Connecting to Standards

The lessons in this unit of study relate to the following National Science Education Standards (NRC, 1996) and National Common Core State Standards in Language Arts and Mathematics.

National Science Education Standards
Grades K–12
Content Standards: Unifying Concepts and Process
• Evidence, models, and explanations

Grades K–5
Content Standard A: Science as Inquiry
• Abilities necessary to do scientific inquiry
• Understanding about scientific inquiry

Content Standard B: Physical Science
• Positions and motion of objects
• Motions and Forces (Grade 5 only)

Content Standard E: Science and Technology
• Abilities of technological design
• Understanding about science and technology

Content Standard G: History and Nature of Science
• Science as a human endeavor


National Common Core State Standards
• National Common Core State Standards in Language Arts and Mathematics.

Moving Through the Air: Weight and Lift

Overview
In this lesson students learn that air is matter and discover how moving air causes a kite to fly. Using a model, students investigate how various factors, specifically weight and surface area, affect how objects move through air. Flight is possible because it occurs in air; without air, flight is not possible. Students ask questions, collect data, test ideas, record results, and draw conclusions about how objects move through air.

The Principles of Flight

The X-38 prototype of the Crew Return Vehicle for the International Space Station is suspended under its giant 7,500-square-foot parafoil during its eighth free flight on Thursday, Dec. 13, 2001. A portion of the descent was flown by remote control by a NASA astronaut from a ground vehicle configured like the CRV’s interior before the X-38 made an autonomous landing on Rogers Dry Lake.

NASA PHOTO / TONY LANDIS
Objectives

Data Collection:

Students will:

- observe that a balloon inflated with air takes up more space and has more mass than an identical balloon that is not inflated with air.
- build and launch a model parachute and observe that the more paper clips they add to their parachute, the faster the parachute travels the same distance through air.

Sense-Making:

Students will:

- explain that air is matter that pushes against objects as they move through it. The greater the amount of surface of an object that comes in contact with air, the more the “push” of the air resists the motion of the object as it moves through the air.
- recall that weight is a measure of the force an object exerts due to gravity.
- begin to develop the idea that pushing or pulling can change the position and motion of objects and the size of the change is related to the strength of the push or pull.
- begin to develop the idea that when an object is being pushed and pulled at the same time, the pushes and pulls will be equal in strength and the object’s motion will be constant or one force will be greater than the other and cause a change in the speed or direction of the object’s motion.
- explain that models are tools used for communicating ideas about objects, events, and processes, including flight. Models do some things well but have limitations.

You Will Need

- Student Handouts
- Leonardo da Vinci Parachute Directions
- Leonardo da Vinci Parachute Flight Research Card
- 2 balloons (teacher demonstration)
- 2 pencils (teacher demonstration)
- Paper
- Thread or string – 18” per student
- Kite string or thread – 20’ per student
- Paper clips
- Tape
- Pencil or marker

Time: 90 minutes

Literature Connection

Ms. Frizzle and her class find out about how things fly.

NASA Website for Students: What Is Aerodynamics?
nasa.gov/audience/forstudents/k-4/stories/what-is-aerodynamics-k4.html
A beginner’s guide to the science of flight.

NASA Website for Teachers: Aeronautics
nasa.gov/topics/aeronautics/index.html
News and features about NASA research.

NASA Website for Teachers: Flexible Wing Design Used for Hang Gliders
nasa.gov/audience/foreducators/topnav/materials/listbytype/NASA_at_50_1961.html
Video, audio, and teachers guide for hang gliders.

NASA Website for Teachers: Key Terms
nasa.gov/audience/foreducators/nasaeclips/toolbox/vocabulary.html

NASA Website for Students: Key Terms– Picture Dictionary
nasa.gov/audience/forstudents/k-4/dictionary/index.html

Teacher Tip: Parachute Flight Problems and Solutions

<table>
<thead>
<tr>
<th>Flight Path</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flies straight, glides smoothly</td>
<td>Do not make any changes</td>
</tr>
<tr>
<td>Wobbles back and forth</td>
<td>Make sure object is centered</td>
</tr>
<tr>
<td>Falls fast</td>
<td>Reduce the weight of the object</td>
</tr>
<tr>
<td>Falls fast</td>
<td>Make sure canopy is airtight</td>
</tr>
</tbody>
</table>
Focus Question:
How can we demonstrate and observe that air is matter?

Procedures

Air is Matter
1. **Matter:** Help students develop the idea that air is something (matter), using two balloons. Hold up the two balloons (not inflated) and show that they are the same size, shape, and material. (You may pass them around so students can observe this for themselves.) Point out to the class that they are made of rubber. Rubber, like all objects, is made of particles that cannot be seen, called **matter**.

2. **Air:** Ask students: What is air made of? Is it something or nothing? Record students’ ideas on the board or on a flip chart. Tell students that all matter has two characteristics: it takes up space and has mass. Write the following on the board:

   - Matter takes up space and has mass.
   - Air is matter because it takes up space and has mass.

3. **What Inflates a Balloon?** Inflate and tie the end of one balloon. Then ask the class to compare how the inflated balloon is alike and different from the one that is not inflated. Students should understand that the balloons are still made of the same material and that the only change is that air has been added to one balloon.

