and the stud falls away. Presto! Liftoff!

The nuts aren't your everyday, run-of-the-mill nuts, says Katnik. They're 15.8 centimeters (6.25 inches) in diameter, which leaves plenty of room to drill a small hole in the top side of each nut. A pyrotechnic device (think fire cracker) is inserted in the hole. A computer-controlled explosion detonates the charge, which splits the metal surrounding the device, and the nut falls away. That allows the studs to fall away with ease.

Those pyrotechnic devices have other uses at launch time. There's a swing arm that holds a hydrogen vent line to the external tank. This line collects gaseous hydrogen from the tanks and removes the explosive vapors. When a pyrotechnic bolt is fired, the arm swings away, moving the hydrogen vent out of the way of the rapidly rising spacecraft.

By the main engine, there are two Time Zero connections that supply plumbing service lines for the orbiter while it's awaiting takeoff. These

lines run through a carrier plate, and guess how they're moved aside when it's time for lift off? More pyrotechnic bolts.

Atop the external tank there are oxygen lines that are useful while the Shuttle is sitting on the launch pad, but dangerous if present at the firing of the booster rockets. The lines vent the excess 20 feet away from the orbiter, but at T-minus-2 minutes, they're hydraulically removed.

The Space Shuttle crew boards the orbiter through the Orbiter Access Arm, which is connected to the famous White Room (where last-minute details are attended to). At T-minus-2 hours, the astronauts enter the Shuttle, the orbiter entrance is sealed at T-minus-20 minutes, and at T-minus-7, the Orbiter Access Arm is moved away. In case of emergency, the Orbiter hatch can be jettisoned and propelled about 200 feet away from the Shuttle by more pyrotechnic devices.

With all those nuts and bolts exploding, you'd think there would be an awful lot of metal pieces on the ground. After the launch, every nut and bolt is collected and analyzed to see if it fired correctly and if the separation was clean. "We can't leave metal on the launch pad," says Katnik. "We have containers surrounding each pyrotechnic bolt or nut; after the launch, we gather the fragments of the bolts and nuts. The ones on the outside of the flight hardware—solid rocket boosters—are contained within the hold-down posts, and are taken back to the lab. The ones attached to the flight hardware itself are contained within the Debris Containment System-a stainless steel basket attached to the side of the solid rocket boosters. When the boosters fall into the ocean and are recovered, there are our nuts and bolt fragments. They're brought back here to Kennedy Space Center and are analyzed."

Referring to the nuts and bolts as "explosive" is a bit misleading, Katnik says. It implies that the firing is uncontrolled and random. Computers handle the timing of the detonation, and it's with split-second precision that each nut is fired. "On many of the structures, there is a pyrotechnic device on each side," says Katnik. "If one side should fire even slightly ahead of the other side, that could result in an unbalanced release of whatever the nut is holding in place. The "explosions" are far from uncontrolled; they're extremely precise and usually timed to the millisecond."

Courtesy of NASA's Space Operations Mission Directorate

Bottle Rocket

Teacher Sheet(s)

Objective: To construct and launch a simple bottle rocket.

Level:	5-8
Subjects(s):	Science
Prep Time:	Overnight / Extended
Duration:	Two class periods
Materials Category:	Special requirements

National Education Standards

Science:	3a, 3b, 6a, 6b
Math:	21
Technology (ISTE):	
Technology (ITEA):	
NGS Geography Standards:	

Materials:

For launch pad:

- Four 5-inch corner irons with 12 3/4-inch wood screws to fit
- One 5-inch mounting plate
- Two 6-inch spikes
- Two 10-inch spikes or metal tent stakes
- Two 5-inch by 1/4-inch carriage bolts with six 1/4-inch nuts
- One 3-inch eyebolt with two nuts and washers
- Four 3/4-inch diameter washers to fit bolts
- One number 3 rubber stopper with a single hole
- One snap-in tubeless tire valve (small 0.453-inch hole, 2-inches long)
- Wood board 12 by 18 by 3/4-inches
- Electric drill and bits including a 3/8–inch bit
- Screwdriver
- Pliers or open-end wrench to fit nuts
- Vice
- 12 feet of 1/4-inch cord
- Pencil
- Bicycle pump with pressure gauge

