Teacher Guide

Investigating Water Rockets: Abbreviated Approach

Background Information

This teacher's guide represents an alternate approach to conducting the Interaction/Synthesis section of this module in a shorter time frame and with less teacher preparation than is required if each group studies different variables in design (expert) teams. However, the safety aspects of this approach are still important and are noted below for the instructor and students to follow. The following table is a synopsis of the two approaches, so you will be able to make a decision that best meets your needs:

Interaction/Synthesis and Assessment	Comprehensive Approach	Abbreviated Approach
Safety Rules/Safety Checklist	Yes	Yes
Measuring Altitude	Yes	Yes
Nose Cone Group	Yes	No (While the nose cone is not tested, it should be constructed for the final assessment.)
Fin Number and Placement	Yes	No
Fin Shape and Size	Yes	Yes
Propulsion Volume of Water	Yes Individually in expert groups	Yes As a class
Pressure of Water	Yes	No
Weather or Not	Yes	No
You Get What You Pay For	Optional	No
Fly Me High (Assessment)	Yes	Yes

A critically important issue for these sessions is safety. Water bottle rocketry is fun, and it can be a great vehicle for understanding many scientific concepts; however, all safety precautions must be followed.

During this session, students will get a complete overview of the safety issues involved with building and launching bottle rockets. Safety is a major issue. Be certain that you study the accompanying "Safety Rules" with your students and that you monitor strict safety regulations during all launches. Instruct students to refer to the "Safety Checklist" each time they build or launch. Specific information is included in this unit.

In addition to learning about safety precautions, students will build an altitude tracker and practice using it in preparation for the upcoming rocket launches. The altitude tracker makes use of simple trigonometry to determine the altitude a rocket reaches in flight. For most accurate readings, at least four altitude readings should be taken. These reading stations should be at a distance of 33 feet (10 meters) from the launch pad at each position including north, east, south, and west. Once a rocket is launched, the four student spotters (standing at reading stations) should follow the path of the rocket through the altitude tracker sighting tube. When the rocket reaches its highest point (apex), each spotter should hold the weighted string in the position that it naturally falls and read and record the angle. Once the four angles are gathered, the high and the low angles should be omitted. The two remaining angles should be averaged. Students should then find the angle on the conversion chart, identifying the height that the rocket reached.

The teacher's guide in this section is divided into information for teachers to interact with student groups. Each group will be working on the same type of testing at the same time. The teacher's role becomes that of a facilitator of learning, rather than the source of knowledge. Encourage them to ask questions and find answers for themselves throughout the process. Your close supervision is required during the test launches. We recommend that you schedule test launches on one specific day of the week or when a critical mass is ready to test their variable. You may want to recruit the assistance of another adult to assist in this process.

National Science Standards Addressed

See: Investigating Water Rockets: Comprehensive Approach

Materials

Activity 1: What Do I Need to Know Before Launch?

- "Appendix J Safety Rules," page 124.
- "Appendix K Safety Checklist," page 126.
- Student activity, "Measuring Altitude," page 62.
- "NASA Altitude Tracker," page 123. (This pattern can be copied or glued onto tag board.)
- Thread, lightweight string, or fishing line.
- Cellophane tape.
- Small washer or 1–2 ounce (28–57 gram) fishing sinker.
- Scissors.
- Rope or string to measure out range (33 feet or 10 meters).
- Angle-to-Height Conversion Chart, page 64.
- Tennis ball per pair of students.

Activity 2: Propulsion for Entire Class

- Student activity, "Altitude vs. Water Volume," page 84.
- Several two-liter plastic soft drink bottles.
- Water.
- Graduated cylinders (one-liter).
- Tire pump or air compressor.
- Safety glasses.
- Altitude trackers.
- Conversion chart, page 64.
- Rope to measure out range (33 feet or 10 meters).
- Compass to determine north, south, east, or west.
- Launcher (see Appendix G) or search the Internet to purchase a launcher.

Activity 3: Fin Shape

- Student activity, "Investigating Fin Shape or Size," page 72.
- Paper towel tubes.
- Tag board (for fins).
- Ruler.
- Cellophane tape and/or glue.
- Scissors.
- Safety glasses.
- Launching mechanism (vacuum with blower or leaf blower).
- Yard (or meter) stick for measuring distances.
- Arrows: some with and some without feathers.

Preparation

1. Gather materials for all of the activities.
2. Make copies of "Student Activity" pages. The Altitude Tracker needs to be copied on heavy weight paper.
3. Make a sample altitude tracker to use as an example.
4. Construct a water bottle rocket launcher or search the Internet to purchase a pre-made launcher. Instructions for construction of the launcher are located in Appendix G.

Activity 1: What Do I Need to Know Before Launch?

Procedure

1. Read through all the "Safety Rules," page 124, with the students and then refer to the "Safety Checklist," on page 126. Students should sign the safety rules. If you have already discussed the safety rules with the students, ask them to point out the safety issues to you as they read through the directions for "Constructing an Altitude Tracker," which is included in the "Measuring Altitude" student activity on page 62.
2. Have each student construct an altitude tracker. The altitude tracker pattern can be found in Appendix I.
3. Have students complete the student activity, "Measuring Altitude," in their small groups.

Activity 2: Propulsion for Entire Class

Working as a class, students will determine the best water volume to make a two-liter bottle go the specified height (98 feet or 30 meters). The goal of this investigation is to gather evidence regarding optimum water volume based on their observations.

Background Information:

A water bottle rocket is a two-liter soda bottle filled with compressed air and water. During launch, when the pump valve is opened, the compressed air and water are released, sending the rocket in an upward direction. Students will have the opportunity to experience Newton's Three Laws of Motion as well as expand their conceptual understanding of motion, force, mass, and momentum.

For a detailed explanation of how these Three Laws of Motion apply to water bottle rockets, see the student text, "Newton's Laws of Motion and Rockets," on page 21.

Procedure:

1. While this activity will be completed as a class, students are each responsible for completing the student activity sheets, "Altitude vs. Water Volume," beginning on page 84. The following procedure will help you to facilitate this whole-class activity:
   a. Remove the labels from the bottles.
   b. Fill bottles with pre-determined volumes of water and cap the bottles. To streamline the procedure, have a group of students measure volumes of water that would have the bottle completely full, three-quarters full, half-full, one-quarter full, and empty.
   c. Put one bottle at a time on the launch pad and apply 50 psi of pressure.
   d. Use a compass to determine locations. Have an altitude tracker spotter positioned at each of these four positions (north, east, south, and west).
   e. Each spotter will use the altitude tracker to measure the angle of the highest point of flight.
   f. Each angle should be recorded; the high and low angles should be omitted.
   g. Two more trials should be made for that volume of water.
   h. Average the remaining angles (once the high and low angles for each of the three trials have been omitted) to come up with an average angle.
   i. Use the conversion chart, located in the "Measuring Altitude" student activity, to determine the height.
   j. Repeat the same procedure for the other volumes of water.

2. Once students have conducted the test, they may wish to look at manipulating other variables. Watch as they unknowingly transform into research scientists attempting to answer questions that they ask themselves. Listen carefully; many will (in their descriptions) be describing Newton's Laws of Motion.

   At just the right teachable moment, these laws can be explained and made understandable to very young students. Typical student statements that set the stage for new understandings include the following:

   a. Why did the rocket that was full of water barely take off? (It was too heavy [massive] — Newton's First Law.)
   b. The rocket did not have enough "oomph" (force) to make it take off. Why? (There was not enough force for the relatively huge mass — Newton's Second Law.)
   c. The water went one way and the rocket went the other way (Newton's Third Law).

3. Questions that might be asked to get the students thinking in the right direction include the following:

   a. What happens to the rocket as the water inside the bottle goes down?
   b. If you could eject the water twice as fast from the rocket, what effect would this have on the rocket?

4. At the end of the lesson, ask each student to write a conclusion, using their own words, describing what makes the bottle rockets fly.

Activity 3: Fin Shape

Students working in groups will examine two variables related to fins. Students may investigate various fin shapes including rectangle, triangle, semicircle, or polygon — each in various sizes. Students should keep the number and placement location on the rocket constant. The goal for this exercise is to gather evidence, based on research and observations, for the best fin design to allow the rocket to be stable during flight.

