Water Rocket Launch

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on aerospace engineering and how space flight has been achieved from an engineering vantage point. Student teams build and launch a rocket made out of a soda bottle and powered with an air pump and consider the forces on a rocket, Newton's Laws, and other principles and challenges of actual space vehicle launch. Teams design their structure on paper, learn about aerospace engineering, launch their rocket, and share observations with their class.

Lesson Synopsis

The "Water Rocket Launch" lesson explores rocketry and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from a soda bottle and everyday materials that is powered by an air pump. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

Age Levels

8-18

Objectives

- Learn about aerospace engineering.
- Learn about engineering design and redesign.
- Learn about space flight.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- aerospace engineering
- engineering design
- space flight
- teamwork

Lesson Activities

Students explore how engineers have developed rockets over the years, and learn about the principals of rocketry. They work in teams to construct and launch a rocket made from a soda bottle that launches with an air pump under teacher supervision. The students compare their accomplishments and challenges with those of other student teams, complete a reflection sheet, and present to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Timeline of Rocket History (http://history.msfc.nasa.gov/rocketry/)
- NASA Beginners Guide to Rockets (www.grc.nasa.gov/WWW/K-12/rocket/bgmr.html)
- European Space Agency - Space Engineering (www.esa.int/SPECIALS/Space_Engineering)
- Rocketry Planet (www.rocketryplanet.com)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Rockets and Missiles: The Life Story of a Technology (ISBN: 978-0801887925)
- Rocket and Spacecraft Propulsion: Principles, Practice and New Developments (ISBN: 978-3642088698)
- It's ONLY Rocket Science (ISBN: 978-0387753775)
- "A Pictorial History of Rockets" (www.nasa.gov/pdf/153410main_Rockets_History.pdf)
- Soda-Pop Rockets: 20 Sensational Rockets to Make from Plastic Bottles (ISBN: 978-1556529603)

Optional Writing Activity

- Write an essay or a paragraph describing an example of rockets might be used to help society in peaceful times.

Safety Notes

- This is an outside activity.
- This exercise should only be done under the supervision of a qualified teacher.
- Safety glasses should be worn at all times.
- Since a quantity of water will be sprayed over the floor, it is suggested that old clothes or rain coats be worn by the test crew.
- Observing students should stand safely back from launch site.

Related Lesson

- TryEngineering.org offers a lesson incorporating traditional rockets called "Blast Off"

Water Rocket Launch

For Teachers:
Teacher Resources

◆ **Lesson Goal**

The "Water Rocket Launch" lesson explores rocketry and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from a soda bottle and everyday materials that is powered by an air pump. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

◆ **Lesson Objectives**

- Learn about aerospace engineering.
- Learn about engineering design and redesign.
- Learn about space flight.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Student Team Materials (if building from everyday items: empty soda bottle, cork, paper, pen, pencil; plastic tubing, bicycle tire valve, cardboard, glue, tape, rubber bands, foil, decoration materials.)
- Kit option: Water bottle rocket kits may be purchased inexpensively (via Amazon.com, Antigravity Research at http://antigravityresearch.com, or through most teacher supply stores globally and might be better for younger students, or where there may be issues in drilling a hole through the required cork.
- Classroom Materials: water source, drill (if not using a kit), bicycle tire pump, system/tools for measuring how high the rockets fly.
- Internet access (optional) to explore www.grc.nasa.gov/WWW/K-12/rocket/ for research and to use online rocket simulator

