The NASA "Why?" Files
The Case of the
Challenging Flight

Segment 2

The tree house detectives continue their quest to win the Egg-tra-ordinary Plane Contest. To learn how aeronautical engineers conceive new and innovative ideas for airplane designs, they turn to the technology of **CU SeeMe TV** and visit with Burt Rutan. The tree house detectives learn how Mr. Rutan thinks "outside of the box" to develop new aircraft designs. They are introduced to several unique designs such as the *Proteus*, the *Voyager*, and the *Long EZ*. Next, the tree house detectives go to meet a pilot for U.S. Airways to learn about thrust. As a result of their investigations, they begin to question if weight affects thrust. To check out their theory, they e-mail a school in the NASA "Why?" Files Kids' Club that is conducting experiments on weight and thrust. To further their knowledge of how weight affects thrust, they are invited aboard an aircraft carrier, the *USS Theodore Roosevelt*. The tree house detectives are flown onboard and introduced to an aircraft carrier's catapult system. They just happen to run into Dr. D, who is on the carrier conducting experiments of his own. Dr. D helps the tree house detectives bring it all together for a better understanding of thrust. As they are catapulted off the carrier at a speed of 160 mph in less than 3 seconds, they learn firsthand about the force of thrust!

Objectives

The students will
- understand Bernoulli's Principle.
- learn the importance of creative thinking and design.
- learn that thrust is a force that is needed to overcome gravity and weight in so that a plane can fly forward through the air.
- learn that weight affects thrust.
- learn how a catapult system helps thrust a plane off the flight deck of an aircraft carrier.
- compare the length of an airport runway to that of a aircraft carrier's catapult.
- relate how the length of a runway affects the amount of thrust needed.

Vocabulary

aerodynamics - the study of the motions and forces of gases on an object

aircraft carrier - a large naval ship with storage and service facilities for aircraft and a long flat deck on which airplanes can take off and land at sea

air pressure - the weight of air pressing on a surface

Bernoulli's Principle - states that the pressure in a moving stream of fluid is less than the pressure in the surrounding fluid

catapult - a mechanism for launching aircraft without a runway or with a short runway, as from an aircraft carrier

cylinder - a round chamber through which a piston moves

dihedral angle - angle that is formed by the intersection of an airplane's wing and the fuselage, creating a "V" shape

nuclear reactor - a device in which a chain reaction is begun and controlled with the production of heat typically used for power generation

pitch - the angle between the nose of an aircraft and the horizon. The nose pitches "up" or "down" in relation to level flight.

piston - a solid cylinder or disk that fits snugly into a larger cylinder and moves back and forth under fluid pressure

roll - one of the three axes of motion for an aircraft; roll raises the wings of the aircraft up or down

runway - a strip of usually paved level ground on which aircraft take off and land

second law of motion - force = mass X acceleration ($f = m \cdot a$). An unbalanced force accelerates an object in the direction of that force. The larger the force, the greater the acceleration. The mass of an object also determines its acceleration. The greater the mass, the less the acceleration.

shuttle - metal object that connects the plane to the catapult system

stability - a measure of how hard it is to knock an object off balance

yaw - one of the three axes of motion for an aircraft; yaw moves the nose of the aircraft side to side

Video Component (15 min)

Before Viewing

1. Briefly summarize the events in segment 1 with the students.
2. Ask the students how learning about the history of flight helped the tree house detectives in their endeavor to build a better plane. Discuss how we can learn from other people's mistakes and build on their accomplishments.
3. Introduce the vocabulary for segment 2. Assign each student a word to look up in the dictionary. Have the student share the definition with the class in the form of an illustration or other medium of their choice.
4. Review scientific inquiry and predict what steps the tree house detectives will take next in the process.