4. **What is Mass?** Next, balance a pencil across the balloon that is not inflated, and balance another on top of the inflated balloon. Ask students to describe what is holding the pencil on the inflated balloon higher. Guide students to understand that adding air to the balloon has added more mass and changed the amount of space it takes up. Therefore, air is matter. It is easy to observe that the air takes up space.

Leonardo’s Parachute Design
Leonardo da Vinci dreamed of flying. He studied birds and made hundreds of sketches trying to unlock the secret of flight. Drawings of bird wings and plans for flying machines filled his science journals. He was never able to build machines that actually flew because he did not understand the physics of flight.
Moving Through the Air: Weight

Leonardo da Vinci Parachute Model

Focus Question:

How does the shape of an object help to slow it down as it falls through the air?

1. Pass out the materials and student handout. Share the story of the scientist Leonardo da Vinci and his parachute. Leonardo da Vinci had an idea for a pyramid-shape parachute. Read to students what he wrote on his sketch of it: “If a man have a tent made from linen of which the apertures [openings] have all been stopped up, and it be twelve braccia [about 23 feet] across and twelve in depth, he will be able to throw himself down from any great height without suffering any injury.” Have students make scale drawings in their CSI Flight Adventure Journals of the device that Leonardo was describing. Tell the students that parachutes are used today by NASA and in many other aviation and non-aviation settings. Drag racers use them to slow down, pilots use them for safety, and the space shuttle and other spacecraft use them on landing. Tell students that Leonardo never made his parachute, but they will be following his plans to make and test his design.

2. Building the Leonardo da Vinci Parachute: Instruct students to follow the steps on the student handout to build the parachute:
   a. Cut out the template of the parachute by cutting along the solid lines.
   b. Tell students to put their name on the parachute and label it the “Leonardo da Vinci Parachute.”
   c. Fold the paper along the dotted lines. Make sure students know to cut and fold carefully to make a centered and balanced model.
   d. Carefully tape the TAB to the canopy side to make a four-sided pyramid shape. It will have one point at the top and four corners at the bottom.
   e. Cut the 18” string in half to make two shroud lines. Tape the two ends of one piece of string to two corners of the parachute. Tape the ends of the other piece of string to the other two corners where a star (H) is placed. When finished, there will be two loops hanging down.

   Teacher Note: Teachers may want to increase the number of paper clips from 3 to 5 to make the parachute fall more quickly.

3. Launching and Testing the Parachute: The parachute is complete and ready to fly. Place students in pairs to complete the investigation and collect data on how weight affects a falling object. One student drops both parachutes at the same time from the same height, while the other student judges which one landed first. Then have students add one paper clip to one parachute and five paper clips to the other. Students should conduct five drop trials and record their answers on the Flight Research Card.

Follow-up questions:

- What is weight?
- How does the weight of an object affect how it moves through air?
- How was the parachute different from the crumpled paper ball and the flat lid?
- How did the model you made help you understand how things fly?
- What else do you want to know about flight that the model can’t show you?
### Different Weights
Work with a partner to collect data on how parachutes fall through the air. One student drops both parachutes and the other records data. Switch positions so each student has the chance to drop the parachutes. Record your data by writing which lands first (F), and which lands last (L) on each drop test. Make sure each drop is a fair test.

<table>
<thead>
<tr>
<th>Object Canopy</th>
<th>Fair Drop Trial 1</th>
<th>Fair Drop Trial 2</th>
<th>Fair Drop Trial 3</th>
<th>Fair Drop Trial 4</th>
<th>Fair Drop Trial 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Paper Clip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–5 Paper Clips</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What did you observe when more paper clips were added to the falling parachute?

What is a fair drop test? What is not a fair drop test?

How did increasing the weight of the parachute affect how quickly it traveled a given distance?

If you made a hole in the top of the parachute would it fall slower, faster, or at the same rate? Why?
Moving Through the Air: Weight

Leonardo da Vinci Parachute Model

Student Handout: Template

Materials
scissors, tape, string, student handout

Procedures
1. Cut out the object along solid lines.
2. Fold along dotted lines to form a pyramid shape.
3. Tape the TAB to the open side to make a canopy.
4. Cut the string in half.
5. Tape one string to two corners to make a loop where the stars (H) are located.
6. Tape the second string to make another loop.
7. Add paper clips for weight.
Moving Through the Air: Lift

Indoor Paper Box Kite Model

Overview
In this experience students investigate how moving air causes a kite to fly. Students construct a paper box kite to investigate weight and lift. Students build and fly the model and collect data and record observations on a Flight Research Card.

Objectives
Data Collection:
Students will:
- build and fly a model paper box kite.
- observe that a kite lifts off the ground despite its weight due to the opposing forces exerted by the string and by moving air.

Sense-Making:
Students will:
- explain that lift describes what happens when the push of air on an object overcomes the object’s weight and pushes it up.
- continue to develop the idea that
  - pushing or pulling can change the position and motion of objects.
  - the size of the change in motion is related to the strength of the push or pull.
- explain that models are tools used for communicating ideas about objects, events, and processes, including flight. Models do some things well but have limitations.