Background Information

A rocket with no fins is much more difficult to control than a rocket with fins. The size and shape of the fins, as well as their number and placement, are critical to achieving adequate stability without adding too much weight. For more information on stability and control systems, see page xiv at the beginning of this guide.

Procedure

1. Distribute the "Investigating Fin Shape or Size" student activity on page 72. Divide the students into small groups and instruct each group to complete the investigations on this sheet.
2. When the groups have completed the investigations, look at their plans. It is important that students examine each variable (i.e., fin shape, fin size) during separate tests.
3. Time should be provided for students to discuss their results and conclusions.
4. Individual students should write a conclusion summarizing what they have learned about the aerodynamics of fins through their research and observations. They need to make their explanation clear enough so that other people can understand it.

Teacher Resources

Publications

Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology, NASA EG-2003-01-108-HQ, Office of Human Resources and Education, Washington, DC, 2003.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Web sites

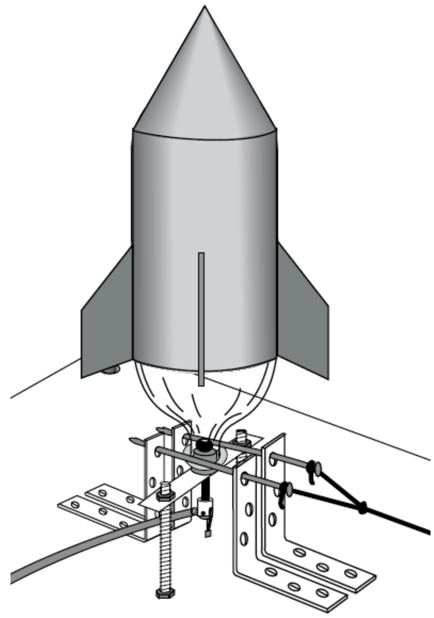
NASA's Beginner's Guide to Rockets — good for teachers and students:
http://exploration.grc.nasa.gov/education/rocket/bgmr.html

Rocket Index from NASA Glenn Research Center:
http://exploration.grc.nasa.gov/education/rocket/shortr.html

Teacher Guide

Investigating Water Rockets: Comprehensive Approach

Background Information



A critically important issue for these sessions is safety. Water bottle rocketry is fun, and it can be a great vehicle for understanding many scientific concepts; however, all safety precautions must be followed.

During this session, students will get a complete overview of the safety issues involved with building and launching bottle rockets. Safety is a major issue. Be certain that you study the accompanying "Safety Rules" (page 124) with your students and monitor strict safety regulations during all launches. Instruct students to refer to the "Safety Checklist" (page 126) each time they build or launch. Specific information is included in this unit.

In addition to learning about safety precautions, students will build an altitude tracker and practice using it in preparation for the upcoming rocket launches. The altitude tracker makes use of simple trigonometry to determine the altitude a rocket reaches in flight. For most accurate readings, at least four altitude readings should be taken. These reading stations should be a distance of 33 feet (10 meters) from the launch pad — one at each compass position — including north, east, south, and west. Once a rocket is launched, the four student spotters (standing at reading stations) should follow the path of the rocket through the altitude tracker sighting tube. When the rocket reaches its highest point (apex), each spotter should hold the weighted string in the position that it naturally falls and read and record the angle. Once the four angles are gathered, the high and the low angles should be omitted. The two remaining angles should be averaged. Students should then find the angle on the conversion chart, identifying the height that the rocket reached.

Students will work in the same collaborative (design) groups for "What Do I Need to Know Before Launch?" as they did for the other parts of the module. This will allow you to observe and experience what they know and do not know about rocketry and provide the motivation for them to want to learn more. Students work in design groups to discuss the first attempt at launching rockets; they will also assign expert roles. In expert groups, students will gain specific knowledge about one of the variables of successful rocket launching. They will bring this information back to their design group and that group will put together a newly designed rocket using each individual's expertise. After additional testing, they will launch in the competition to find who can launch a water rocket the highest.

The teacher guide in this section is divided into information for teachers to use in their interactions with the specific expert groups. The teacher's role becomes that of a facilitator of learning rather than the source of knowledge. With your supervision, your students can complete the activities within the expert learning group sessions. Encourage them to ask questions and find answers for themselves throughout the process. Your close supervision is required during the test launches. We recommend that you schedule test launches on one specific day of the week or when a critical mass is ready to test their variable. You may want to recruit the assistance of another adult to assist in this process.

Prior to the launch activity, students explore the safe parameters (weather conditions, etc.) that are guidelines used to determine if a launch can take place at a given time. Students use a simple fault-tree analysis to make decisions regarding a launch. This will include using technology to monitor the conditions at the local launch site to determine whether the launch should be conducted.

National Science Standards Addressed

Grades 5–8

Science as Inquiry
Abilities necessary to do scientific inquiry.
Physical Science
Motion and forces.
Science and Technology
Abilities of technological design.
Understandings about science and technology.
Science in Personal and Social Perspectives
Personal health.

Grades 9–12

Science as Inquiry
Abilities necessary to do scientific inquiry.
Physical Science
Motion and forces.
Science and Technology
Abilities of technological design.
Understandings about science and technology.
Science in Personal and Social Perspectives
Personal and community health.

Principles And Standards For School Mathematics Addressed

Measurement Standard for Grades 6–8

Understand measurable attributes of objects and the units, systems, and processes of measurement
Understand both metric and customary systems of measurement.
Apply appropriate techniques, tools, and formulas to determine measurements
Select and apply techniques and tools to accurately find length and angle measures to appropriate levels of precision.

Problem Solving Standard for Grades 6–8

Solve problems that arise in mathematics and in other contexts

Measurement Standard for Grades 9–12

Understand measurable attributes of objects and the units, systems, and processes of measurement
Make decisions about units and scales that are appropriate for problem situations involving measurement.

Problem Solving for Grades 9–12

Solve problems that arise in mathematics and in other contexts.

National Educational Technology Standards Addressed

Technology Standards for Students K–12
Technology Productivity Tools
Students use technology tools to enhance learning, increase productivity, and promote creativity.
Technology Research Tools
Students use technology to locate, evaluate, and collect information from a variety of sources.
Technology Problem-solving and Decision-making Tools
Students use technology resources for solving problems and making informed decisions.
Technology Standards for Students 6–8
Use content specific tools, software, and simulations to support learning and research.
Collaborate with peers, experts, and others using telecommunications and collaborative tools to investigate curriculum-related problems, issues, and information, and to develop solutions or products or audiences inside and outside the classroom.

Materials

Activity 1: What Do I Need to Know Before Launch?

- "Appendix J: Safety Rules," page 124.
- "Appendix K: Safety Checklist," page 126.
- Student activity, "Measuring Altitude," page 62.
- "NASA Altitude Tracker," page 123. (This pattern can be copied or glued onto tag board.)
- Thread, lightweight string, or fishing line.
- Cellophane tape.

- Small washer or 1–2 ounce (28–57 gram) fishing sinker.
- Scissors.
- Rope or string to measure out range (33 feet or 10 meters).
- Angle-to-Height Conversion Chart, page 64.
- Tennis ball per pair of students.

Activity 2: Nose Cone Experts

- Student activity, "What a Drag," page 65.
- Paper towel tube.
- "Appendix L: Nose Cone Pattern," page 127.
- Yard (or meter) stick.
- Several two-liter plastic soft drink bottles.
- Modeling clay.
- Card stock.
- Leaf blower or vacuum set to blow.
- Books to make a path.
- Long hall or open area.

Activity 3: Fin Experts (two groups)

- Student activity, "Flying Straight," page 68, for students in both groups.
- Student activity, "Investigating Fin Shape or Size," page 72, for one group. (Optional for students needing more structure.)
- Student activity, "Investigating Fin Number and Placement," page 78 for the second group. (Optional for students needing more structure.)
- Paper towel tubes.
- Tag board (for fins).
- Ruler.
- Cellophane tape and/or glue.
- Scissors.
- Safety glasses.
- Launching mechanism (vacuum with blower or leaf blower).
- Yard (or meter) stick for measuring distances.
- Arrows: both with and without feathers.