Materials:

For each student group:

- 2-liter plastic soft drink bottles
- Low-temperature glue guns
- Poster board
- Tape
- Modeling clay
- Scissors
- Safety glasses
- Decals
- Stickers
- Marker pens

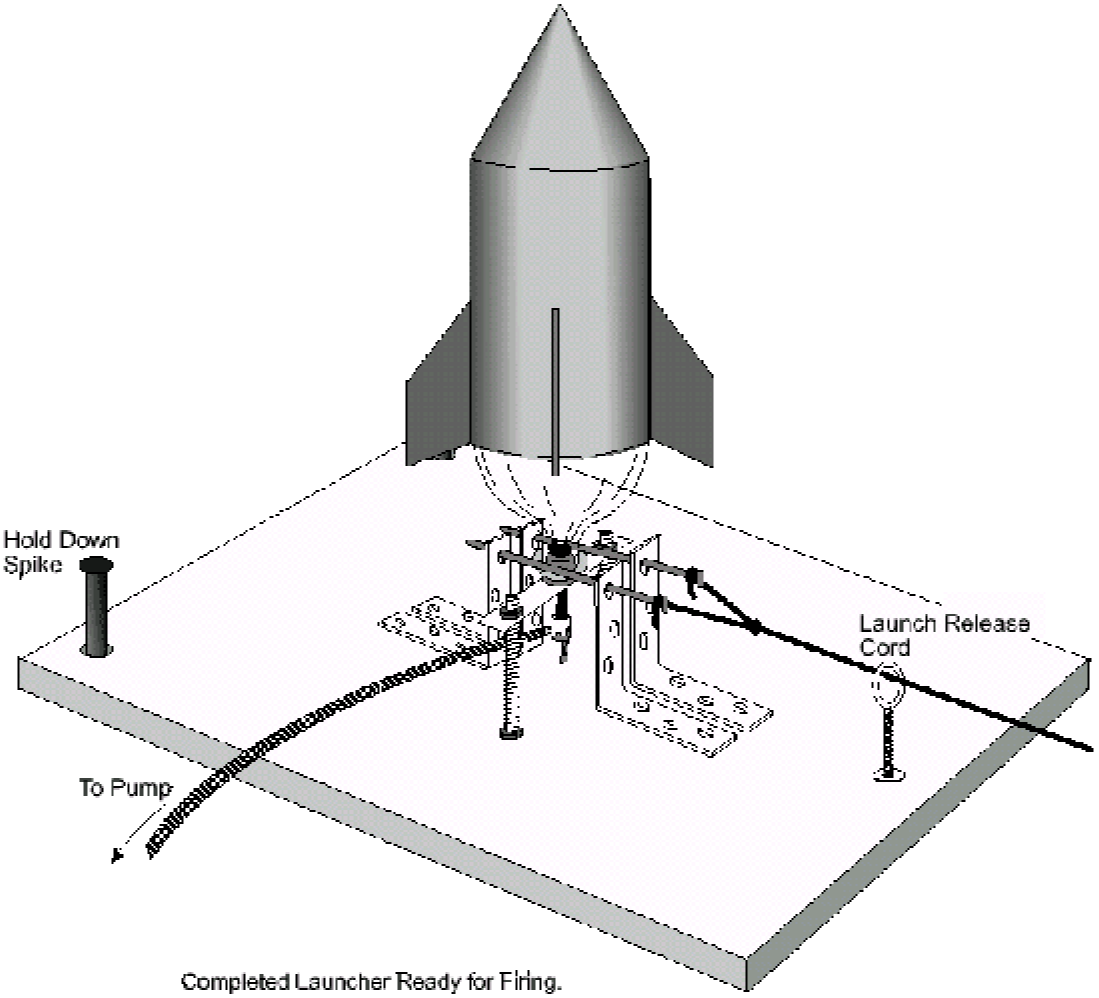
Related Links:

NASA Site used for derivation of Lesson Plan
Rockets Educator Guide

Supporting Article(s):
Bolting it Down

Pre-Lesson Instructions:
Consult the materials and tools list to determine what you will need to construct a single bottle rocket launcher. The launcher is simple and inexpensive to construct. Air pressure is provided by means of a hand-operated bicycle pump. The pump should have a pressure gauge for accurate comparisons between launches. Most needed parts are available from hardware stores. In addition, you will need a tire valve from an auto parts store and a rubber bottle stopper from a school science experiment. The most difficult task is to drill a 3/8-inch hole in the mending plate called for in the materials list. Electric drills are a common household tool. If you do not have access to one, or do not wish to drill the holes in the metal mending plate, find someone who can do the job for you. Ask a teacher or student in your school's industrial arts shop, a fellow teacher, or the parent of one of your students to help.

If you have each student construct a bottle rocket, having more than one launcher may be advisable. Because the rockets are projectiles, safely using more than one launcher will require careful planning and possibly additional supervision. Please refer to the launch safety instructions.



Completed Launcher Ready for Firing.

Background Information:

Bottle rockets are excellent devices for investigating Newton's Three Laws of Motion. The rocket will remain on the launch pad until an unbalanced force is exerted propelling the rocket upward (First Law). The amount of force depends upon how much air you pumped inside the rocket (Second Law). You can increase the force further by adding a small amount of water to the rocket. This increases the mass the rocket expels by the air pressure. Finally, the action force of the air (and water) as it rushes out the nozzle creates an equal and opposite reaction force propelling the rocket upward (Third Law). The fourth instruction on the Student Sheet asks the students to press modeling clay into the nose cone of the rocket. Placing 50 to 100 grams of clay into the cone helps to stabilize the rocket by moving the center of mass farther from the center of pressure.

Having the learners work in teams will reduce the amount of materials required. Begin saving 2-liter bottles several weeks in advance to have a sufficient supply for your class. You will need to have at least one bottle rocket launcher. Construct the launcher described in the previous activity or obtain one from a science or technology education supply catalog.

The simplest way to construct the rockets is to use low-temperature electric glue guns that are available from craft stores. High-temperature glue guns will melt the plastic bottles. Provide glue guns for each table or set up glue stations in various parts of the room.

Collect a variety of decorative materials before beginning this activity so students can customize their rockets. When the rockets are completed, test fly them. When launching rockets, it is important for the other students to stand back. Countdowns help everybody know when the rocket will liftoff. In group discussion, have your students create launch safety rules that everybody must follow. Include how far back observers should stand, how many people should prepare the rocket for launch, who should retrieve the rocket, etc.

Guidelines:

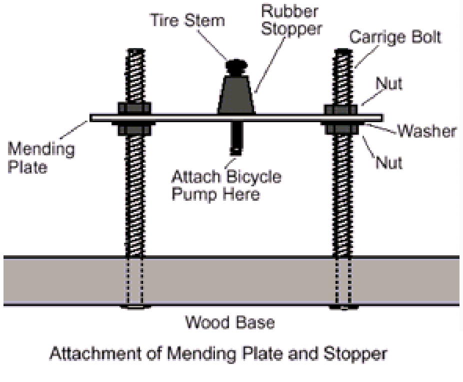
Instructions for constructing Launch Pad

1. Prepare the rubber stopper by enlarging the hole with a drill. Grip the stopper lightly with a vice, and gently enlarge the hole with a 3/8-inch bit and electric drill. The rubber will stretch during cutting, making the finished hole somewhat less than 3/8 inches.

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

3. Prepare the mounting plate by drilling a 3/8-inch hole through the center of the plate. Hold the plate with a vice during drilling, and wear eye protection. Enlarge the holes at the opposite ends of the plates using a drill bit slightly larger than the holes to do this. The holes must be large enough to pass the carriage bolts through them. (See Attachment of Mending Plate and Stopper diagram below.)