After Viewing

1. Discuss the questions that are asked at the end of the second video segment.
   - Will the tree house detectives change the mode of thrust for their plane?
   - Do they still need to investigate drag?
   - Can they combine all that they've learned so far to make a plane fly faster and farther?
2. Continue to guide the students in modifying and adding to the K-W-L chart.
3. Continue working with the display board to reinforce the investigation steps that the tree house detectives are taking to solve the problem. Point out that the detectives frequently stop to summarize what they know and discuss what they have discovered to see if they need to change their hypothesis.
4. Catapults are discussed in this segment due to the short runways on aircraft carriers. Have your students investigate the history of catapults. The use of this technology has varied widely from supersonic jets to pumpkin launching.
5. If you have older students, you might want to access activities from the *Exploring Aeronautics CD*, enclosed with this guide. You can access the web site at **http://www.exploringaerospace.arc.nasa.gov**
6. Runway lengths vary widely depending on their uses. Have your students investigate their local airports to find out what kinds of aircraft land there.
7. Choose from the activities in this guide or on the web site to help reinforce the concepts and objectives being emphasized in segment 2.

Careers

aeronautical engineer
inventor
commercial airline pilot
sailor
nuclear physicist
military fighter pilot
flight engineer
copilot
flight attendant
cargo loader
air traffic controller
aircraft engine mechanic

Resources

Asmiov, Isaac and Elizabeth Kaplan: *How Do Airplanes Fly?* Gareth Steven's Inc. (1993), ISBN: 0836808002

Baker, David: *Navy Strike Planes.* Rourke Enterprises, Inc. (1989), ISBN: 0865925348

Burkett, Molly: *Pioneers of the Air.* Barron's Educational Series, Inc. (1998), ISBN: 0764106333

Collins, John C.: *The Gliding Flight: 20 Excellent Fold and Fly Paper Airplanes.* Ten Speed Press. (1989), ISBN: 0898153131

Doherty, Paul and David Learmont: *The Eyewitness Visual Dictionaries: Flight.* DK Publishing, Inc. (1993), ISBN: 1564581012

Green, Michael and Gladys Green: *Aircraft Carriers.* Friedman, Michael Publishing Group, Inc. (1999), ISBN: 1567997228

Hardesty, Von and Dominick Pisano: *Black Wings: The American Black in Aviation.* Smithsonian Institution Press (1988), ISBN: 087474511X

Web Sites

United States Navy
Click on "Our Ships," then on "Carriers" to see digital images of aircraft carriers and discover unique facts about these fascinating floating cities at sea.
http://www.navy.mil

University of California, Berkeley: Museum of Paleontology - Vertebrate Flight
Provides a comprehensive look at flight, including topics such as evolution of flight, origins of flight, basic flight physics, and gliding and parachuting. Pictures are provided that implement animals in the discussion of the basic flight principles.
http://www.ucmp.berkeley.edu/vertebrates/flight/enter.html

NASA - Ask-a-Scientist
Tap into the wealth of knowledge NASA scientists have by submitting a question in the areas concerning space science, earth science, life science, rockets, the shuttle, and robotics.
http://science.msfc.nasa.gov/FAQ/ask-a-scientist.htm

***USS Theodore Roosevelt* - CVN - 71**
Official web site of the aircraft carrier, *USS Theodore Roosevelt*.
http://www.spear.navy.mil/tr/

Activities and Worksheets

In the Guide

On the Web

You can find the following activities on the Web at http://whyfiles.larc.nasa.gov.

Airport
An activity to design and build a tabletop airport.

Bernoulli and More Bernoulli

Try one or more of these activities to better understand Bernoulli's Principle.

Tent with a Straw

Fold a 20-cm X 13-cm piece of paper in half to make a tent. Place the paper tent on the desk. Using a straw, blow under the tent and observe what happens. Blow harder and observe what happens. Try blowing hard against the side of the tent and observe what happens.

Balloon Blow

Blow up two balloons and tie off the ends. Cut two pieces of string 30 cm each. Tie one end of each string to each balloon. Hold the balloons in front of you by the strings about 5 cm apart. Blow very hard between the two balloons and observe what happens. What did the balloons do?

Ping Pong

Place two ping pong balls on a table about 2 cm apart. Using a straw, blow very hard between the two balls and observe what happens. Did the balls move closer together or farther apart?