Teacher Tip

Jigsaw is a type of structure for use in cooperative learning activities in which students work with one group of students for a defined task. After completing the defined task, students then disperse and join into new groups. These new groups are jigsaw groups comprised of representative members from each of the original groups. For example, if the original groups are identified as groups 1, 2, or 3, each jigsaw group would be comprised of members from groups 1, 2, and 3. This is an effective and efficient way of taking larger content, breaking it into smaller parts for in-depth investigation, and piecing the parts together again so that all participants gain some exposure to the larger content.

Activity 4: Propulsion Experts

- Student activity, "Fly Like an Eagle," page 81.
- Student activity, "Altitude vs. Water Volume," page 84. (Optional for students needing more structure.)
- Student activity, "Altitude vs. Water Pressure," page 87. (Optional for students needing more structure.)
- Several two-liter plastic soft drink bottles.
- Water.
- Graduated cylinders (one-liter).
- Tire pump or air compressor.
- Safety glasses.
- "NASA Altitude Tracker," page 123.
- Conversion charts, page 64.
- Rope to measure out range (33 feet or 10 meters).
- Compass to determine north, south, east, or west.
- Launcher (see Appendix G) or search Internet to purchase a launcher.

Alternate Strategy Tip

Refer to the teacher guide "You Get What You Pay For," page 105, to include an economics component for the interaction and the assessment sections.

Activity 5: Weather or Not

- Copy of the student activity, "Weather or Not," page 90.
- Access to a computer with the Internet.
- Weather instruments for measuring wind speed, direction, visibility, and temperature.

Preparation

1. Gather materials for all of the activities.
2. Make copies of "Student Activity" pages. The Altitude Tracker needs to be copied on heavy weight paper.
3. Make a sample altitude tracker to use as an example. The altitude tracker pattern can be found in Appendix I.
4. Construct a water bottle rocket launcher or search the Internet to purchase a pre-made launcher. Instructions for construction of the launcher are located in Appendix G.

Activity 1: What Do I Need to Know Before Launch?

Procedure

1. Read through all "Safety Rules" with students and refer to the "Safety Checklist." Students should sign the safety rules. If you have already discussed the safety rules with students, ask them to point out the safety issues to you as they read through the directions for "Constructing an Altitude Tracker" included in the "Measuring Altitude" student activity.
2. Have each student construct an altitude tracker.
3. Have students complete the student activity, "Measuring Altitude," in their design groups.
4. Using a jigsaw method (see teacher tip box on previous page), divide your design groups into four expert groups. These include the following:

   a. Nose cone.
   b. Fin numbers and placement.
   c. Fin size and shape.
   d. Propulsion.

Once the expert groups have been assembled, provide student activity sheets and instructions to the four groups.

Activity 2: The Nose Cone Experts

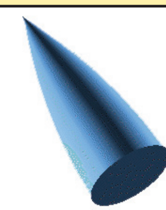
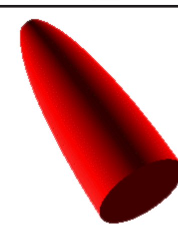
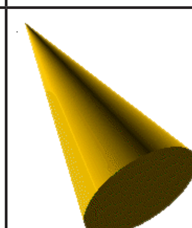
Description

Types of nose cones include the parabolic, the conical (cone), and the elliptical. Students working in this expert group will experiment with different nose cone shapes to determine the advantages and disadvantages of each type.

Background

Aerodynamics is the branch of science that deals with the motion of air and the forces on bodies moving through the air. There are four forces that act on a rocket. They are lift, drag, weight, and thrust. For a graphic illustration of these forces, go to: http://exploration.grc.nasa.gov/education/rocket/rktfor.html

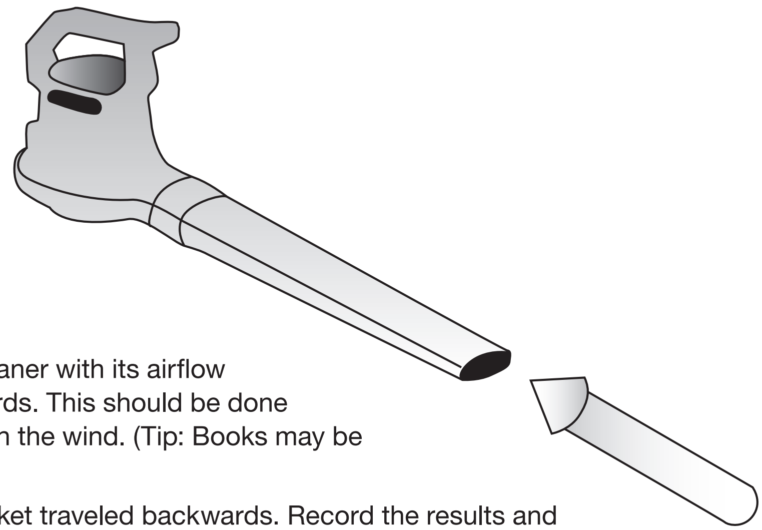
Drag is a force that opposes the upward movement of the rocket. It is generated by every part of the rocket. Drag is a sort of aerodynamic friction between the surface of the rocket and the air. Factors that affect drag include the size and shape of the rocket; the velocity and the inclination of flow; and the mass, viscosity and compressibility of the air. For an interesting

Types of Nose Cones		
Parabolic	A parabolic cone has a smooth curved surface and a sharp pointed nose.	
Elliptical	An elliptical cone is similar to the parabolic cone except the nose is blunted and not sharp. If the nose cone were cut in half, perpendicular to the base, the resulting cross-section would be half of an ellipse.	
Conical (cone)	A very common nose cone shape is a simple cone. The sides of the cone are straight lines.	

computer simulation where you can manipulate an airfoil's thickness, the air speed, altitude, and angle, go to http://exploration.grc.nasa.gov/education/rocket/rktsim1.html

Procedure

1. To allow them to build on their past experiences with aerodynamics, students in this expert group will complete questions 1–4 of the student activity sheet, "What a Drag."
2. Students construct nose cones by cutting out two different nose cone shapes from card stock. (A template for one is available in Appendix L. The students will also do one of their own design.) They will then attach the nose cones onto paper towel tubes.



3. Use a commercial leaf blower or a vacuum cleaner with its airflow reversed to "blow" to force the rocket backwards. This should be done on a narrow track to keep the rocket in line with the wind. (Tip: Books may be lined up to make this track.)
4. Students should measure the distance the rocket traveled backwards. Record the results and complete the nose cone expert report on the "What a Drag" sheet. When students have completed the expert group work, instruct them to begin the student activity "Weather or Not."

Activity 3: The Fin Experts

Description

Students working in these expert groups will examine the variables related to fins. One group will investigate shape and size, while the other will explore fin number and placement. Students in the first group investigate various fin shapes including rectangle, triangle, semicircle, or polygon — each in various sizes. The second group investigates three, four, or six fins placed in an even or uneven pattern. The goal for the fin experts is to gather evidence, based on research and observations, as to what makes for the most effective fin design for allowing the rocket to remain stable during flight. They will then share their collective findings with their own design team.

> **Teaching Tip**
>
> **You may want to further divide the fin shape and size group into two groups. One group should investigate shape; the other should investigate size.**

Background Information

A rocket with no fins is much more difficult to control than a rocket with fins. The size and shape of the fins, as well as their number and placement, are critical to achieve adequate stability while not adding too much weight. For more information on stability and control systems, see page xiv at the front of this guide.

Procedure

1. Have students complete the student activity "Flying Straight." They will probably want to know:
    - Does fin shape make a difference?
    - Does fin size make a difference?
    - Would more fins work better?
2. Students capable of designing their own investigation should complete "Flying Straight," numbers 12–14.
3. Students who need more structure should complete the student activity "Investigating Fin Shape or Size" or "Investigating Fin Number and Placement," depending on their designated expert group. Distribute the "Investigating Fin Shape or Size" activity and instruct one group to complete the investigations on this sheet. Distribute the student activity, "Investigating Fin Number and Placement," to the other group.

4. When the groups have completed the investigations, look at their plans. It is important that students examine at least these three separate variables: fin shape, fin size, and fin number/placement. Some students may be ready to conduct their own experiments; other students may require more structure.
5. Time should be provided for students to discuss their results and conclusions.
6. (Optional) Individual students should write a summary of what they have learned through their research and observations about the aerodynamics of fins. They need to make their explanation clear enough so that other people in their design group can understand it. Have students exchange papers and complete a short peer review.
7. Each of the two groups that investigated fins should write a group paper summarizing their findings, based on evidence gathered during their research and observations. That summary should be shared with other members of the design team. When students have completed the expert group work, instruct them to begin the student activity, "Weather or Not."