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



Attachment of Mending Plate and Stopper

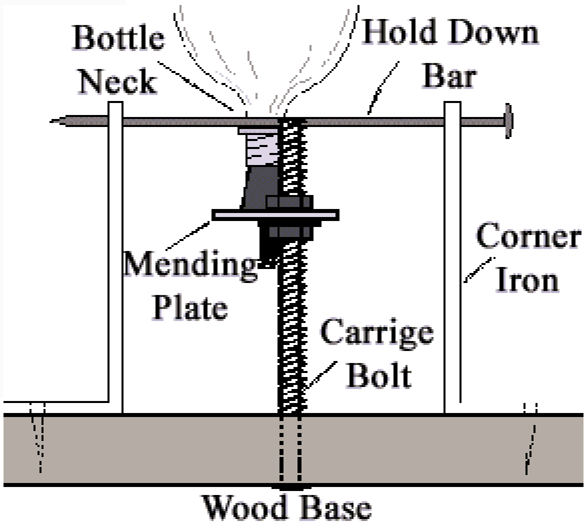
5. Push and twist the tire stem into the hole you drilled in the center of the mounting plate. The fat end of the stopper should rest on the plate.

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

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

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

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



Positioning Corner Irons

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

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

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

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

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

Guidelines:

Instructions for leading student activity

1. Read the article, "Bolting It Down."
2. Go over the procedure listed on the Student Sheet.
3. Show students the launch pad, and ask them what part of the launch pad is similar to the hold-down bolts talked about in the article. (The spikes holding the bottle on the pad.)
4. Have students construct their rockets. Encourage imagination, creativity, and scientific thought (symmetry, etc.).
5. Have the students present their designs to the class.
6. Launch the rockets (see Launch Safety Instructions below).

Discussion/Wrap-up:

Evaluate each bottle rocket on its quality of construction. Observe how well fins align and attach to the bottle. Also observe how straight the nose cone is at the top of the rocket. If you choose to measure how high the rockets fly, compare the altitude the rockets reach with their design and quality of the construction.

Launch Safety Instructions:

1. Select a grassy field that measures approximately 30 meters across. Place the launcher in the center of the field, and anchor it in place with the spikes or tent stakes. (If it is a windy day, place the launcher closer to the side of the field from which the wind is coming so that the rocket will drift on to the field as it comes down.)
2. Have each student or student group set up their rocket on the launch pad. Other students should stand back several meters. It will be easier to keep observers away by roping off the launch site.
3. After the rocket is attached to the launcher, the student pumping the rocket should wear eye protection. The rocket should be pumped no higher than about 50 pounds of pressure per square inch.
4. When pressurization is complete, all students should stand behind the rope for the countdown.
5. Before conducting the countdown, be sure the place where the rocket is expected to come down is clear of people. Launch the rocket when the recovery range is clear.
6. Only permit the students launching the rocket to retrieve it.

Extensions:

- Challenge rocket teams to invent a way to attach a parachute to the rocket that will deploy on the rocket's way back down.
- Parachutes for bottle rockets can be made from a plastic bag and string. The nose cone is merely placed over the rocket and parachute for launch. The cone needs to fit properly for launch or it will slip off. The modeling clay in the cone will cause the cone to fall off, deploying the parachute or paper helicopters, after the rocket tilts over at the top of its flight.
- Extend the poster board tube above the rounded end of the bottle. This will make a payload compartment for lofting various items with the rocket. Payloads might include streamers or paper helicopters that will spill out when the rocket reaches the top of its flight. Ask the students to identify other possible payloads for the rocket. If students suggest launching small animals with their rockets, discuss the purpose of flying animals and the possible dangers if they are actually flown.
- Conduct flight experiments by varying the amount of air pressure and water to the rocket before launch. Have the students develop experimental test procedures and control for variables.
- Conduct spectacular nighttime launches of bottle rockets. Make the rockets visible in flight by taping a small-size chemical light stick near the nose cone of each rocket. Light sticks are available at toy and camping stores and can be used for many flights. This is an especially good activity for summer "space camp" programs.