You Will Need
- Student Handouts
- Flight Research Card Box Kite
- Box Kite directions
- Thread/string
- Scissors
- Clear or masking tape
- Pencil
- Electric fan
Moving Through the Air: Lift

Indoor Paper Box Kite Model

The photograph above shows the Wright Brothers at Kitty Hawk, North Carolina, with their 1901 Glider being flown as a kite. It weighed 98 pounds and had a wingspan of 22 feet. The kite appears to be floating in the air, but it is actually being held motionless because the forces that are acting on it are “balanced.”

PHOTO COURTESY OF NASA

Background
People around the world have used kites for hundreds of years for military observation and even to look for fish from a vessel at sea. The Wright brothers used a kite to learn how to control an aircraft. When air moves against the surface of a kite, it exerts a force. When the force of the moving air is greater than the weight of the kite, the kite lifts off the ground and flies. The kite—because it is being pulled with an attached string—exerts an equal but opposite force against the moving air. When the force due to the moving air and the force exerted by the kite string are equal, the kite stays aloft.

NASA Website for Students: The Beginner’s Guide to Kites
www.grc.nasa.gov/WWW/K-12/airplane/bgk.html
Teaches basic math and physics that govern the design and flight of kites.

NASA Website for Teachers: Courage to Soar
nasa.gov/audience/foreducators/topnav/materials/listbytype/The_Courage_to_Soar.html
An integrated unit of scientific experiments, aircraft models, and research topics about aviation.

Literature Connection
Mayer, Mercer. Shibumi and the Kite-maker. New York: Marshall Cavendish, 1999. After seeing the disparity between the conditions of her father’s palace and the city beyond its walls, the emperor’s daughter has the royal kite maker build a huge kite to take her away from it all.


Focus Question:
How can air make an object lift off the ground?

1. Ask students how air can make an object lift up from the ground. Record their ideas on the board or a flip chart.
2. Remind students of their findings from Experience 1: that air is matter and that it exerts a force on objects. Remind students that they observed that air can slow down falling objects by pushing up on them, which means that air can change the motion of objects. Have students list things that can be blown up into air by the movement of air (e.g., leaves or feathers). Discuss with your class the difference between a falling object being slowed down by air and an object being lifted off of the ground by moving air.
3. Remind students that weight is the force an object pulled by gravity. Gravity is the force that pulls objects toward the Earth’s surface. For flight to be possible, the force of an object’s weight must be overcome by a stronger force. Let students know that they will explore how to use moving air to cause a kite to fly.
Moving Through the Air: Lift

Indoor Paper Box Kite Model

4. Tell the students that there are many different types of kites. Some kites, like the Chinese and Japanese designs, come from hundreds of years of research and flying. Modern kites are made with special materials for special purposes. Regardless of size or type, all kites **lift** into the sky because of the push of moving air. Ask students: What force must be overcome to cause a kite to fly?

5. Building the Paper Box Kite: Distribute the student handouts for the box kite. Instruct students to follow the steps on the handout to build the box kite.
   a. Cut out the two parts of the box kite.
   b. Cut out the box kite pattern along the solid lines.
   c. Fold down along the dash lines so edge A-B touches edge C-D.
   d. Apply a piece of tape to the TAB to join edge A-B to edge C-D.
   e. Cut out the tail.
   f. Tape one end of the tail to the kite at corner B-D.
   g. Tape the end of the thread to corner A-C.
   h. Adjust the edges of the kite to form a box.

<table>
<thead>
<tr>
<th>Flight Path</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flies straight and smooth</td>
<td>Do not make any changes</td>
</tr>
<tr>
<td>Does not fly</td>
<td>Shorten tail</td>
</tr>
<tr>
<td>Bobs up and down</td>
<td>Lengthen tail</td>
</tr>
</tbody>
</table>

Teacher Tip: Box Kite Flight Problems and Solutions
1. Flying the Box Kite: The paper box kite is complete and ready to fly. In the classroom, instruct students to launch the model gently in front of a fan to observe lift. Outdoors, students can run to launch the kites in a gentle wind.

2. Testing the Box Kite: Once students have flown the box kite, ask them to make one of the following changes and fly the kite again. They should record how the kite behaves on their Flight Research Card for each trial.
   a. Change where the tail is connected to the box kite.
   b. Add an additional tail.
   c. Shorten or lengthen the tail.
   d. Change the speed of the fan.
   e. Change the length of the kite string.
   f. Make a larger box kite.

Sense-Making Discussion and Questions
Ask students to predict what is needed to make a heavier kite fly into the air. Students should understand that the push of air from the fan lifts the kite. The pushing force and the angle of the air moving on the kite create lift. Two things can be changed to make a heavier kite fly: stronger wind (faster wind speed) or greater air surface.

Ask students: How did the model you made help you understand how things fly? How was the model not helpful?
Indoor Paper Box Kite Model

Student Handout: Flight Research Card

Name: ______________________________________ Date: ______________

Follow the steps on the student handout to build the box kite. Materials: pattern, scissors, tape, thread

1. Cut out the two parts of the box kite in the student handout.
2. Cut out the box kite pattern along the solid lines.
3. Fold down along the dash lines on the kite so edge A-B touches edge C-D.
4. Apply a piece of tape to the TAB to join edge A-B to edge C-D.
5. Cut out the tail.
6. Tape one end of the tail to the kite at corner B-D.
7. Tape the end of the thread to corner A-C.
8. Adjust the edges of the kite to form a box.