Activity 4: The Propulsion Experts

Description

Students working in this expert group will determine the best water volume and the best launch pressure to make a plain two-liter bottle go the specified height (98 feet or 30 meters). The goal of the propulsion experts is to gather evidence regarding optimum pressure and water volume, based on research and observations, and then share their collective findings with their own design group.

Background Information

A water bottle rocket is a two-liter soda bottle filled with compressed air and water. During launch, when the pump valve is opened, the compressed air and water are released, sending the rocket in an upward direction. Students will have the opportunity to experience Newton's Three Laws of Motion and expand their conceptual understanding of motion, force, mass, and momentum.

For a detailed explanation of how these Three Laws of Motion apply to water bottle rockets, see the student text "Newton's Laws of Motion and Rockets."

Procedure

1. Have students complete the student activity "Fly Like an Eagle." They will probably want to know the following:
   - What volume of water works best?
   - Will the bottle rocket fly without water?
   - If a little water works, will a lot work better?
   - Will it fly best when it is totally full?
   - Does the launch pressure matter?
2. Look at their plans. It is important that students in this expert group examine at least two variables: volume of water and launch pressure. Some students may be ready to conduct their own experiments; other students may require more structure. The student activities "Altitude vs. Water Volume" and "Altitude vs. Water Pressure" are available to use as a guide. Once students have tested the variables (volume of water and launch pressure) independently, they may wish to look at manipulating other variables. They may also want to look at various volumes of water at various pressures. Watch as they unknowingly transform into research scientists attempting to answer questions that they ask themselves. Listen carefully; many will (in their descriptions) be describing Newton's Laws of Motion. At just the right teachable moment, these laws can be explained and made understandable to very young students. Typical student statements that set the stage for new understandings include the following:
   - Why did the rocket that was full of water barely take off? (It was too heavy [massive] — Newton's First Law.)
   - The rocket did not have enough "oomph" (force) to make it take off. Why? (There was not enough force for the relatively huge mass — Newton's Second Law.)
   - The water went one way and the rocket went the other way (Newton's Third Law).

3. Questions that might be asked to get the students thinking in the right direction include the following:
   - Why did the rocket that was full of water barely take off?
   - What happens to the rocket as the water inside the bottle goes down?
   - If you could eject the water twice as fast from the rocket, what effect would this have on the rocket?
4. (Optional) At the end of the lesson, ask each student to write a summary, using their own words, describing what makes the bottle rockets fly. They need to make their explanation clear enough for other people in their design group to understand it. Have students exchange papers and complete a short peer review.
5. Finally, ask students to write a group paper, to be shared with their design group, which explains what makes a rocket fly best. When students have completed the expert group work, instruct them to begin the student activity "Weather or Not."

Activity 5: Weather or Not

Procedure

1. Distribute a copy of the student activity, "Weather or Not," to each student.

   Play the following audio clip of Kris Walsh (Appendix H) explaining launch period and launch window. Instruct students to read the background information and work in their design groups to develop weather criteria for determining if a launch should take place. Circulate around the room offering assistance to groups who might need it.
2. Listen to students to determine the best way to come to a consensus on the weather conditions necessary to launch a water rocket. Using this method, synthesize the student criteria into a class launch criterion to be used during the competition in the assessment section.

Alternate Strategy Tip

Have weather instruments available for students to take real-time weather data and record this in the classroom. This will allow students to read weather instruments and at the same time find weather information at your launch site.

Teacher Resources

Publications

Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology, NASA EG-2003-01-108-HQ, Office of Human Resources and Education, Washington, D.C., 2003.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

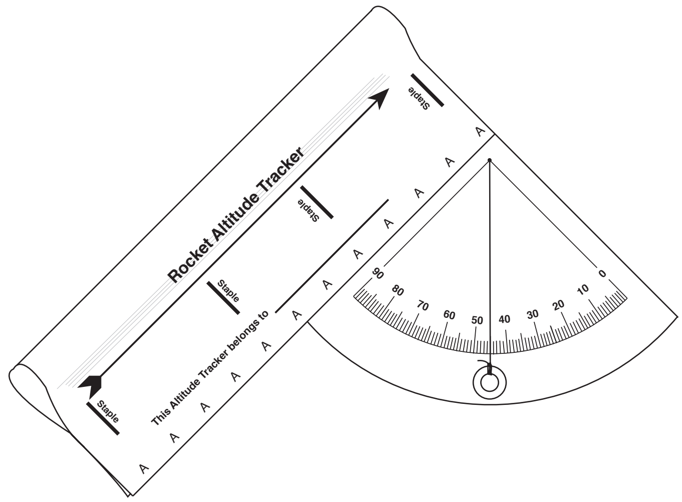
Web sites

NASA Beginner's Guide to Rockets — good for teachers and students:
http://exploration.grc.nasa.gov/education/rocket/bgmr.html

Rocket Index from NASA Glenn Research Center:
http://exploration.grc.nasa.gov/education/rocket/shortr.html

Student Activity

Measuring Altitude



Materials

- "NASA Altitude Tracker Pattern," page 123.
- Scissors.
- Pin or small nail.
- Thread, lightweight string, or fishing line.
- Cellophane tape.
- Small washer or 1–2 ounce (28–57 gram) fishing sinker.

Constructing the Altitude Tracker Scope

Procedure

1. Give each student an altitude tracker pattern located on page 123, Appendix I.
2. Cut out the pattern on the dark outside lines.
3. Curl (do not fold) the B edge of the pattern to the back until it lines up with the A edge.
4. Staple the edges together where marked. If done correctly, the As and Bs will be on the outside of the tracker.
5. Punch a small hole through the apex of the protractor quadrant on the pattern (black dot).
6. Slip a thread or lightweight string through the hole. Knot the thread or string on the backside.
7. Complete the tracker by hanging a small washer from the other end of the thread.

Measuring Altitude

1. Find an object whose height you would like to know but cannot measure directly.
2. Stand 33 feet (10 meters) from the object that you will be measuring.
3. Hold the tracker like a pistol and look through the sighting tube to locate the highest point of the object.
4. While the object is still in your sight, hold the string in the position that it naturally falls because of the weight.
5. Record the angle on the chart below.

6. Use the conversion chart to convert the angle into height in feet (meters) and record the height on the chart below.
7. Try this process with at least five other objects or until you feel that you have mastered the art of measuring the altitude of stationary objects.
8. Challenge: Stationary objects are easy; just wait until you try to track a rocket moving at 65 miles (105 kilometers) per hour! Now, have someone toss a tennis ball into the air and see if you can follow the path of the tennis ball through the sighting tube. Remember, the person with the tracker should be 33 feet (10 meters) away from the person throwing the ball. When the tennis ball reaches its highest point (apex), capture the angle by holding the string in the position that it naturally falls because of the weight. Do this several times until you become proficient at tracking the ball. Record the angle and height on the chart below.

Object	Angle (degrees)	Height (feet or meters)

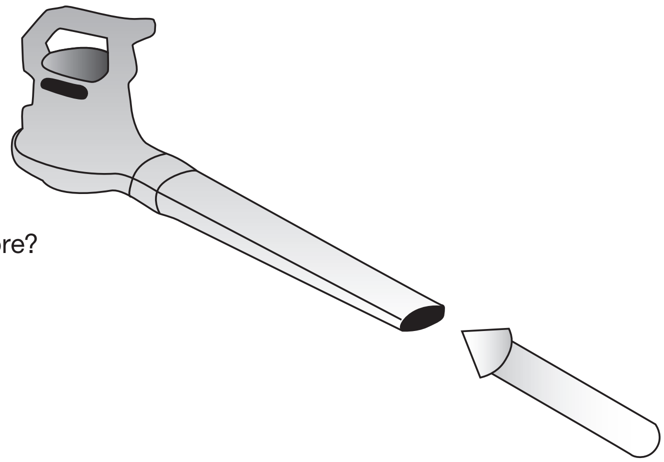
9. Write a summary describing the process of finding the height of an object using an altitude tracker.