Bottle Rocket

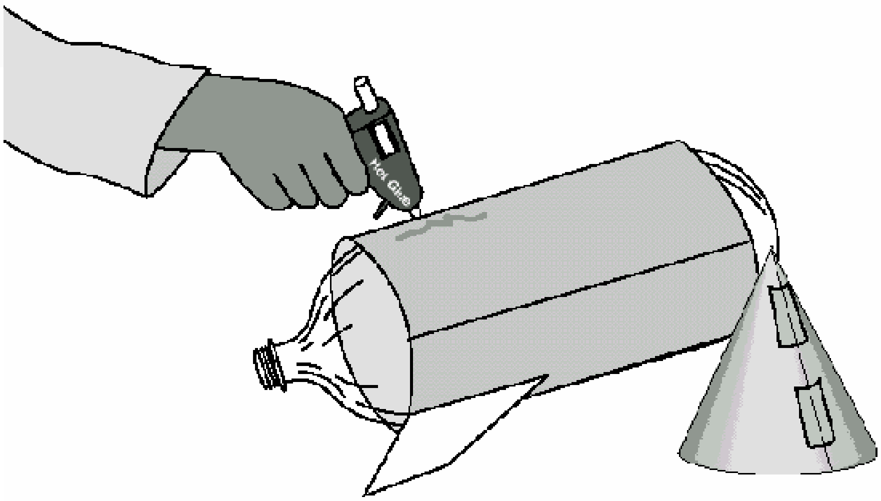
Student Sheet(s)

Materials:

- 2-liter plastic soft drink bottles
- Low-temperature glue guns
- Poster board
- Tape
- Modeling clay
- Scissors
- Safety glasses
- Decals
- Stickers
- Marker pens
- Launch pad

Procedure:

1. Wrap and glue or tape a tube of poster board around the bottle
2. Cut out several fins of any shape and glue them to the tube.
3. Form a nose cone and hold it together with tape or glue.
4. Press a ball of modeling clay into the top of the nose cone.
5. Glue or tape nose cone to upper end of bottle.
6. Decorate your rocket.



Related Lesson: Thrust Versus Fuel

Article: Escape Velocity: Fun and Games

Did you ever watch a group of children playing "Red Rover?" Arms linked up for strength, they chant, "Red Rover, Red Rover, let Sally come over," and Sally's challenge is to break through that chain of linked arms. If she does it, Sally wins.

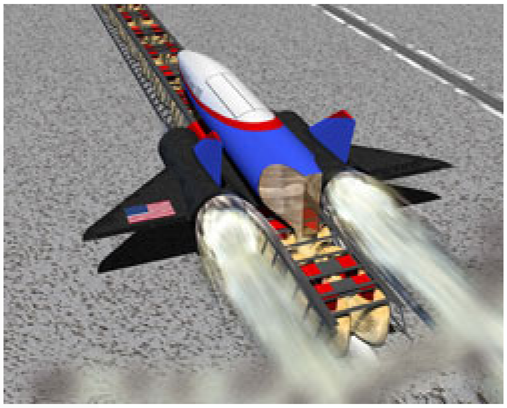
If Sally breaks through the chain of arms, she's also demonstrated several key aspects to the space concept of escape velocity. Escape velocity—or a rousing game of Red Rover—requires an object to propel itself with enough speed and thrust to break through a barrier. Sally's reward is the cheers of her teammates. A spacecraft's reward is a journey into space or orbit.

Escape velocity is the speed at which an object must travel to break free of a planet or moon's gravitational force, and enter orbit. A spacecraft leaving the surface of Earth, for example, needs to be going about 11 kilometers (7 miles) per second, or over 40,000 kilometers per hour (25,000 mph) to enter orbit.

An Endless Cycle

Achieving escape velocity is one of the biggest challenges facing space travel. The vehicle requires an enormous amount of fuel to break through Earth's gravitational pull. All that fuel adds significant weight to the spacecraft … and when an object is heavier, it takes more thrust to lift it. To create more thrust, you need more fuel. It's a cycle that scientists are hoping to resolve by creating lighter vehicles, more efficient fuels, and new methods of propulsion that don't require the same ingredients to attain great speeds.

That cycle of speed, fuel and weight was a primary reason the Saturn V rocket that took the first astronauts to the Moon was so large. It required such enormous quantities of fuel to break free of the Earth's gravitational pull that a vehicle of this size was the only workable solution. The Space Shuttle in use now is much smaller, but it doesn't have nearly as far to travel, or nearly as much gravitational force to overcome. Future space propulsion projects, such as magnetic levitation could reduce size requirements because speed and propulsion will be created in a manner that doesn't require large fuel tanks.