◆ **Procedure**

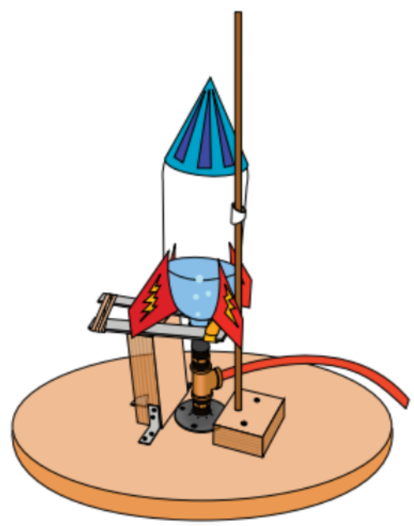
1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how they think a rocket can fly and how engineers have to consider payload, weather, and the shape and weight of a rocket when developing a new or re-engineered rocket design.
3. Teams of 3-4 students will consider their challenge, read about rocketry, and explore the online rocket simulator (if internet access is available)
4. Teams next build and launch their rocket as a team, and observe the flight patterns of other rockets that are launched.
5. For an optional challenge, require students to launch a payload with their rocket. They'll have to develop a design, add a way to hold an item such as a hardboiled egg or tennis ball on their rocket, and evaluate which design worked best.
6. Teams reflect on the experience, and present to the class.

For Teachers:
Teacher Resources (continued)

◆ Detailed Assembly and Launch Instructions

If not using a kit, the procedure is as follows:

- Empty and clean a large plastic soda or water bottle.
- You will need to make the rocket stand up on its own upside down (cap down)…so either guide students to make "tail fins" out of cardboard that can support the weight of a bottle that is 1/4 filled with tap/still water, or make a stand for the class out of wood that will keep the rocket upright during launch. Lengths of wooden dowel held together with duct tape would suffice. For younger students, it is best to have a "launch pad" prepared by the teacher -- this will help ensure that rockets go up and not sideways.
- If you intend to do this lesson multiple times, or want to add another layer of consistency in results, consider building a launching stand for your school. A good plan is at www.nasa.gov/pdf/153405main_Rockets_Water_Rocket_Launcher.pdf. There are many options for building a launcher. Another idea is to set up a joint project with a high school class. The high schools students can design and build the launcher, and the younger students can build the rockets.



- For older students, or to provide additional challenge, after the initial launch, tell student teams that their rockets must now carry a payload (hardboiled egg, tennis ball, packs of sugar).
- Students may decorate their rockets, or, for an extra challenge, require student teams to develop a way to adapt the rocket to carry a payload. This can be done mid-way through testing the rockets to add a twist to the experience.
- Set up a connection from the bottle to a bicycle air pump.
  - You'll need to gather corks which will need to be drilled in order to insert a small plastic tube. Some "corks" are actually made from plastic now, and would be easier to drill evenly. Another alternative is to obtain one of the soft rubber plugs used as temporary stoppers in partially emptied wine bottles. (The type which can be pushed into the neck of the bottle and the air then pumped OUT with a small pump). In essence, the objective here is to somehow obtain a plug which can be tightly squeezed into the neck of the plastic bottle so that it is virtually air-tight.

For Teachers:
Teacher Resources (continued)

◆ **Detailed Assembly and Launch Instructions (continued)**

- Next obtain a small valve of the type which is used to pump up a football. Carefully drill a hole down the length of the cork. The drill used should be smaller than the diameter of the air valve, to ensure it is a really tight fit in the cork.
- For extra safety use a plastic tube (hardware store) to add some space between the bicycle pump and the rocket --- you'll need to have two valves to make this connection work. (Note: many kits come with an extension tube for safety.)

✦ Blast Off! Fill the bottle ¼ full with tap/still water and place it in a vertical position in its launchpad. Connect a bicycle pump to the air valve and start pumping GENTLY. Eventually, the pressure of air in the bottle should be sufficient to expel the cork from the bottle. The water in the bottle will then significantly slow down the outgoing flow of air thus giving time for the rocket to rise to a reasonable height. The actual height will partly depend on the weight of water in the bottle and the tightness of fit of the cork in the neck of the bottle. You can try using more or less water to adjust height of the rocket. Make sure you launch in an open area and keep student back from the launching rocket. You may get wet so ponchos or towels are recommended!

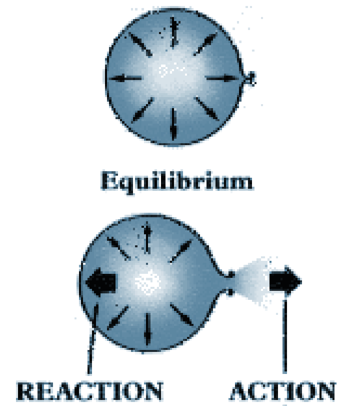
◆ **Safety Notes**

- This outdoor lesson is intended for students who are under the continual supervision of a responsible teacher or teacher team with prior experience with rocket launch kits.
- Be sure to follow your school's safety guidelines at all times.
- Observing students should stay back from launch pad.
- Extend the tube from the bicycle pump to the rocket as far as possible.
- Never stand over a rocket when it is launching.