<table>
<thead>
<tr>
<th>Trials and Changes</th>
<th>Describe How the Box Kite Flies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1 First Flight</td>
<td></td>
</tr>
<tr>
<td>Draw tail position</td>
<td></td>
</tr>
<tr>
<td>Trial 2 Change the position of the tail</td>
<td>Draw tail position</td>
</tr>
<tr>
<td>Trial 3 Add another tail</td>
<td></td>
</tr>
<tr>
<td>Draw tail position</td>
<td></td>
</tr>
<tr>
<td>Trial 4 Shorten the tail</td>
<td>Measure change in inches or centimeters</td>
</tr>
<tr>
<td>Trial 5 Lengthen the tail</td>
<td>Measure change in inches or centimeters</td>
</tr>
<tr>
<td>Trial 6 Another change</td>
<td></td>
</tr>
</tbody>
</table>

Using the data you have collected, explain how moving air causes a kite to fly by overcoming its weight.
Moving Through the Air: Lift

Indoor Paper Box Kite Model

Kite Tail

Box Kite Body

Name: ____________________________

Date: ____________________________

A

B

C

D
Moving Through the Air: Thrust and Drag

Overview
In this lesson students learn about two more forces important for flight. Students construct a rocket using paper, pencil, and tape to investigate thrust and drag. Students build, test, collect data, and record observations using their paper rocket model. They investigate how a single variable on the rocket fin will change the performance of the model. They make careful observations, drawings, and notes as they investigate how the paper rocket model moves.

Objectives

**Data Collection:**
Students will
- build, test, and fly a model rocket made of paper;
- make and record observations about the flight of a paper model rocket;
- observe that a force must be applied to make a paper model rocket fly; and
- observe that drag increases when they bend the fins on a model rocket.

**Sense-Making:**
Students will
- explain that thrust is the force that propels an object through air;
- explain that drag is the force that slows the motion of an object moving through air;
- apply the idea from Lesson 1 (that the more surface of an object air comes in contact with, the more the “push” of the air resists the motion of the object as it moves through it) to explain why changing the fins on the paper model rocket increased drag;
- explain, using the paper model rocket as an example, that the position and motion of objects can be changed by pushing or pulling the object and that the size of the change in the motion of an object is related to the strength of the push or pull acting on the object; and
- demonstrate that models are tools used for communicating ideas about objects, events, and processes, including flight.
- give examples of how models do some things well but have limitations.
Moving Through the Air: Thrust and Drag

Paper Rocket Model

<table>
<thead>
<tr>
<th>You Will Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Student Handouts</td>
</tr>
<tr>
<td>• Flight Research Card Paper Rocket</td>
</tr>
<tr>
<td>• Paper Rocket Directions</td>
</tr>
<tr>
<td>• Cardstock or a 3” x 5” index card</td>
</tr>
<tr>
<td>• Straws, 1 per student</td>
</tr>
<tr>
<td>• Scissors</td>
</tr>
<tr>
<td>• Clear or masking tape</td>
</tr>
<tr>
<td>• Pencils, 1 per student</td>
</tr>
<tr>
<td>• Meter stick or tape measure</td>
</tr>
<tr>
<td>• Goggles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teacher Tip: Parachute Flight Problems and Solutions</th>
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<tbody>
<tr>
<td><strong>Flight Path</strong></td>
</tr>
<tr>
<td>Flies straight, glides smoothly</td>
</tr>
<tr>
<td>Banks to the right or left</td>
</tr>
<tr>
<td>Spins</td>
</tr>
<tr>
<td>Sticks on straw</td>
</tr>
<tr>
<td>Doesn’t go far</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Background</th>
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<tbody>
<tr>
<td>NASA Website for Students: The Beginner’s Guide to Rockets</td>
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<tr>
<td><a href="http://www.grc.nasa.gov/WWW/K-12/rocket/bgmr.html">www.grc.nasa.gov/WWW/K-12/rocket/bgmr.html</a></td>
</tr>
<tr>
<td>Teaches basic math and physics that govern the design and flight of rockets.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literature Connection</th>
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<tr>
<td>A Pictorial History of Rockets, NASA</td>
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<tr>
<td>nasa.gov/pdf/153410main_Rockets_History.pdf</td>
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<tr>
<td>NASA Website for Teachers: Educator’s Guide to Rockets</td>
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<tr>
<td>nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html</td>
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<tr>
<td>A comprehensive guide to and history of rockets.</td>
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| • Evidence, models, and explanations |

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| • Understanding about scientific inquiry |

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| • Abilities of technological design |
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| Content Standard G: History and Nature of Science |
| • Science as a human endeavor |


| National Common Core State Standards |
| • National Common Core State Standards in Language Arts and Mathematics |
Moving Through the Air: Thrust and Drag

Paper Rocket Model

Focus Question:

How does an aircraft overcome its weight and the push of air to lift into the air and fly?

Procedures

1. Opening Discussion and Teacher Demonstration: Help students review what they learned by asking them to explain why a parachute falls slowly to the ground and a kite lifts into the air (air is pushing up on them). Help students recall that weight and lift are opposing forces, and that when one force is greater than another, an object’s motion will change, but when they are equal in strength the object’s motion will not change. (In other words, if weight is greater than lift, the object will fall).