In astronomy, the term orbit refers to the path of an object whose motion through space is controlled by the gravitational pull of another object. The Moon orbits the Earth, and the Earth, in turn, orbits the Sun. Spacecraft can also orbit the Earth. If an object gains enough speed to attain escape velocity, its orbit becomes an open curve called a parabola. If it continues moving faster than escape velocity, its orbit is a flattened curve called a hyperbola. A spacecraft that leaves its orbit around the Earth on a journey toward another planet travels in a hyperbolic orbit.

Using Sally's Red Rover game as an example, think how much more easily she could break through the chain if she approached the line on turbo-charged roller skates, or if she had a spear-shaped battering ram in front of her. Alternate methods of propulsion and maximized aerodynamics are two factors scientists are researching as they explore the possibilities for achieving escape velocity with less difficulty.

Courtesy of NASA's Aeronautics Mission Directorate

Thrust Versus Fuel

Teacher Sheet(s)

Objective: Using a common toy store water rocket, students do “hands-on” group activities to complete a fun graphing mathematics exercise.

Level:	5-8
Subjects(s):	Science, Mathematics
Prep Time:	Less than 10 minutes
Duration:	One class period
Materials Category:	Special requirements

National Education Standards

Science:	2a, 3b
Math:	4a, 4b, 6a, 14a
Technology (ISTE):	
Technology (ITEA):	
NGS Geography Standards:	

Materials:

- Toy store water rockets with pump mechanism
- Container for water
- Graph paper
- Pencil
- Outdoor open area, free of parked cars

Related Links: *(None)*

Supporting Article(s):
Escape Velocity: Fun and Games

Background Information:
This activity demonstrates a common problem that occurs when trying to launch a rocket into space. The students will see the relationship between fuel and thrust.

Guidelines:

1. Read the article "Escape Velocity: Fun and Games."
2. Assign teams of rocket engineers.
3. Have a safety briefing for the time rocket is launched:
    - Cover heads during the descent of rocket.
    - Stand back during launch.
4. Have students prepare the graph template.
    - Establish a horizontal axis incremented with water levels.
    - Establish a vertical axis incremented in terms of altitude.
    - Mark the bottom of the vertical scale "low altitude" and the top labeled "very high altitude."
5. Graph the flight of each rocket.

Discussion/Wrap-up:

- From the experiment, what was the optimal water level for achieving maximum heights?
- Discuss the role of an aeronautical engineer.
- People designing aircraft are constantly making decisions concerning the degree or magnitude of things like thrust versus fuel consumption versus weight versus payload, etc.
- Force involves Newton's Third Law of Motion in which the action of the water rushing from its nozzle (filling port) caused the rocket to go in the opposite direction.
- When there was no water in the rocket, the air rushed through the nozzle so rapidly that the duration of thrust production was so low that it was incapable of sustained flight.
- Where the water levels were high, the weight of the rocket was such that the amount of thrust produced could hardly lift the rocket.
- The rockets with no water level and the ones with a lot of water will barely achieve altitude, while the 1/4- and 1/3-filled units will reach altitudes high enough to get caught in gutters or dent the metal of a parked automobile if it lands on one.

Extensions:

Computerize the data gained from the outdoor activity.

Thrust Versus Fuel

Student Sheet(s)

Materials:

- Toy store water rockets with pump mechanism
- Container for water
- Graph paper
- Pencil
- Outdoor open area, free of parked cars

Procedure:

1. You will test your rocket seven times.
2. For each test, you will fill your rocket with a different amount of water (fuel). The amounts you will test are:
    - empty
    - 1/4 full
    - 1/3 full
    - 1/2 full
    - 2/3 full
    - 3/4 full

    2.1. completely full
3. Place the rockets on the launch pad (pump mechanism) and apply an equal number of pumps for each test (about 15 strokes).
4. Observe the flight of the rocket when released following the countdown (10, 9, 8, 7 . . . 1, liftoff!)
5. Graph the flight of each rocket.

Altitude	**Very high**							
	Very low							
		empty	**1/4 full**	**1/3 full**	**1/2 full**	**2/3 full**	**3/4 full**	**full**
	Water Level							