Paper Paper

Hold two pieces of notebook paper in front of you about 5 cm apart. Blow hard between the papers and observe what happens. Which way did the papers move?

Stuck to It

Cut out a square of paper approximately 3 cm X 3 cm. Place the paper in the palm of your hand, and using your thumb and middle finger, hold a quarter (or nickel) about 1 cm above the paper. Place your mouth above the coin and blow hard. Observes what happens.

Ball and Straw

Bend a flexible straw so that the short end is pointing up. Hold a ping pong ball over the opening of the straw and blow. Let go of the ball and observe what happens. What happens if you tilt the straw?

Explanation

Air is pretty pushy stuff. It never pulls or sucks; it only pushes. Right now, air is pushing on you from every direction. This constant push of air is called air pressure. We are so used to air being around us that we don't even notice it. In the 1700's a Swiss mathematician named Daniel Bernoulli discovered that when flowing air or water changed its speed, its pressure also changed. In all of the experiments, the air speed was increased, creating a decrease in pressure. When the air pressure under the tent; between the balloons, papers, and balls; and under the paper with the coin was decreased, the air on the other sides had higher pressure. This higher pressure pressed inward, causing the tent to fall to the table and the balloons, pieces of paper, and ping pong balls to go together. In "Stuck to It" the air quickly moves between the paper and the coin, creating low pressure; therefore, the air pressure below the paper is greater and "holds" it against the coin. Now you describe what is happening with the ping-pong ball and straw.

Misconceptions

Many books state that air speeds up over a wing because it has farther to travel than air moving under the wing. This statement implies that air separates at the front of the wing and must rejoin behind the wing, but this isn't true. Air moving over the top of a wing speeds up so much that it arrives behind the wing sooner than air that travels beneath the wing.

Thinking Out of the Box

Scientists, designers, engineers, and many others have to be creative in their thinking as they develop new ideas and designs. You have to cast off the old way of doing things and try to free your mind for innovative ideas. So clear out the old ideas and get ready for the new. Your mission for this lesson is to help NASA design a new airplane for the future.The field is wide open for your design. You decide what the plane should look like, how it should fly, how long it should fly, and its uses. First, you will want to brainstorm some ideas, and once you get an idea of your plane's design, draw your design on the grid below. Share your ideas and drawing with the class. Make a model of your plane for a great presentation.

Scale: 1 square = _________

Flight Plan

Purpose

To learn about flight plans and airports.

Materials

Aero-Chart
ruler
flight plan cards

Procedure

1. Hand out Aero-Chart (p. 31) and a flight plan card to each student.
2. Discuss map features on Aero-Chart. Note airplane icon for measuring flight time and review how to use the scale.
3. Ask the students to study the map and choose any departure and destination airport shown on the chart.
4. Have the students mark their route on the map by connecting the lettered dots. Tell the students that routes don't have to be direct, but they should consider other factors that might influence their route choice such as mountains or restricted flying areas.
5. Using the time icon on the chart and their ruler, have the students determine the amount of time the flight will take. Enter the time on their flight plan card.
6. Ask the students to decide upon a departure time and add the flight time to determine the arrival time. Add this information to the flight plan.
7. Have the students complete the remainder of the flight plan card.
8. Share flight routes and flight plans as time allows.

Conclusion

1. What were factors that you considered in your choosing your route?
2. If after takeoff you discovered that your plane only had enough fuel to fly for 2 hours, could you land at your destination? If not, what would you do? Where would you land? Explain why.

Extension

1. Students draw their own Aero-Chart and file a flight plan.
2. Students can create a scale for distance for the Aero-Chart and measure the distance from each airport.