◆ **Time Needed**

Two to four 45 minute sessions.

Student Resource:
Rocket Principles



A rocket in its simplest form is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape, and in doing so provides a thrust that propels the rocket in the opposite direction. A good example of this is a balloon. Air inside a balloon is compressed by the balloon's rubber walls. The air pushes back so that the inward and outward pressing forces are balanced. When the nozzle is released, air escapes through it and the balloon is propelled in the opposite direction.

When we think of rockets, we rarely think of balloons. Instead, our attention is drawn to the giant vehicles that carry satellites into orbit and spacecraft to the Moon and planets. Nevertheless, there is a strong similarity between the two. The only significant difference is the way the pressurized gas is produced. With space rockets, the gas is produced by burning propellants that can be solid or liquid in form or a combination of the two.

One of the interesting facts about the historical development of rockets is that while rockets and rocket-powered devices have been in use for more than two thousand years, it has been only in the last three hundred years that rocket experimenters have had a scientific basis for understanding how they work.

The science of rocketry began with the publishing of a book in 1687 by the English scientist Sir Isaac Newton. His book, entitled Philosophiae Naturalis Principia Mathematica, described physical principles in nature. Today, Newton's work is usually just called the Principia. In the Principia, Newton stated three important scientific principles that govern the motion of all objects, whether on Earth or in space. Knowing these principles, now called Newton's Laws of Motion, rocketeers have been able to construct the modern giant rockets of the 20th century such as the Saturn V and the Space Shuttle.

◆ Newton's Laws of Motion

- Objects at rest will stay at rest and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.
- Force is equal to mass times acceleration.
- For every action there is always an opposite and equal reaction.

All three laws are really simple statements of how things move. But with them, precise determinations of rocket performance can be made.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource: Rocket Principles (Continued)

◆ Newton's First Law

This law of motion is just an obvious statement of fact, but to know what it means, it is necessary to understand the terms rest, motion, and unbalanced force.

Rest and motion can be thought of as being opposite to each other. Rest is the state of an object when it is not changing position in relation to its surroundings. If you are sitting still in a chair, you can be said to be at rest. This term, however, is relative. Your chair may actually be one of many seats on a speeding airplane. The important thing to remember here is that you are not moving in relation to your immediate surroundings. If rest were defined as a total absence of motion, it would not exist in nature. Even if you were sitting in your chair at home, you would still be moving, because your chair is actually sitting on the surface of a spinning planet that is orbiting a star. The star is moving through a rotating galaxy that is, itself, moving through the universe. While sitting "still," you are, in fact, traveling at a speed of hundreds of kilometers per second.

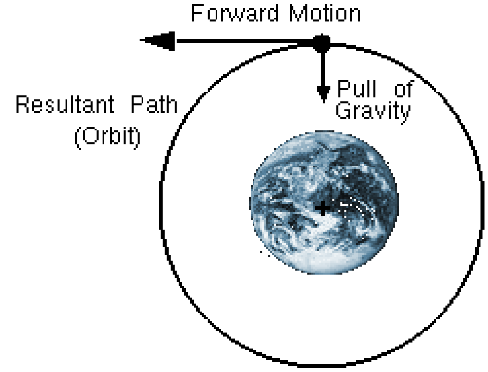
Motion is also a relative term. All matter in the universe is moving all the time, but in the first law, motion here means changing position in relation to surroundings. A ball is at rest if it is sitting on the ground. The ball is in motion if it is rolling. A rolling ball changes its position in relation to its surroundings. When you are sitting on a chair in an airplane, you are at rest, but if you get up and walk down the aisle, you are in motion. A rocket blasting off the launch pad changes from a state of rest to a state of motion.