Angle-to-Height Conversion Chart

Angle (at 10 m or 32.8 ft)	Height (ft)	Height (m)	Angle (at 10 m or 32.8 ft)	Height (ft)	Height (m)
0	0	0.0	45	32.8	10.0
1	0.7	.2	46	33.8	10.3
2	1.3	.4	47	35.1	10.7
3	1.6	.5	48	36.4	11.1
4	2.3	.7	49	37.7	11.5
5	3	.9	50	39	11.9
6	3.3	1.0	51	40.4	12.3
7	3.9	1.2	52	41.7	12.7
8	4.6	1.4	53	43.3	13.2
9	5.2	1.6	54	45.3	13.8
10	5.9	1.8	55	46.9	14.3
11	6.2	1.9	56	48.6	14.8
12	6.9	2.1	57	50.5	15.4
13	7.5	2.3	58	52.5	16.0
14	8.2	2.5	59	54.5	16.6
15	8.9	2.7	60	56.8	17.3
16	9.5	2.9	61	59.1	18.0
17	9.8	3.0	62	61.7	18.8
18	10.5	3.2	63	64.3	19.6
19	11.2	3.4	64	67.3	20.5
20	11.8	3.6	65	70.2	21.4
21	12.5	3.8	66	73.5	22.4
22	13.1	4.0	67	77.1	23.5
23	13.8	4.2	68	81	24.7
24	14.8	4.5	69	85.3	26.0
25	15.4	4.7	70	89.9	27.4
26	16.1	4.9	71	95.1	29.0
27	16.7	5.1	72	101	30.8
28	17.4	5.3	73	107.3	32.7
29	18.0	5.5	74	114.5	34.9
30	19.0	5.8	75	122.4	37.3
31	19.7	6.0	76	131.6	40.1
32	20.3	6.2	77	142.1	43.3
33	21.3	6.5	78	154.2	47.0
34	22	6.7	79	168.6	51.4
35	23	7.0	80	186	56.7
36	23.6	7.2	81	207	63.1
37	24.6	7.5	82	233.3	71.1
38	25.6	7.8	83	267.1	81.4
39	26.6	8.1	84	312	95.1
40	27.6	8.4	85	374	114.0
41	28.5	8.7	86	469.2	143.0
42	29.5	9.0	87	626.6	191.0
43	30.5	9.3	88	938.3	286.0
44	31.5	9.6	89	1879.9	573.0

Student Activity

What a Drag!



Procedure

Directions: In your expert groups, complete the following.

1. What is the first thing you think of when you hear the word "aerodynamic?" Where have you heard the term before?

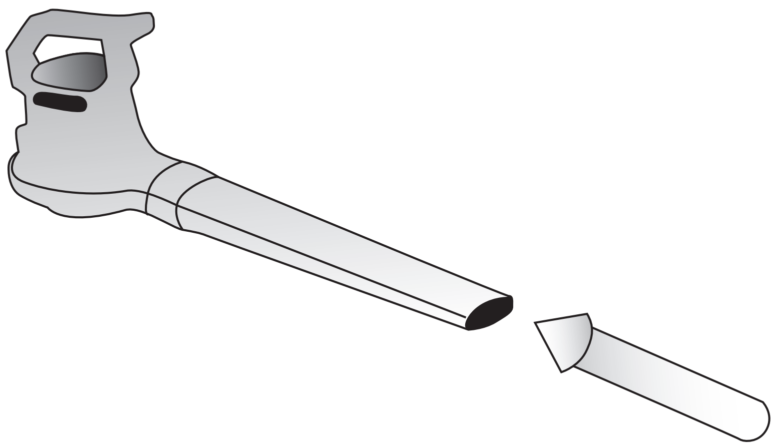
2. Using the resources on the Internet or in your library, find information on aerodynamics and the importance of using wind tunnels. Give several examples.

3. What is drag as it relates to aerodynamics? What are some things that can be done to an object to decrease its drag?

4. What are the parts of a rocket that may result in drag?

5. Using the pattern in Appendix L to get started, cut out the conical nose cone pattern from card stock and design a nose cone of your own. Assemble the nose cones and attach them onto paper towel tubes. The tubes will be tested with the leaf blower as shown below.
6. List the variables that need to be controlled in this activity.

7. Use a commercial leaf blower or vacuum set to blow air to force the rocket backwards. To keep the rocket in line with the wind, this should be done between two rows of books, or against a curb. Place the nose cone design structure in front of the blower, as shown below. While holding the blower, turn the blower on until the nose cone design structure stops moving. Be sure to maintain the same distance from the blower and paper towel tubes for each test. The blower should be turned on to the same power level and the same amount of time for each test.



Leaf blower and paper towel tube with nose cone

8. Measure the distance the rocket traveled backwards. Record results in the data table below.
9. Set up a data table, similar to what is below, to record your results in your journal.

Shape of Nose Cone	Distance Traveled			
	Trial 1	Trial 2	Trial 3	Average
Cone Shaped				
My Design				

10. Construct more tubes as in procedure #5 above. This time, modeling clay can be used inside the nose cone to provide mass. Write down the amount of clay used and where in the nose cone it was placed. Describe which nose cone you used. Make a table for your results.

11. Write down what you learned (from this activity) about nose cones and write a recommendation indicating which nose cone your design group should choose.

12. Be prepared to report your results to your design group.

Student Activity

Flying Straight

Procedure

1. What questions occur to you about the fins of a rocket?

The Ares I will not have fins. Roll control monitors, which turn (or gimbal) the nozzle of the engine to direct the air flow, will be used to control the direction of the vehicle.

2. Think about rocket fins. What effect do you think fins have on a rocket?

3. Have you ever stuck your hand out of the car window at 55 miles (88 kilometers) per hour? What did you notice?

4. What happened when you moved your hand around?

5. What would happen to a rocket with a nose that moved around like your hand?

6. Look at an arrow. What is there about the structure of the arrow that allows it to fly through the air with such incredible stability? How is an arrow similar to a rocket? Why does it fly straight?

7. Balance an arrow on one of your fingers. Lay the arrow on top of a student's two outstretched index fingers. Have the student slowly bring her or his fingers together. Where is most of the mass of the arrow? Friction will cause the arrow to slide on the lightest side until a balance point is found. The balance point is much closer to the front than it is to the back. You have just discovered where the arrow's transverse center of mass lies.

8. Next, examine why an arrow has feathers toward the back. Using an arrow without feathers, lightly toss it underhanded across an area where you do not hit other students. Do the same with an arrow with its feathers intact. What differences did you see?

9. What happens to the stability when the mass at the end of the arrow is changed? Add mass to one end of the arrow and describe the change in stability.

10. What are some of the factors (variables) that are important to rocket fins? Think about what you experienced in the activity in numbers 7–9.

11. Choose one fin variable to test (manipulated variable). What variable are you testing (i.e., fin shape, size, number, or placement)?

12. What response or effect will you be looking for (responding variable)?

13. List all the things that have to stay the same to ensure that the test is fair (controlled variables).

14. Have your teacher or supervisor approve your plan and schedule a time for testing.

Teacher Signature ____

Testing Time ____

Student Activity

Investigating Fin Shape or Size

Fin Shape

Problem: Which fin shape is the most stable? Remember that right now you are testing for fin shape; all other variables (including fin size, fin number, and fin placement) should remain constant.

Background: Fins are used to stabilize the rocket. As you would expect, fins with their thin edges facing into the wind have very little drag. However, increasing the thickness, the surface area, or the number of fins can increase the drag.

Procedure

1. Using tag board, design several shapes of fins that could be attached to a paper towel tube. The fins should be the same size, but different shapes.
2. Make three to four fins of each shape that you designed.
3. Construct a simple rocket using the paper towel tube, without a nose cone covering, and use tape to attach the fins you have designed.
4. Draw a diagram of your fin shape on your data table.
5. Put your rocket on the ground so it faces a leaf blower or vacuum cleaner. Direct the air from the leaf blower or vacuum cleaner toward the rocket. Turn on the blower until the rocket starts moving.
6. Using the blower, "launch" your rocket three times, recording each of the three distances on the data table. Be sure to maintain the same distance from the blower and paper towel tubes for each test. The blower should be turned on to the same power level and the same amount of time for each test.

7 Determine the average distance and record it.

8. Record any other observations on the data table.
9. Complete the same procedure with at least two other fin shapes.
10. Graph your results.
11. Using your data as a basis, write your conclusions.