Pilot's Flight Plan

Aircraft Number ______________________ Departure Time __________

Departure Point ______________________________________

Route of Flight ______________________________________

Destination ______________________________________

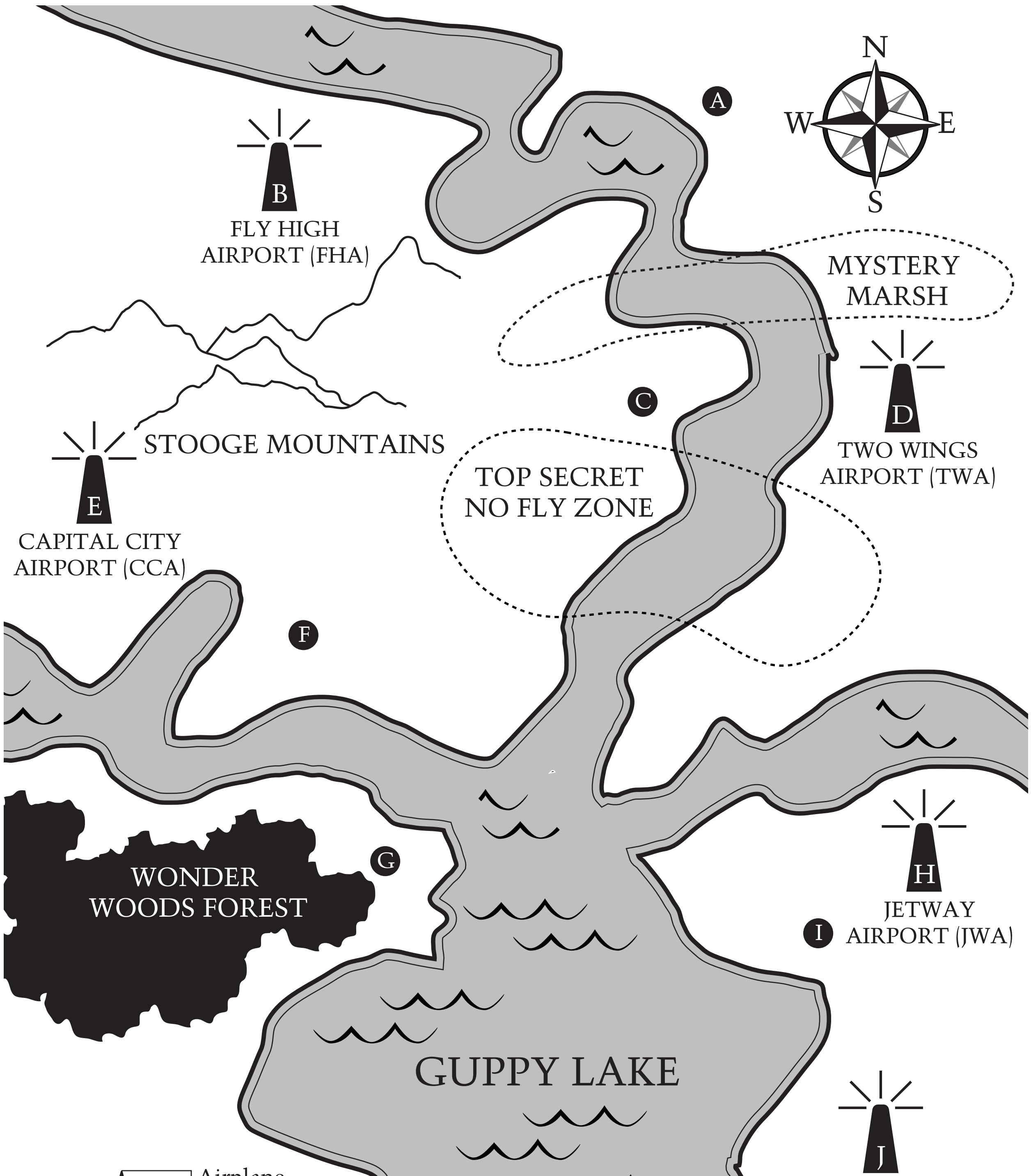
Estimated Time En Route __________________ Arrival Time __________

Color of Aircraft ______________________________________

Name and Address of Pilot ______________________________

____

Flight Plan (continued) Aero Chart



Thrust Experiment

Purpose

To determine if weight affects thrust.