2. Remind students that they looked at models that either fell through air or were lifted off the ground by moving air. Tell them that they will now look at objects that take off from the ground.

Collect and record students’ ideas for discussion later. Next, crumple a piece of paper into a ball and throw it across the room. Then ask students: What caused the paper to move? What caused it to stop? Slowly repeat the motion of throwing the paper ball to show students that you applied a force with your arm to make the paper move, and that the force of the air pushing against the paper and the force due to the weight of the paper were greater than the force applied by your throw, causing the paper ball to fall.

3. Distribute the five student handouts for this experience found on pages 37-41 of this unit. Tell students that in this experience they will build a paper rocket and test it just like a NASA engineer might test a real one. The paper rocket model to be constructed has three sections, including tube, nose, and fins. Hand out the other materials needed for this lesson.

4. Rocket Tube: Cut a narrow rectangular strip of paper about 5 inches long and roll it tightly around the pencil. Roll the paper at an acute angle less than 90 degrees. This will cause the paper to cover the entire length of the pencil. Make sure that it is not tight on the pencil. If the tube is wound tight it will be difficult to remove from the pencil and the straw will not fit into the body. Have students rewind the paper if this occurs. Remove the tube from the pencil. Make sure it slides back and forth on the pencil. Students may need additional help rolling the paper on the pencil to form the tube. Several attempts may be necessary to make the rocket tube five to six inches long. Tape the tube once it is the correct size. Point out to the students that one end of the rocket tube is thicker than the other end. The thick end will be the bottom of the rocket.

5. Rocket Nose: Squeeze flat the front end of the rocket tube about 1.5 centimeters (about 1 inch). Crease it and fold it hotdog style. Place your pencil back in the paper rocket tube and push it toward the front. Tape the folded tip of the rocket. Make sure the front end of the paper rocket is airtight and pointed. Remove the pencil and gently blow into the open end of the tube to check for leaks. If air easily escapes, use more tape to seal the rocket tube.

6. Rocket Fin: Cut out two sets of fins using the pattern. Place the pencil back inside the rocket tube to make it easier to tape the fins. Each student should write his or her name on the rocket tube near the fins. Tape the two sets of fins near the open end (bottom) of the rocket tube. Use a small amount of tape to secure the bottom tab of the fin to the bottom of the rocket tube. Make sure that the tape does not stick to the pencil. Repeat with the second rocket fin. Check to make sure that the rocket fins are even and perpendicular to the rocket tube.
Paper Rocket Model

Moving Through the Air: Thrust and Drag

7. Launch Measurements: In the classroom or a hallway use masking tape to lay out a launch pad and landing area 5 to 8 meters long. (Mark off the area in meters ahead of class in order to save time.) Place markers along the path at regular intervals. Many classrooms, lunchrooms, gyms, and hallways have uniform ceiling or floor tiles that can be used for easier measurement—both to create the launch pad and to estimate the distance the rockets travel. Most ceiling tiles are two- or four-foot sections. Teachers can help students pace the distance based on their own stride. Students need only count their own distance because they are not comparing data with each other.

8. Teacher-Led Launch: Students should wear goggles when launching the paper rockets. The following is an effective way to conduct paper rocket launching with students:

   a. Divide the students into two groups: launchers and observers. Each student should have a partner in the opposite group.

   b. Line up the students on opposite sides of the classroom. This system will also work in a larger area—gym, hallway, lunchroom, or other group area.

   c. Direct the launcher group to prepare their rockets for flight. Each student should slip the straw into the rocket’s opening at the bottom of the tube. Remind students to be careful not to aim the rocket toward anyone but only toward the landing area. Each student should take a deep breath and blow into the straw to produce a strong push of air as you give a “3, 2, 1, launch!” command. The rocket will be propelled into the air. Each student in the observers group should try to follow the flight of his or her partner’s rocket. Do not allow any student to enter the landing area until you give the command.

   d. Direct students to wait for your “All clear!” command before the observer students may enter the landing area. Remind them to look for their partner’s name on the rocket without disturbing it from its landing position.

   e. Students should record the distance flown and draw the flight path on their worksheets. Then the rockets may be retrieved.

   f. Repeat the paper rocket launch procedures with the other half of the class from the opposite side of the room. Students who were observers are now launchers, and vice versa. Students can complete the investigation in a safe manner by taking turns this way.

9. Student Launch Trials: The paper rocket is complete and ready to fly. The first step in flying the model is to make sure it is trimmed to fly in a straight path. Instruct students to gently launch the model directly in front of them and away from any other person. Tell them to make sure to launch the rockets with the same strength and at the same angle each time. Ask them to observe how the paper rocket moves. Show students how to make small adjustments to the rocket fins and tube until the rockets fly in a straight path. Let the students continue to make adjustments after each test flight. Once a paper rocket flies in a straight path for a distance of 5 feet, allow students to complete the launch trials on the student handout Flight Research Card. Students will complete three rocket launches with the fins straight and streamliner. They should get long straight flight paths. After students record their observations, they should change the position of the fins. Direct students to bend each of the four fins to control the flight of the rocket. If students bend all four fins in the same direction, the rocket will spiral and have more drag and less distance. Have students complete three more launches. Each flight with bent fins should be a shorter distance than the three when the fins were straight. Rockets should move in a spiral through the air as the air hits and interacts with the fins.
Paper Rocket Model

Teacher Tip

Working in pairs, one student can launch and the other can measure; then they can switch.