The third term important to understanding this law is unbalanced force. If you hold a ball in your hand and keep it still, the ball is at rest. All the time the ball is held there though, it is being acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. The forces acting on the ball are balanced. Let the ball go, or move your hand upward, and the forces become unbalanced. The ball then changes from a state of rest to a state of motion.

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity tries to pull it down. As the engines are ignited, the thrust from the rocket unbalances the forces, and the rocket travels upward. Later, when the rocket runs out of fuel, it slows down, stops at the highest point of its flight, then falls back to Earth.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource:
Rocket Principles (Continued)

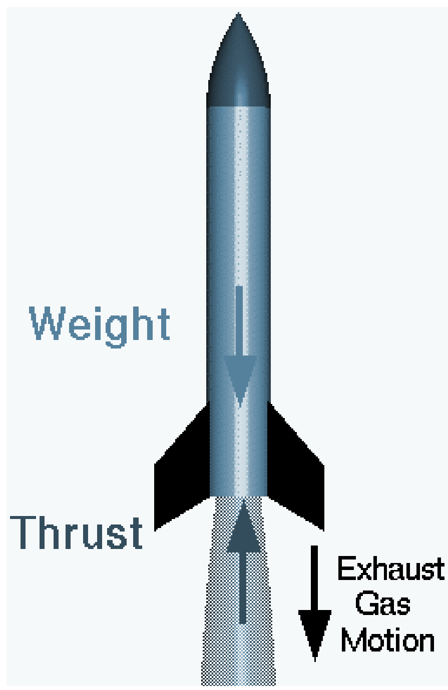


Objects in space also react to forces. A spacecraft moving through the solar system is in constant motion. The spacecraft will travel in a straight line if the forces on it are in balance. This happens only when the spacecraft is very far from any large gravity source such as Earth or the other planets and their moons. If the spacecraft comes near a large body in space, the gravity of that body will unbalance the forces and curve the path of the spacecraft. This happens, in particular, when a satellite is sent by a rocket on a path that is parallel to Earth's surface. If the rocket shoots the spacecraft fast enough, the spacecraft will orbit Earth. As long as another unbalanced force, such as friction with gas molecules in orbit or the firing of a rocket engine in the opposite direction from its movement, does not slow the spacecraft, it will orbit Earth forever.

Now that the three major terms of this first law have been explained, it is possible to restate this law. If an object, such as a rocket, is at rest, it takes an unbalanced force to make it move. If the object is already moving, it takes an unbalanced force, to stop it, change its direction from a straight line path, or alter its speed.

◆ Newton's Third Law

For the time being, we will skip the second law and go directly to the third. This law states that every action has an equal and opposite reaction. If you have ever stepped off a small boat that has not been properly tied to a pier, you will know exactly what this law means.



A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The whole process is very similar to riding a skateboard. Imagine that a skateboard and rider are in a state of rest (not moving). The rider jumps off the skateboard. In the third law, the jumping is called an action. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's opposite motion is called a reaction. When the distance traveled by the rider and the skateboard are compared, it would appear that the skateboard has had a much greater reaction than the action of the rider. This is not the case. The reason the skateboard has traveled farther is that it has less mass than the rider. This concept will be better explained in a discussion of the second law.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource:
Rocket Principles (Continued)

With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the mass of the rocket. In space, however, even tiny thrusts will cause the rocket to change direction.

One of the most commonly asked questions about rockets is how they can work in space where there is no air for them to push against. The answer to this question comes from the third law. Imagine the skateboard again. On the ground, the only part air plays in the motions of the rider and the skateboard is to slow them down. Moving through the air causes friction, or drag. The surrounding air impedes the action-reaction. As a result rockets actually work better in space than they do in air. As the exhaust gas leaves the rocket engine it must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely.