Materials (per group)

balloons
masking tape
clothespin
straw
small paper cup (3-oz size)
string
scissors
20 paper clips
hole punch

Procedure

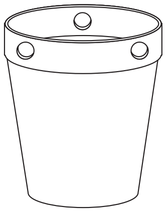


Diagram 1

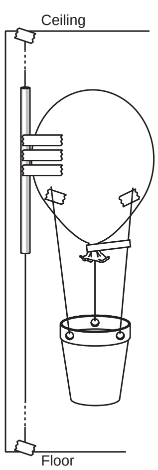


Diagram 2

1. Measure the distance from the ceiling to the floor.
2. Add 15 cm to that measurement and cut a length of string for that amount.
3. Tape or tie the string to a spot on the ceiling.
4. Thread the straw onto the string.
5. Stretch the string taut and tape it to the floor.
6. Using a hole punch, punch three holes evenly spaced around the top of the cup. See diagram 1.
7. Cut three pieces of string 30 cm each.
8. Tie one string in each hole of the cup.
9. Blow the balloon up, but do not tie it off. Use a clothespin to keep the air from escaping until ready to release.
10. Position the cup under the balloon and tape the other ends of the strings to the balloon so that it looks like a hot air balloon with a basket under it.
11. Tape the balloon to the straw. See diagram 2.
12. Lower the balloon to the floor, count down, and release.
13. Mark how high the balloon rose on the string.
14. Measure and record.
15. Blow the balloon up again being sure that it is about the same size as before, but this time place 5 paper clips in the basket.
16. Repeat steps 12-14.
17. Repeat Steps 15-16 adding five paper clips at a time until the balloon will no longer launch.
18. Analyze data and draw a graph.

Data

Balloon launch	Launch height in cm from floor
1 with no paper clips	
2 with 5 paper clips	
3 with 10 paper clips	
4 with 15 paper clips	
5 with 20 paper clips	

Graph

Conclusion

1. What happened to the height of launch as you added weight?
2. Explain why this occurred.

Clear for Launch

Purpose

To learn how a catapult launches a plane.

Materials

2 cardboard tubes (4 1/2 in.long each)
various sized rubber bands
15 cm wooden dowel
ping-pong ball
thin cardboard or cardstock
masking tape
glue
scissors
balsa wood
markers
science journal
pencil

Procedure

1. To make the launcher, tie one end of a rubber band around one end of the wooden dowel. See diagram 1.
2. To make the fuselage of the plane, tape the two cardboard tubes together, end to end.
3. Place the ping-pong ball inside one end of the tube so that half the ball is visible outside of the tube and glue into place. This is the nose of the plane. See diagram 2.

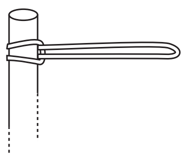


Diagram 1

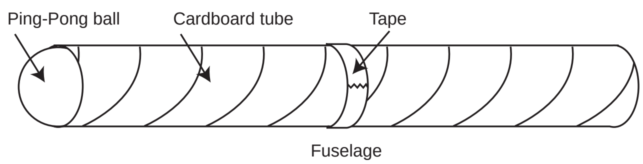


Diagram 2

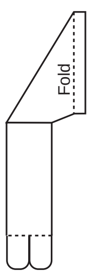


Diagram 3

4. Using the pattern (p. 35), trace a delta wing shape on cardboard and cut out. The wings should be the same length as the fuselage.
5. Trace and cut out the tail fin from cardboard (p. 35).
6. Fold flaps along dotted lines as indicated on pattern. See diagram 3.
7. Cut a rectangle of cardboard 23 cm by 14 cm.
8. On each 23-cm side of the rectangle, draw a line 1-cm from the edge. See diagram 4.
9. Fold along the lines to form flaps and glue cardboard over the fuselage, leaving flaps free.
10. Make a 4-cm slit through the top of the fuselage and cardboard at the tail end of the plane.
11. Carefully, slide the tail fin into the slit. See diagram 5.
12. Glue the flaps at the base of the tail fins inside the tube fuselage.