Sense-Making Discussion and Questions

- Review student responses to the focus question after the paper ball demonstration, and ask: How did you get your paper model rocket to launch? Was that a force? Which one (push or pull)?

- Tell students that the force applied to propel an aircraft into and through air is called **thrust**. Explain that thrust creates lift by causing air to move over the surface of an aircraft. Remind students of the kite example and how the air had to move against the kite to lift it into the air. Ask: How did you cause lift with the paper rocket? What force or forces were opposing the forward motion of the rocket due to thrust and the upward motion due to lift?

- Students should be able to explain that the weight of the rocket and the push of air were opposing lift and thrust. Remind them of the parachute trials: air is matter and pushes against objects that move through it. Tell students that when the push of air resists the motion of an aircraft, it is called **drag**. Have students summarize that weight and drag oppose thrust and lift by drawing a diagram of a rocket and the direction of each force as it flies.

- Ask students how the paper ball demonstration was similar to and different from the trials with their rockets. Guide students to think about the shape of the paper ball and the shape of the rocket, and how they interacted differently with air. Ask: How did the design of the paper rocket affect the way it moved through air? How did the changes you made to the fins change the motion of the rockets? Why?

- Students should be able to apply what they have learned in this experience and previous experiences to explain that the paper rocket was designed to allow air to pass over its body with little resistance (drag), and that when they bent the fins, drag was increased and changed the motion of the rocket (slowed it down and caused it to spin).

- Ask: How did the model you made help you understand how things fly? How was the model not helpful?

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**NASA Aeronautics Student Reports**

Aircraft models have been tested in wind tunnel facilities at NASA Langley, NASA Ames, and NASA Glenn research centers, and NASA Dryden Flight Research Center. Wind tunnels at NASA Marshall Space Flight Center have been and continue to be used to develop launch vehicles. Teachers may want to assign a student report about one of the following topics.

- X-1
- X-15
- Robert Goddard
- Wallops Island Sounding Rockets
- NASA Langley Research Center
- NASA Dryden Flight Research Center
- NASA Ames Research Center
- NASA Glenn Research Center
- NASA Marshall Space Flight Center
- NASA Career: Flight Engineer
- NASA Fact Sheet: X-1
- NASA Fact Sheet: X-15

Information can be found at [nasa.gov](https://nasa.gov)
# Paper Rocket Model

**Student Handout: Flight Research Card**

Name: ___________________________ Date: __________________

Build a rocket to investigate thrust and drag.

Materials: pattern, scissors, tape, pencils, straws.

1. **Rocket Tube:** Cut a narrow rectangular strip of paper about 5 inches long and roll it tightly around the pencil. Tape the tube. Make sure that it is not tight on the pencil. Remove it from the pencil. Make sure it slides back and forth on the pencil.

2. **Rocket Nose:** Squeeze flat the front end of the rocket tube, about 1 inch. Crease it and fold it hotdog style. Place your pencil back in the paper rocket tube and push it toward the front. Tape the folded tip of the rocket. Make sure the front end of the paper rocket is airtight and pointed.

3. **Rocket Fin:** Cut out two sets of fins using the pattern. Place the pencil back inside the rocket tube to make it easier to tape the fins. Tape the two sets of fins near the open end (bottom) of the rocket tube. Use a small amount of tape to secure the bottom tab of the fin to the bottom of the rocket tube. Make sure that the tape does not stick to the pencil. Repeat with the second rocket fin. Check to make sure that the rocket fins are even and perpendicular to the rocket tube. Put your name on the rocket.

4. **Trials:** Launch your rocket six times. For the first three launches, keep the fins straight to reduce drag. Use alignment guide provided. Then bend the fins to increase drag for the last three launches. Record the distance traveled, the path of the rocket, and any other observations.

<table>
<thead>
<tr>
<th>Launch Trials</th>
<th>Record the Distance, Path, and Flight Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1 Straight Fins</td>
<td></td>
</tr>
<tr>
<td>Trial 2 Straight Fins</td>
<td></td>
</tr>
<tr>
<td>Trial 3 Straight Fins</td>
<td></td>
</tr>
<tr>
<td>Trial 4 Bend one fin</td>
<td></td>
</tr>
<tr>
<td>Trial 5 Bend two fins</td>
<td></td>
</tr>
<tr>
<td>Trial 6 Bend three fins</td>
<td></td>
</tr>
</tbody>
</table>

Did the paper rocket move differently when the fins were bent? How?

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Academy of Model Aeronautics | Education Through Aviation
www.amatflightschool.org | education@modelaircraft.org
Paper Rocket Model

Moving Through the Air: Thrust and Drag
The Principles of Flight

Design Your Own Aircraft: FPG-9 Glider

Focus Question:

How can an airplane move in different directions?

1. Remind students what they have discovered. Air is matter and it exerts a force on objects as they move through it. Weight and lift are opposing forces that affect how an object moves up and down in air. Thrust and drag are opposing forces that affect how an object moves forward in air. Tell students that in this experience they will use what they have learned about the forces that govern flight to control a model airplane’s motion.