◆ **Newton's Second Law**

This law of motion is essentially a statement of a mathematical equation. The three parts of the equation are mass (m), acceleration (a), and force (f). Using letters to symbolize each part, the equation can be written as follows:

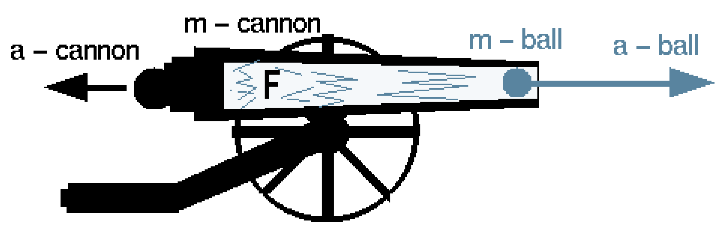
$$f = ma$$

By using simple algebra, we can also write the equation two other ways:

$$a = f/m$$

$$m = f/a$$

The first version of the equation is the one most commonly referred to when talking about Newton's second law. It reads: force equals mass times acceleration. To explain this law, we will use an old style cannon as an example.



When the cannon is fired, an explosion propels a cannon ball out the open end of the barrel. It flies a kilometer or two to its target. At the same time the cannon itself is pushed backward a meter or two. This is action and reaction at work (third law). The force acting on the cannon and the ball is the same. What happens to the cannon and the ball is determined by the second law. Look at the two equations below.

$$f = m(\text{cannon}) * a(\text{cannon})$$

$$f = m(\text{ball}) * a(\text{ball})$$

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource:
Rocket Principles (Continued)

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement. Because the force (exploding gun powder) is the same for the two equations, the equations can be combined and rewritten below:

$$m(\text{cannon}) * a(\text{cannon}) = m(\text{ball}) * a(\text{ball})$$

In order to keep the two sides of the equations equal, the accelerations vary with mass. In other words, the cannon has a large mass and a small acceleration. The cannon ball has a small mass and a large acceleration.

Let's apply this principle to a rocket. Replace the mass of the cannon ball with the mass of the gases being ejected out of the rocket engine. Replace the mass of the cannon with the mass of the rocket moving in the other direction. Force is the pressure created by the controlled explosion taking place inside the rocket's engines. That pressure accelerates the gas one way and the rocket the other. Some interesting things happen with rockets that don't happen with the cannon and ball in this example. With the cannon and cannon ball, the thrust lasts for just a moment. The thrust for the rocket continues as long as its engines are firing. Furthermore, the mass of the rocket changes during flight. Its mass is the sum of all its parts. Rocket parts include engines, propellant tanks, payload, control system, and propellants. By far, the largest part of the rocket's mass is its propellants. But that amount constantly changes as the engines fire. That means that the rocket's mass gets smaller during flight. In order for the left side of our equation to remain in balance with the right side, acceleration of the rocket has to increase as its mass decreases. That is why a rocket starts off moving slowly and goes faster and faster as it climbs into space.

Newton's second law of motion is especially useful when designing efficient rockets. To enable a rocket to climb into low Earth orbit, it is necessary to achieve a speed, in excess of 28,000 km per hour. A speed of over 40,250 km per hour, called escape velocity, enables a rocket to leave Earth and travel out into deep space. Attaining space flight speeds requires the rocket engine to achieve the greatest action force possible in the shortest time. In other words, the engine must burn a large mass of fuel and push the resulting gas out of the engine as rapidly as possible. Newton's second law of motion can be restated in the following way: the greater the mass of rocket fuel burned, and the faster the gas produced can escape the engine, the greater the thrust of the rocket.

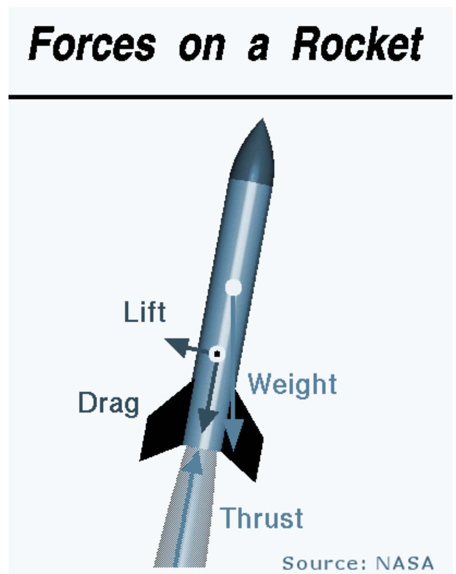
◆ Putting Newton's Laws of Motion Together

An unbalanced force must be exerted for a rocket to lift off from a launch pad or for a craft in space to change speed or direction (first law). The amount of thrust (force) produced by a rocket engine will be determined by the mass of rocket fuel that is burned and how fast the gas escapes the rocket (second law). The reaction, or motion, of the rocket is equal to and in the opposite direction of the action, or thrust, from the engine (third law).