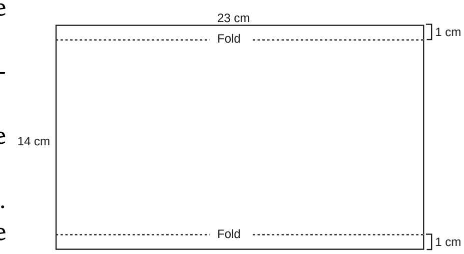


Diagram 4

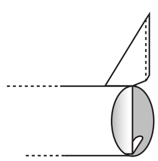


Diagram 5

13. Center the fuselage over the delta wing and tape the cardboard flaps of the fuselage to the wings on both sides.
14. With adult help, trace and cut out the launching hook from balsa wood (p. 35).
15. With adult supervision, carefully cut a 2-cm slit in the underside of the fuselage 5 cm from the nose of the plane.
16. Place the hook in the slit. Glue in place and let dry. See diagram 6.
17. To launch your airplane, loop the rubber band over the hook under the nose. Hold the launcher in one hand and the plane in the other. Stretch the rubber band and tilt the plane upward slightly and release. ALWAYS LAUNCH YOUR PLANE OUTSIDE AND AWAY FROM OTHER PEOPLE.
18. Experiment with various sizes of rubber bands, measuring the distance that the plane traveled after launch with each rubber band. Record distances in your science journal.
19. Experiment with various angles of launch and record distances in your science journal.
20. Organize data into a chart or graph and share with class.

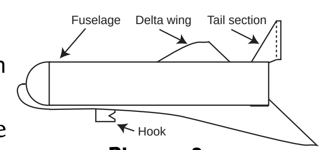


Diagram 6

Clear for Launch (continued)