2. Pass out the student handouts for this experience. Tell students they are going to build a special model airplane with control surfaces called the FPG-9. The FPG-9 derives its name from its origins, the venerable and ubiquitous foam picnic plate. The Foam Plate Glider is created from a 9"-diameter plate. They will build and use the glider to investigate how aircraft use control surfaces to climb, turn, and maintain stable flight.

3. Pass out the materials and student handouts for this lesson. Introduce the concept of controlled flight to the students. Share how the Wright brothers used kites and gliders to understand ways to control an aircraft in flight.

4. Pass out the FPG-9 pattern, tape, penny, and foam plate to each student. Use less expensive foam that bends. Teachers may want to print the FPG-9 pattern on card stock. Some students may benefit from having the template taped onto the foam plate.

5. Instruct students to cut out the paper FPG-9 pattern. Do not cut along the dotted line on the paper pattern. Cut only along the bold lines. (Teachers may want to cut out a set of foam plate master templates for students to trace around.)

6. Place the paper (or foam) pattern in the center of the foam plate, ensuring that the tail of the pattern stays inside the curved portion of the plate bottom. The tail must remain on the plate's flat bottom. The tab on the front of the pattern may be on the curve of the plate; it will be folded over later in the construction. The ends of the wings should reach the edge of the round plate.

7. Trace around the pattern with a ballpoint pen. Mark lines for the slots A and B.

8. Cut out the foam template by following the pen lines drawn. Cut along the dotted line to separate the tail from the wing. It is better to make all the cuts from the outside of the plate toward the center. Do not try to turn the scissors; instead, cut from a different angle.

9. The wing and the tail each have slots drawn on them. Have the students make a cut along each of these lines. The slots should be only as wide as the thickness of the foam plate. If the slots are cut too wide, the pieces of the plane will not fit together snugly.

10. To attach the tail to the wing, slide slot 1 into slot 2. Use small (2") pieces of tape to secure the bottom of the tail to the top and bottom of the wing. Make sure the tail is perpendicular to the wing before adding tape.

11. In order to make the plane fly successfully, the students must attach the penny on the top of the wing, right behind the square tab. They should refer to the paper FPG-9 pattern. Fold the tab back over the penny and tape it down to secure the coin. This adds weight to the front of the plane, allowing it to fly farther. Ask students to put their name on the FPG-9.

12. Teacher-Led Launches: The following is an effective way to conduct FPG-9 glider launching for the students:

   a. Divide the students into two groups: observers and launchers. All students should wear safety goggles.

   b. Assign students in pairs, one from each group.

   c. Have the two groups line up on opposite sides of the room. This system works best in a large area, such as a gym, a hallway, or a lunchroom, with ample space for children to try to make the FPG-9 loop.

   d. Direct the launchers group to prepare their gliders for flight. Remind students not to aim toward anyone but to point the gliders toward the landing area. Direct students to wait for your "3, 2, 1,"
Design Your Own Aircraft: FPG-9 Glider

**Launch**! command and to remain in the launch area to watch as the gliders are propelled into the air. Give an “all clear” command to allow the observers group to enter the launch area to measure flight distances.

e. Student pairs should collaborate to record how their gliders moved, and how far they traveled, on their worksheets.

**14. FPG-9 Glider Flight Trials:** Once a glider is trimmed and flies in a straight path for a distance of several feet, instruct the students to perform the following three flight trials with elevons or rudders and record their observations on the Flight Research Card:

a. **Pitch** — Refer students to the drawings at the bottom of the Flight Research Card. Hold up a glider with the nose facing away from you. Show students how you are now looking at the back of the airplane tail. Tilt the nose of the glider up and then down. Explain that this movement is called pitch. Have all the students repeat the word while making pitch movements with their gliders. Pitch is the up and down movements an aircraft makes in flight. The nose pitches up when climbing and pitches down when descending.

b. **Pitch Up** — Ask students how they could get their FPG-9 to pitch up. Which control surface would have to be adjusted and how? Then, have students test their ideas. Determine which students’ adjustments resulted in pitch up (bending both elevons up). Then have all students demonstrate pitch up. Some students will bend the elevons at almost a 90-degree angle. Instruct one of those students to point his or her glider with the nose facing away, tilted slightly upward, and not aimed toward anyone, and then to throw the glider with great force. Ask the class to observe how the glider moves. The FPG-9 should do a big loop and have enough speed for a glide of 6 to 10 meters after that. Instruct the class to adjust the bend in their elevons a little and then launch their gliders with the same amount of force and at the same angle for each step in this activity. They should repeat the trial until they succeed.

c. **Pitch Down** — Ask students how they think they could get their gliders to pitch down. Which control surface would have to be adjusted, and how? Have students test their ideas. Ask students whose adjustments resulted in pitch down (bending both elevons down) to show the class what they did. Then have all students make similar adjustments and launch their gliders again. The gliders should make a steep downward dive to the floor and not travel far.

d. **Roll Right** — While holding the glider with the nose facing away from you, ask students to imagine a rod running through the glider from the nose to the tail. Rotate the glider around the axis of (continued on next page)
that imaginary rod. Tell the students that when a plane moves like this it is called **roll**. Instruct students to move the right elevon located on the wing up a small amount. The elevons and ailerons are interconnected: when one goes up the other goes down. Tell students to move the left elevon **down** a little. The tail rudder should be neutral. This should cause the plane to roll right. Ask students to observe how the glider moves. Tell students to make minor adjustments if the glider did not roll right.