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Worksheet: How Rockets Fly

In flight, a rocket is subjected to four forces; weight, thrust, and the aerodynamic forces, lift and drag. The magnitude of the weight depends on the mass of all of the parts of the rocket. The weight force is always directed towards the center of the earth and acts through the center of gravity, the yellow dot on the figure. The magnitude of the thrust depends on the mass flow rate through the engine and the velocity and pressure at the exit of the nozzle. The thrust force normally acts along the longitudinal axis of the rocket and therefore acts through the center of gravity. Some full scale rockets can move, or gimbal, their nozzles to produce a force which is not aligned with the center of gravity. The resulting torque about the center of gravity can be used to maneuver the rocket. The magnitude of the aerodynamic forces depends on the shape, size, and velocity of the rocket and on properties of the atmosphere. The aerodynamic forces act through the center of pressure, the black and yellow dot on the figure. Aerodynamic forces are very important for model rockets, but may not be as important for full scale rockets, depending on the mission of the rocket. Full scale boosters usually spend only a short amount of time in the atmosphere.



In flight, the magnitude -- and sometimes the direction -- of the four forces is constantly changing. The response of the rocket depends on the relative magnitude and direction of the forces, much like the motion of the rope in a "tug-of-war" contest. If we add up the forces, being careful to account for the direction, we obtain a net external force on the rocket. The resulting motion of the rocket is described by Newton's laws of motion.

Although the same four forces act on a rocket as on an airplane, there are some important differences in the application of the forces:

- On an airplane, the lift force (the aerodynamic force perpendicular to the flight direction) is used to overcome the weight. On a rocket, thrust is used in opposition to weight. On many rockets, lift is used to stabilize and control the direction of flight.
- On an airplane, most of the aerodynamic forces are generated by the wings and the tail surfaces. For a rocket, the aerodynamic forces are generated by the fins, nose cone, and body tube. For both airplane and rocket, the aerodynamic forces act through the center of pressure (the yellow dot with the black center on the figure) while the weight acts through the center of gravity (the yellow dot on the figure).
- While most airplanes have a high lift to drag ratio, the drag of a rocket is usually much greater than the lift.
- While the magnitude and direction of the forces remain fairly constant for an airplane, the magnitude and direction of the forces acting on a rocket change dramatically during a typical flight.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource:
Commercial Spaceflight - News

SpaceShipTwo: The World's First Commercial Spaceship

In 2011, in the skies above Mojave Air and Spaceport CA, SpaceShipTwo, the world's first commercial spaceship, demonstrated its unique reentry 'feather' configuration for the first time. In 2012, Virgin Galactic announced that its vehicle developer, Scaled Composites (Scaled), has been granted an experimental launch permit from the Federal Aviation Administration (FAA) for its suborbital spacecraft, SpaceshipTwo, and the carrier aircraft, WhiteKnightTwo

Already, SpaceShipTwo and WhiteKnightTwo have made significant progress in their flight test program. With 80 test flights completed, WhiteKnightTwo is substantially through its test plan, while the more recently constructed SpaceShipTwo has safely completed sixteen free flights, including three that tested the vehicle's unique "feathering" re-entry system. Additionally, ten test firings of the full scale SpaceShipTwo rocket motor, including full duration burns, have been safely and successfully completed.
With this permit now in hand, Scaled is now authorized to press onward towards rocket-powered test flights. In preparation for those powered flights, SpaceShipTwo will soon return to flight, testing the aerodynamic performance of the spacecraft with the full weight of the rocket motor system on board. Integration of key rocket motor components, already begun during a now-concluding period of downtime for routine maintenance, will continue into the autumn. Scaled expects to begin rocket powered, supersonic flights under the just-issued experimental permit toward the end of the year.
"The Spaceship program is making steady progress, and we are all looking forward to lighting the vehicle's rocket engine in flight for the first time," said Doug Shane, president of Scaled.