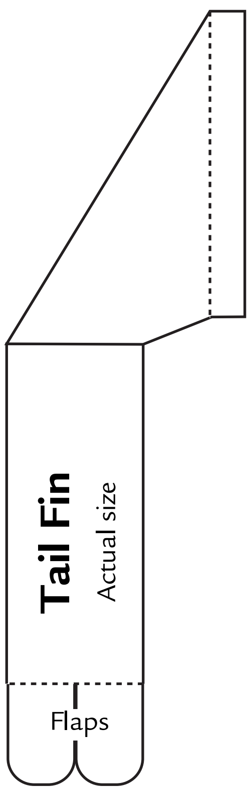
Conclusion

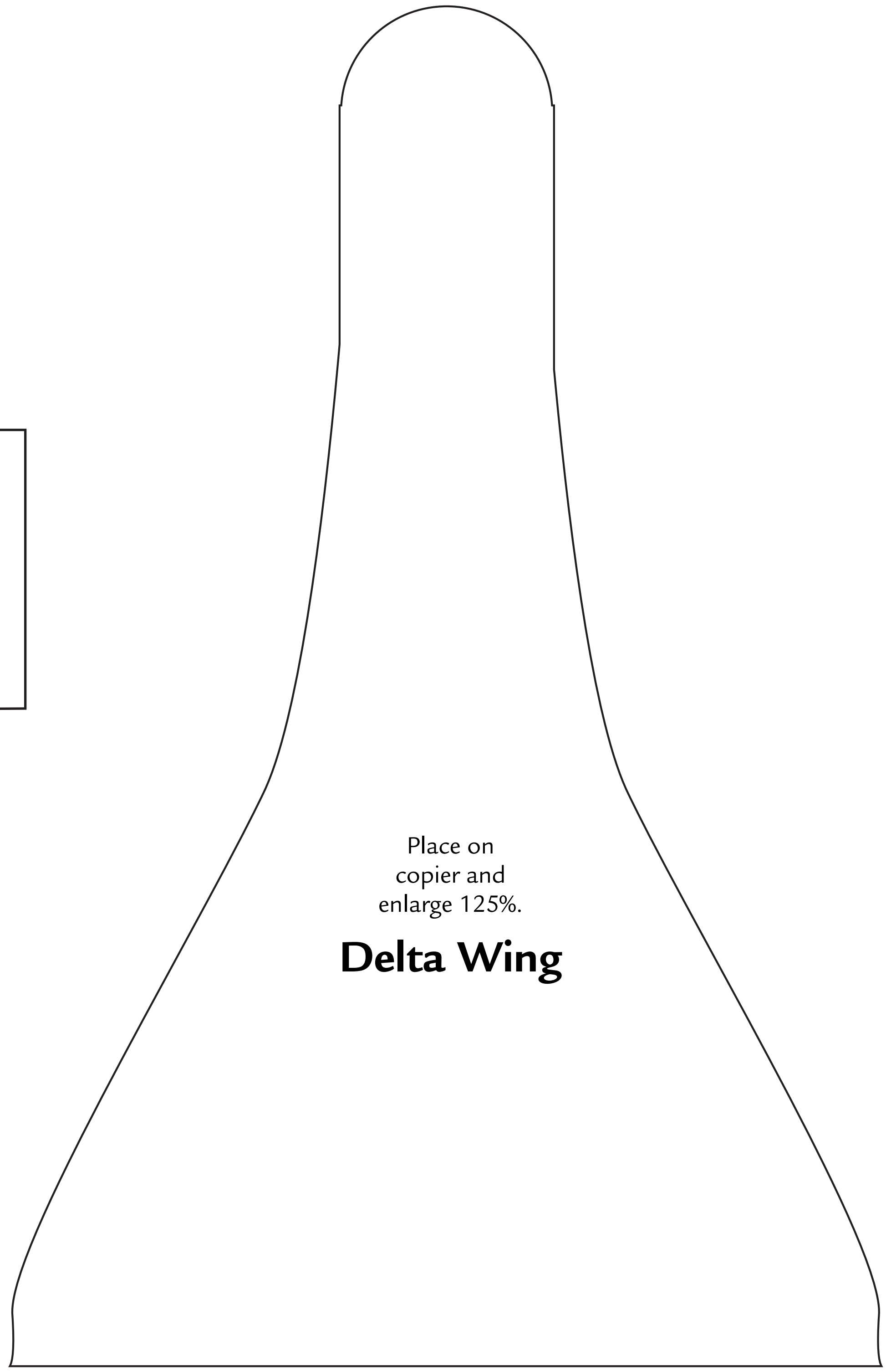
1. Which rubber bands launched the plane the farthest?
2. Explain why.
3. How does your launcher compare to the catapult on the aircraft carrier?
4. Explain what other variables you might change to make your plane launch farther?
5. How does the shape of the wing affect the distance your plane travels after launch?
6. How does the angle that you launch the plane from affect the distance it travels?

Extensions

1. Experiment with different shaped wings.
2. Add flaps to the wings and determine if they affect the distance that it travels after launch.
3. Make the plane out of other materials.

Clear for Launch (pattern)





Answer Key

Thrust Experiment

1. As weight was added to the cup, the height of the launch was reduced.
2. Adding weight to the cup increased the amount of thrust needed to launch the balloon.

Clear for Launch

1. Answers will vary.
2. There are a variety of factors about the rubber bands that could increase the distance that the plane traveled after launch. Some include the length of the rubber band, the thickness of the rubber band, and/or the ability of the rubber band to stretch.
3. Answers will vary, but should include information comparing the aircraft carrier's catapult system to the rubber band. The notched wood under the model plane is similar to the location on an airplane where it is connected to the shuttle. When a plane is launched on a carrier, steam builds and is released to power the pistons that jettison the plane to 160 mph in about 3 seconds. This launch can be compared to the pulling back of the rubber band (building up steam), and when you let go, you have released the energy in the rubber band to jettison the model.
4. Answers will vary, but may include changing the wing shape or designing the plane out of lighter weight materials.
5. The shape of the wing is important to achieve maximum lift. Some shapes will create more lift, therefore allowing the plane to travel farther.
6. The angle at which you launch the model plane will affect lift. Too much angle will make the plane fly in a straight up path, and the distance the plane travels will not be as great. Too little angle, and there will not be enough lift to fly very far.

Flight Plan

1. Some factors might include mountains, no fly zones, or length of time.
2. Answers will vary.