**e. Roll Left** — Instruct students to put the right elevon back to level with the wing, then move the left elevon down and the rudder to the left. This configuration should cause the plane to roll left. Ask students to observe how the glider moves. Tell students to make minor adjustments if the glider did not roll left.

**f. Yaw** — Demonstrate yaw by holding the glider and moving it side to side while keeping it horizontal to the floor. Instruct students to hold their gliders and demonstrate yaw, roll, and pitch. Tell students that these are the basic ways an aircraft can move while flying. Moving the elevons and rudder is a way to control the flight of an airplane. The Wright brothers were early aviators who learned how to control the flight of an airplane by moving the control surfaces on the plane.

15. Identify the two **elevons** on the wings and label them with a ball-point pen. They are control surfaces for the glider. Gently bend the elevons on the wing upward to provide for a small climb at launch and a longer glide. Students may benefit by putting two arrows on the wings of the airplane that point in the direction it will fly.

16. Identify and label the **rudder** on the vertical **fin** (tail) of the glider. This is another control surface for the glider.

17. Show the Total Control video to your class. Discuss how an aircraft can be controlled. Use the FPG-9 as an example of the three ways an aircraft can move: pitch, roll, and yaw.

18. **Control Surfaces:** Ask students to add elevons (2) and a rudder to their model. Once they add the control surface, have them complete the trials and record their observations on the Flight Research Card.

**Sense-Making Discussion and Questions:**

After completing their trials, ask students to review which control surface resulted in each motion of the FPG-9 (pitch, roll, and yaw). Then ask: What were the control surfaces on your aircraft? What are the functions of these control surfaces? How did the control surfaces affect the flight of your airplane? Were you able to make your FPG-9 fly in a predictable path? How? Why did changing the position of the control surface change the way your model flew? How could a model be useful for learning about how a full-size aircraft flies?

Guide students to explain that the model FPG-9 had special parts called control surfaces that interacted with air as it passed over them to change the motion of the model. When the control surfaces were moved into the airflow it changed the motion of the aircraft in predictable ways. Explain that understanding how each control surface changes an aircraft’s motion allows pilots to control how aircraft move.

Ask: How did the model you made help you understand how things fly? How was the model not helpful?

**Experience Assessment**

Ask students to answer the following application question: NASA engineers worked on the F-15 to improve control. Using what you have learned in your investigations, explain how the F-15 controls pitch, roll, and yaw.

**NASA Aeronautics Student Reports**

Aircraft models have been tested in wind tunnel facilities at NASA Langley, NASA Ames, and NASA Glenn research centers and NASA Dryden Flight Research Center. Wind tunnels at NASA Marshall Space Flight Center have been and continue to be used to develop launch vehicles. Teachers may want to assign a student research report about one of the following:

- Wright brothers
- Control surfaces: canards, elevons, rudder, flaps, ailerons
- NASA Langley Research Center
- NASA Dryden Flight Research Center
- NASA Ames Research Center
- NASA Glenn Research Center
- NASA Marshall Space Flight Center
- NASA Career: Research Pilot
- NASA Fact Sheet: F-15

Information can be found at nasa.gov
Design Your Own Aircraft: FPG-9 Glider

Width of the slot is determined by the thickness of the foam plate.

Design by: Jack Reynolds, AMA
Design Your Own Aircraft: FPG-9 Glider

Student Handout: Flight Research Card

Name: _______________________________       Date: _____________

When your FPG-9 Glider is built and ready to fly, complete the following flight trials and record your observations.

<table>
<thead>
<tr>
<th>Flight Trials</th>
<th>Control Surface</th>
<th>Describe How the FPG-9 Flies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trial Flight</td>
<td>Control surfaces neutral</td>
<td></td>
</tr>
<tr>
<td>2. Trial Flight</td>
<td>Control surfaces neutral</td>
<td></td>
</tr>
<tr>
<td>3. Trial Flight</td>
<td>Control surfaces neutral</td>
<td></td>
</tr>
<tr>
<td>4. Pitch Up</td>
<td>Elevons slightly bent up, rudder flat</td>
<td></td>
</tr>
<tr>
<td>5. Pitch Down</td>
<td>Elevons slightly bent down, rudder flat</td>
<td></td>
</tr>
<tr>
<td>6. Roll Right</td>
<td>Right elevon up, Left elevon down</td>
<td></td>
</tr>
<tr>
<td>7. Roll Left</td>
<td>Left elevon down, Right elevon up</td>
<td></td>
</tr>
<tr>
<td>8. Yaw Right</td>
<td>Rudder right</td>
<td></td>
</tr>
<tr>
<td>9. Yaw Left</td>
<td>Rudder left</td>
<td></td>
</tr>
<tr>
<td>10. Loop</td>
<td>Elevons up, hard throw to the ground</td>
<td></td>
</tr>
</tbody>
</table>

Pitch

Roll

Yaw