Data

Diagram of Fin Shape	Trial 1 Distance (in/cm)	Trial 2 Distance (in/cm)	Trial 3 Distance (in/cm)	Average Distance (in/cm)	Flight Observations

Results

(Graph Distance vs. Fin Shape)

Conclusion

What did you determine about fin shape from your activities? Support your conclusions with specific data.

Fin Size

Problem: Which fin size is the most stable? Remember that right now you are testing for fin size; all other variables (including fin shape, fin number and fin placement) should remain constant.

Background: Fins are used to stabilize the rocket. As you would expect, fins with their thin edges facing into the wind have very little drag. However, increasing the thickness, the surface area, or the number of fins can increase the drag.

What sizes of fins will you test? List three or four different sizes.

Procedure

1. Using tag board, design several fins of different sizes that could be attached to a paper towel tube. The fins should be the same shape but different sizes.
2. Make three to four fins of each size that you designed.
3. Construct a simple rocket using the paper towel tube and attach the fins you have designed.
4. Trace your fin size on your data table.
5. Put your rocket on the ground so it faces a leaf blower or vacuum cleaner. This should be done between two rows of books to keep the rocket in line with the wind. Direct the air from the leaf blower or vacuum cleaner toward the rocket. Turn on the blower until the rocket starts moving. Be sure to maintain the same distance from the blower and paper towel tubes for each test. The blower should be turned on to the same power level and the same amount of time for each test.
6. Using the blower, "launch" your rocket three times, recording each of the three distances on the data table.
7. Determine the average distance and record it.
8. Record any other observations on the data table.
9. Complete the same procedure with at least two other fin sizes.
10. Graph your results.
11. Write your conclusions based on your data.

Data

Diagram of Fin Size	Trial 1 Distance (in/cm)	Trial 2 Distance (in/cm)	Trial 3 Distance (in/cm)	Average Distance (in/cm)	Flight Observations

Results

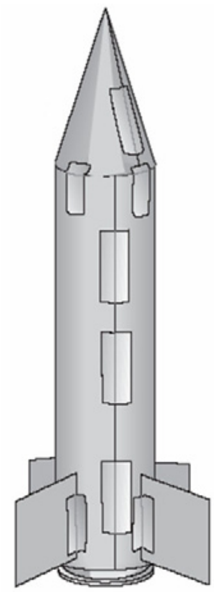
(Graph Distance vs. Fin Size)

Conclusion

What did you find is the optimum fin size for stable flight? Support your conclusions with specific data from your activity.

Student Activity

Investigating Fin Number and Placement



Fin Number And Placement

Problem: Which fin number and placement are the most stable? Remember that right now you are testing for fin number; all other variables (including fin shape and size) should remain constant. If time permits, try testing the same number of fins with different placements or spacing between them.

Background: Research information on fin number and placement at any of the Web sites or other resources you may have. Take notes in the space below.

What numbers and placement will you test?

Procedure

1. Using tag board, design one type of fin that could be attached to a paper towel tube. The fins should all be the same size and shape.
2. Make five or six fins that are identical.
3. Construct a simple rocket using the paper towel tube and attach the fins you have designed.
4. Record the number of fins and their placement on your data table.
5. Put your rocket on the ground so it faces a leaf blower or vacuum cleaner. This should be done between two rows of books to keep the rocket in line with the wind. Direct the air from the leaf blower or vacuum cleaner toward the rocket. Turn on the blower until the rocket starts moving. Be sure to maintain the same distance from the blower and paper towel tubes for each test. The blower should be turned on to the same power level and the same amount of time for each test.
6. Using the blower, "launch" your rocket three times, recording each of the three distances on the data table.
7. Determine the average distance and record it.
8. Record any other observations on the data table.
9. Complete the same procedure with at least two other numbers of fins.
10. Graph your results.
11. Write your conclusions based on your data.

Data

Diagram of Fin Number and Their Placement	Trial 1 Distance (in/cm)	Trial 2 Distance (in/cm)	Trial 3 Distance (in/cm)	Average Distance (in/cm)	Flight Observations

Results

(Graph Distance vs. Fin Number and Placement)

Conclusion

What did you learn from these experiences? Support your understanding with data from the activities.

Student Activity

Fly Like an Eagle

Procedure

1. What questions do you have about how a water rocket works?

2. Write a question that deals with finding out if the amount of water in the bottle affects how high a water rocket will travel.

3. Describe how you could vary the amounts of water in your bottle rocket (operational definitions).

4. What variable are you testing? This is your manipulated variable and the one thing that you will change during the experiment.

5. What response or effect will you be looking for? This is your responding variable.

6. List all of the things (factors) that have to stay the same to ensure that the test is fair. These things make up your controlled or constant variables.

7. Write a procedure explaining how you could test your manipulated variable.

8. Make a data table for recording the responding variable. Make sure that you test your water rocket more than one time with each amount of water.

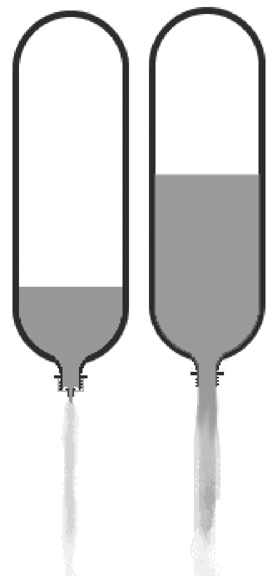
9. Have your teacher or supervisor approve of your plan and schedule a time for testing.

Teacher Signature ____

Testing Time ____

Student Activity

Altitude vs. Water Volume



Problem

How much water should be added to the two-liter bottle to make it go the highest? Remember, right now you are testing for volume of water; all other variables (including launch pressure) should remain constant.

Background Information

Background information on "Rocket Principles" (pages viii-xi) and "Practical Rocketry" (pages xii-xvii) is available at the front of this guide.

Procedure

1. Fill bottles with pre-determined volumes of water and cap the bottles. Keep the water level the same each time you test for the optimal pressure.
2. Put one bottle at a time on the launch pad and apply 50 psi of pressure.
3. Use a compass to determine locations. Have an altitude tracker spotter positioned at each of these four positions (north, east, south, and west).
4. Each spotter will use the altitude tracker to measure the angle of the highest point of flight.
5. Each angle should be recorded; the high and low angles should be omitted.
6. Two more trials should be made for that volume of water.
7. Average the remaining angles (once the high and low angles for each of the three trials have been omitted) to come up with an average angle.
8. Use the conversion chart, located in the "Measuring Altitude" student activity, to determine the height.
9. Repeat the same procedure for the other volumes of water.
10. Graph your results.
11. Write your conclusion.

Data

Volume of Water (oz/mL)	Trial 1 Angles (degrees)	Trial 2 Angles (degrees)	Trial 3 Angles (degrees)	Average Angle (degrees)	Average Height (ft/m)
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		

Results

(Graph Altitude vs. Volume of Water)

Conclusion

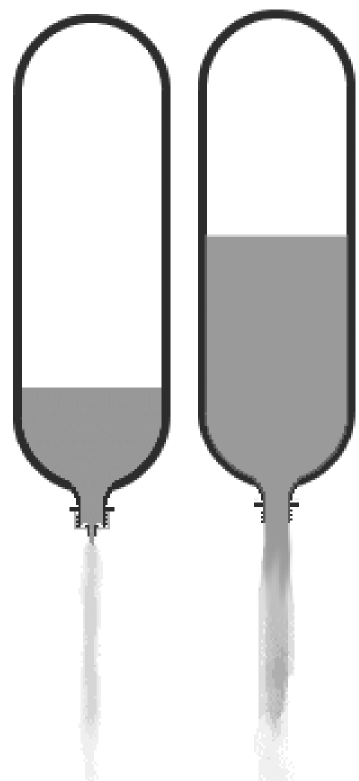
What did you determine was the optimum volume of water needed to meet the specifications for your flight? Support your decision with data that you collected.

Student Activity

Altitude vs. Water Pressure

Problem

What launch pressure will make the two-liter bottle go to the specified height (98 feet or 30 meters)? Remember that right now you are testing for launch pressure; all other variables (including volume of water) should remain constant.