Although a handful of experimental launch permits have been granted to other rockets, SpaceShipTwo is the first rocket-powered vehicle that carries humans on board to receive such a permit.

Virgin also announced in 2012 that they will construct a rack system to allow research payloads to fly to space aboard Virgin Galactic's SpaceShipTwo (SS2). With these new racks, SS2 will allow researchers to conduct experiments during several minutes of microgravity using a mounting system also employed on the International Space Station (ISS). Standard racks will support up to 108 cubic feet of usable payload volume. Additionally, experiments can be positioned within the rack system for a view through Virgin Galactic's large, 17-inch-diameter-windows should acquisition of spectral data or imaging be desired

(Source: Virgin Galactic. More details and updates on this effort at www.virgingalactic.com)

Student Worksheet:

◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of building a model rocket using a soda or water bottle that will be attached to a bicycle air pump which will be the source of propulsion or energy. You can either make your rocket from everyday materials or use a kit that is provided to you. Either way, your goal is to have your rocket shoot up the highest and the straightest within your class. You'll research ideas online (if you have internet access), learn about rocket design and flight, and work as a team to construct and test your rocket. You'll consider the results of other teams, complete a reflection sheet, and share your experiences with the class.

◆ Research Phase

Read the materials provided to you by your teacher. If you have access to the internet, also visit www.grc.nasa.gov/WWW/K-12/rocket/ for additional research and to use the online rocket simulator, RocketModeler III.

◆ Planning and Design Phase

On a separate piece of paper draw a detailed diagram of how your rocket will look when completed and estimate how high you believe your rocket with travel. You'll need to design a base to hold your rocket before launch. Include a list of materials you will need and consider the weight you are adding to your base bottle.

If you have been given the challenge of adding a payload to your rocket, you'll need to design a way to have the bottle hold the item(s) you are launching into space. Payloads cannot be held inside the bottle.

◆ Build and Launch

As a team, build your rocket -- but always under the supervision of your teacher! You'll then test the rocket. Be sure to observe how high and how straight the rockets built by other teams go.

◆ Estimate Results

As a team, estimate how high your rocket will fly in the box below:

◆ Reflection / Presentation Phase

Complete the attached student reflection sheet and present your experiences with this activity to the class.

Student Worksheet:

◆ **Reflection**

Complete the reflection questions below:

1. How did the height you estimated your rocket would reach compare with the actual estimated height?

2. What do you think might have caused any differences in the height you achieved?

3. Did your rocket launch straight up? If not, why do you think it veered off course?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. Did you adjust your model rocket at all? How? Do you think this helped or hindered your results?

◆ **Reflection (continued)**

Complete the reflection questions below:

6. How do you think the rocket would have behaved differently if it were launched in a weightless atmosphere?

7. What safety measures do you think engineers consider when launching a real rocket? Consider the location of most launch sites as part of your answer.

8. When engineers are designing a rocket which will carry people in addition to cargo, how do you think the rocket will change in terms of structural design, functionality, and features?

9. Do you think rocket designs will change a great deal over the next ten years? How?

10. What tradeoffs do engineers have to make when considering the space/weight of fuel vs. the weight of cargo?

For Teachers:
Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the National Science Education Standards which were produced by the National Research Council and endorsed by the National Science Teachers Association, and if applicable, also to the International Technology Education Association's Standards for Technological Literacy or the National Council of Teachers of Mathematics' Principles and Standards for School Mathematics.

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of
- Properties of objects and materials
- Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop
- Abilities of technological design
- Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of
- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of
- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop
- Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of
- Risks and benefits
- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of
- Science as a human endeavor
- History of science

Water Rocket Launch

For Teachers:

Note: All lesson plans in this series are aligned to the National Science Education Standards which were produced by the National Research Council and endorsed by the National Science Teachers Association, and if applicable, also to the International Technology Education Association's Standards for Technological Literacy or the National Council of Teachers of Mathematics' Principles and Standards for School Mathematics.

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Chemical reactions
- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.