Background Information

Research additional information on Newton's Three Laws of Motion as they relate to the force necessary to lift the bottle off the launch pad to a height of 98 feet (30 meters). Include in your reading and research, concepts related to force (balanced and unbalanced), motion, mass, thrust, lift, acceleration, propellant, center of mass, roll, pitch, yaw, and center of pressure. Conduct an Internet search and take notes on these terms in a notebook or separate sheet of paper as directed by your teacher.

Procedure

1. Put one bottle at a time on the launch pad and apply the pre-determined amount of pressure.
2. Have an altitude tracker spotter positioned at each of the four positions (north, east, south, and west).
3. Each spotter will use the altitude tracker to measure the angle of the highest point of flight.
4. Each angle should be recorded; the high and low angles should be omitted.
5. Two more trials should be made for that launch pressure.
6. Average the remaining angles (once the high and low angles for each of the three trials have been omitted) to come up with an average angle.
7. Use the conversion chart, located in the "Measuring Altitude" student activity, to identify the height.
8. Repeat the same procedure for the other launch pressures.
9. Graph your results and write your conclusion.

Data

Volume of Water (oz/mL)	Trial 1 Angles (degrees)	Trial 2 Angles (degrees)	Trial 3 Angles (degrees)	Average Angle (degrees)	Average Height (ft/m)
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		
	N E S W	N E S W	N E S W		

Results

(Graph Altitude vs. Launch Pressure)

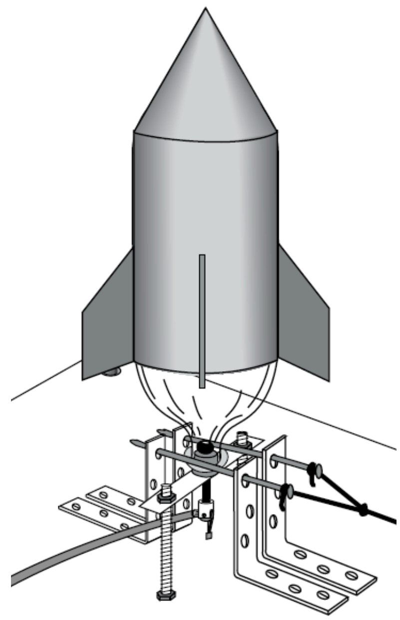
Conclusion

What did you discover about launch pressure during your tests? Support your conclusion with data.

Student Activity

Weather or Not

Background Information



In order to have a successful launch, not only do all of the rocket systems and subsystems have to be in order, but the conditions at the launch site and in the direction the rocket is moving toward have to be optimal for launch. The launch weather officer monitors cloud cover, knowing how close clouds can be to the launch site as well as how deep the clouds can be. The upper level winds are measured with balloons that go up six hours before launch. The balloons give a profile of the winds. This information is fed back to mission control and compared with the constraints of the rocket for that mission.

The launch period is the number of days the rocket can be launched into the proper orbit. For a low-Earth orbit, there is no concern; a launch can take be conducted on any given day. For missions going to Mars, the launch period is limited because of the energy that needs to be imparted to the spacecraft. The mission might use the gravitational pull of a planet or the Moon to get into the proper orbit. The launch team works with the spacecraft provider to determine the target. The rocket gets the spacecraft to the target with certain energy, and then the mission designers take over.

The launch window is the time period on the day of launch that a rocket can be launched. The launch window ranges from one second to one hour, and it changes on a day-to-day basis. If the launch window is twelve minutes or more, there is more flexibility. If there is more than one window and a problem occurs, the rocket could still fly that day. According to Boeing Mission Integration Officer Kristen Walsh, “If there is a problem with the launch countdown, then we can safe the vehicle, recycle, and attempt again that same day.” If the launch window is less than 12 minutes, and there is a problem, then the delay will be for 24 hours.

In the next phase of this module, your design teams will take all of the information that you learned in your expert groups and apply it to building a water rocket that can fly as high as possible. For the launches that will take place in the competition, your teacher will set the launch period. The launch window should be twelve minutes. That means if your team cannot launch your water rocket in twelve minutes, you will have to launch during the next launch period. In this activity, your group will determine which weather conditions are acceptable for launch, and which weather conditions should cause a delay.

Procedure

1. Using the information in the previous background section, work in your design groups to develop the weather constraints for launching a water rocket.
2. For each of the following conditions, write the necessary conditions that the safety officers and the teacher will use to determine if a launch will occur. As you develop the conditions, include a rationale for each of the weather requirements.

Weather Constraints and Launch Criteria:

Weather Component	Conditions Necessary	Method of Measurement	Rationale
Wind Speed			
Wind Direction			
Visibility			
Temperature			
Precipitation			
Cloud Cover			

3. Use the Internet or your school's weather instruments to determine the current weather conditions. Record the current conditions below and whether or not you should launch today based on your team's criteria.

Current Conditions and Launch Decision

Weather Component	Today's Conditions	Launch Decision (Yes or No)	Rationale
Wind Speed			
Wind Direction			
Visibility			
Temperature			
Precipitation			
Cloud Cover			

4. Take notes about other group's criteria. What are the similarities and the differences? Think about how the class should come to a consensus for determining the conditions necessary for launch.

Teacher Guide

Fly Me High

Background Information

During this performance assessment, students will work in their design groups to design, build, and test launch a water rocket. Students will begin by sharing with their groups what they each learned from their previous expert-group investigations (e.g., nose cone shape, fin shape and size, water volume, etc.). Such "expert" input will inform the design process of the group's water rocket. Then, once the teacher has approved the designs, students may assemble the materials and begin building their rockets.

Students will have the opportunity to revise their initial designs based on their rocket's performance during a practice launch. Just as actual rocket designers do not use the first design they create, your students will also be able to test their initial design before making revisions and deciding on the final design for the contest. Encourage students to refer back to earlier work and findings as they prepare for the contest.

Once students have completed construction and before the first test launch, the rockets should be put through a stability test. Design groups will determine the center of mass and the center of pressure for their test rockets. The center of mass is the point about which the rocket balances. Students could practice this by trying to balance a ruler on one finger. The center of pressure is the point where half of the surface area of a rocket is on one side and half is on the other. Students could model this by finding the mid-point of a ruler. A stable rocket has the center of mass in front of the center of pressure.

Ares I

Once the design group has found these centers on their rocket, they should complete the swing test to verify their rocket's stability. To perform the swing test, students attach a string loop, like a collar, around the rocket's center of pressure. Next, they attach another string to this loop, like a leash. Then, they swing the rocket in a circle; if it is stable, the rocket should point in the direction it is being swung.

National Science Standards Addressed

Grades 5–8

Science as Inquiry
Abilities necessary to do scientific inquiry.
Physical Science
Motion and forces.
Science and Technology
Abilities of technological design.
Understandings about science and technology.
Science in Personal and Social Perspectives
Personal health.

Grades 9–12

Science as Inquiry
Abilities necessary to do scientific inquiry.
Physical Science
Motion and forces.
Science and Technology
Abilities of technological design.
Understandings about science and technology.
Science in Personal and Social Perspectives
Personal and community health.

Principles and Standards for School Mathematics Addressed

Measurement Standard for Grades 6–8

Understand measurable attributes of objects and the units, systems, and processes of measurement
Understand both metric and customary systems of measurement.
Apply appropriate techniques, tools, and formulas to determine measurements
Select and apply techniques and tools to accurately find length and angle measures to appropriate levels of precision.

Problem Solving Standard for Grades 6–8

Solve problems that arise in mathematics and in other contexts

Measurement Standard for Grades 9–12

Understand measurable attributes of objects and the units, systems, and processes of measurement
Make decisions about units and scales that are appropriate for problem situations involving measurement.

Problem Solving for Grades 9–12

Solve problems that arise in mathematics and in other contexts

National Educational Technology Standards Addressed

Technology Standards for Students K–12

Technology Productivity Tools
Students use technology tools to enhance learning, increase productivity, and promote creativity.
Technology Research Tools
Students use technology to locate, evaluate, and collect information from a variety of sources.
Technology Problem-solving and Decision-making Tools
Students use technology resources for solving problems and making informed decisions.

Technology Standards for Students 6–8

Use content specific tools, software, and simulations to support learning and research.
Collaborate with peers, experts, and others using telecommunications and collaborative tools to investigate curriculum-related problems, issues, and information, and to develop solutions or products or audiences inside and outside the classroom.

Materials

- One or more two-liter plastic soft drink bottles.
- String.
- Safety goggles.
- Glue or tape.
- Cardboard or thick paper.
- Modeling clay.
- Scissors.
- Pens and decorating supplies.
- Scale.
- Measuring devices: rulers, yard or meter sticks, and measuring tape.
- Balance.

- Launch pad with secure pin and washers.
- Water.
- Safety goggles.
- Air pump or tank.
- Altitude tracker.
- Decorative decals.
- Background information on stability in rockets can be found in "Rocket Principles" (pages viii-xi) and "Practical Rocketry" (pages xii-xvii) at the front of this guide.
- "Appendix J: Safety Rules," page 124.
- "Appendix K: Safety Checklist," page 126.
- Student activity, "Fly Me High," page 97.

Procedure

1. Explain to students that they will work in their design groups for this assessment activity. Each student will be expected to share what he/she learned in their respective expert groups (e.g., nose cone shape, fin shape and size, water volume — whichever variables are applicable) to help inform the overall design of their group's water rocket.
2. Assign the following jobs to students in each group. Review the role of each:
    - Safety Officer: Checks for safe practices and can stop a launch whenever unsafe practices are observed.
    - Loading Officer: Responsible for securing the rocket to the pad and charging the rocket with the appropriate air pressure.
    - Principal Investigator/Launch Officer: Makes final decisions about rocket design. Commences the countdown and launches the vehicle.
    - Downrange Officer: Observes the launch, measures the height of the rocket at apogee (the greatest distance from the ground), and records data. Spots the rocket and assures the safe landing of the rocket.
3. Distribute a copy of the "Appendix K: Safety Checklist" to each design team. Go over the list and answer any questions students may have. Review the following competition rules:
    - Only materials approved by the teacher may be used in the construction of any part of the bottle rocket system.
    - Safety rules and checklists must be followed at all times.
    - The rocket may not be pressurized over 50 psi.
4. Distribute the student activity, "Fly Me High." Students should share their expertise and make recommendations for the design phase. The design group should complete the planning guide portion of the sheet to document their original design and the rationale for their design decisions. Final decisions for the designs of the rocket will be up to the Principal Investigator in each design group. The teacher should review and approve rocket designs before construction begins.
5. Allow students time to assemble the materials before construction. Students should measure the mass of the cone, body, and tail separately. Students in each group will construct their own rocket. Deadlines should be given for both test launches and final launches so that all group launches take place on the same days.
6. During the trial launch, students should assume their respective roles: Safety Officer, Loading Officer, Principal Investigator/Launch Officer, and Downrange Officer.
7. After the trial launch, when students return to the classroom, each group should review the results of the test launch, including the height the rocket reached. Students will then redesign the rocket with changes, as necessary, for the second official competition. On the student activity sheet, using evidence from the test-trial process, groups should document the modifications they make to their original design, as well as the rationale behind these changes. Again, students should be given a clear deadline in order to prepare the rocket for the official launch.

8. During the official competition, if you choose to declare one overall winner, independent judges (perhaps an older student or parent volunteer) should be used to measure, with an altitude tracker, the height to which the rockets travel. The group whose launch results in the hightest altitude is the winner. The judge's decision is final.

Student Evaluation Criteria

Criteria	Advanced (4)	Proficient (3)	Partially Proficient (2)	Novice (1)
Development of Rocket Design	Designs are complete and detailed. Rationale demonstrates a sophisticated understanding of all the components/ variables of the rocket.	Designs are complete. Rationale demonstrates an understanding of most of the components/ variables of the rocket. No clear inaccuracies or misconceptions.	Designs are incomplete. Rationale demonstrates a basic understanding of components/ variables of the rocket design. May contain inaccurate or incomplete information.	Designs are missing important information. Rationale does not demonstrate a basic understanding of components/ variables of the rocket design.
Construction and Testing of Rocket	The design group easily constructs and tests the rocket based on their original designs. Revisions to their original design are carefully documented and based on evidence from the test-trial process.	The design group experiences minimal difficulty with constructing and testing the rocket based on their design. Revisions to their original design are based on evidence from the test-trial process.	The design group experiences difficulty with constructing and testing the rocket. Revisions to their original design are partially based on evidence from the test-trial process.	The design group experiences great difficulty constructing and testing the rocket. Revisions, if made, are not based on evidence from the test-trial process.
Performs Assigned Duties During Launch	Students exceed expectations as they follow their assigned roles and responsibilities.	Students consistently follow their assigned roles and responsibilities.	Students sometimes follow their assigned roles and responsibilities.	Students rarely follow their assigned roles and responsibilities.
Safety Officer: Checks for safe practices and can stop a launch whenever unsafe practices are observed. **Loading Officer**: Responsible for securing the rocket to the pad and charging the rocket with the appropriate air pressure. **Principal Investigator/Launch Officer**: Commences the countdown and launches the vehicle. **Downrange Officer**: Observes the launch, measures the height of the rocket at apogee (the greatest distance from the ground), and records data. Spots the rocket and assures the safe landing of the rocket.				

Teacher Resources

Publication

Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology, NASA EG-2003-01-108-HQ, Office of Human Resources and Education, Washington, D.C., 2003.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Student Activity

Fly Me High

Procedure

1. In the design groups, everyone should share what was learned in their expert-group investigations (e.g., nose cone shape, fin shape and size, water volume, etc.). Group members should ask questions of the experts to help determine the design of the group's water rocket. During the launch, each student in the design group will assume one the following roles:
    - **Safety Officer**: Checks for safe practices and can stop a launch whenever unsafe practices are observed.
    - **Loading Officer**: Responsible for securing the rocket to the pad and charging the rocket with the appropriate air pressure.
    - **Principal Investigator/Launch Officer**: Makes final decisions about rocket design. Commences the countdown and launches the vehicle.
    - **Downrange Officer**: Observes the launch, measures the height of the rocket at apogee (the greatest distance from the ground), and records data. Spots the rocket and assures the safe landing of the rocket.
2. Read "Appendix K: Safety Checklist." Review the following competition rules:
    - Only materials approved by the teacher may be used in construction of any part of the bottle rocket system.
    - Safety rules and checklists must be followed at all times.
    - The rocket may not be pressurized over 50 psi.
3. After everyone has shared information from the expert groups, your group should decide what variables should be tested during the design phase. During this time, experts in your group should have input into the design process for the component they investigated during their previous work. Write out your design specifications using the rubric that follows as a guide. Final decisions for the designs of the rocket will be up to the Principal Investigator in each design group. Your teacher should review and approve rocket designs before construction begins.

Ares I

Use the space below to plan your design:

Drawings.

Nose Cone

Fin Shape

Water rocket with nose cone, number of fins, and placement/location of fins illustrated.
Side View

Water rocket with nose cone, number of fins, and placement/location of fins illustrated.
Top View

Take your measurements and record the data in the blanks below. Be sure to accurately measure all factors that are constant (such as the bottles) and those you will control (like the size and design of fins). Under the first column, list each rocket component and explain what influenced your design selection for that component. Finally, at the end, include a rationale for the complete rocket design.

Component and Rationale	Length	Width	Diameter	Mass
Rationale for how components work together (overall design).				

4. Assemble the materials before construction. Measure the mass of the cone, body, and tail. You will then construct the rocket. Make sure that you are ready for the test launch by the deadline.
5. Once construction is complete, perform a rocket stability determination using the directions below. Determine the center of mass and the center of pressure. Using the results from this test, your group can make adjustments to your rocket prior to the test launch.
   a. Tie a string loop around the middle of your rocket. Tie a second string to the first so that you can pick it up. Slide the string loop into a position where the rocket balances. You may have to temporarily tape the nose cone in place to keep it from falling off.
   b. Draw a straight line across a scale diagram of the rocket to show the ruler position. Mark the middle of the line with a dot. This is the rocket's center of mass.
   c. Lay your rocket on a piece of cardboard. Carefully trace the rocket on the cardboard and cut it out.
   d. Lay the cardboard cutout you just made perpendicular on the ruler and balance it.
   e. Draw a straight line across the diagram of your rocket where the ruler is. Mark the middle of this line with a dot. This is the center of pressure of the rocket. See diagram.
6. Your group will be allowed one test launch and one final launch. After your test launch, you may make minor changes before the final launch competition. Before each launch, complete the prelaunch readiness review information that follows.