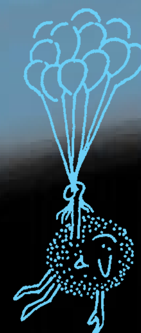
SMITHSONIAN IN YOUR Classroom

September/October 1997



HOW THINGS FLY

Activities for Teaching Flight

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Lesson Plans from

ART to ZOO

Inside
Lesson Plan
Take-Home Pages in English/Spanish

Subjects
Math
Science

Grades
4–9

Publication of this issue of *Smithsonian in Your Classroom* is made possible through the generous support of the Pacific Mutual Foundation.

Have you ever dreamed of flying? As a child, you may have run full speed with your arms stretched and flapping, hoping that—just a little faster—you could take off. Most of us, including your students, have probably had these dreams. This issue of *Smithsonian in Your Classroom* embraces that spirit of adventure and discovery by having students draw upon their own experiences and sense of movement to understand the basic physics of flight. They'll even learn that they can fly, if only for a moment at a time. The lessons and activities in this issue of *Smithsonian in Your Classroom* have been adapted from classroom-tested materials developed by the education department of the Smithsonian Institution's National Air and Space Museum.

Contents

New name, same great content! *Art to Zoo: Teaching with the Power of Objects* has a new name, *Smithsonian in Your Classroom: Lesson Plans from Art to Zoo.*

Smithsonian in Your Classroom's purpose is to help teachers bring into their classrooms the educational power of museums and other community resources. *Smithsonian in Your Classroom* draws on the Smithsonian's hundreds of exhibitions and programs—from art, history, and science to aviation and folklife—to create classroom-ready materials for grades four through nine. Each of the four annual issues explores a single topic through an interdisciplinary, multicultural approach. The Smithsonian invites teachers to duplicate *Smithsonian in Your Classroom* materials for educational use.

You may request a large-print or disk version of *Smithsonian in Your Classroom* by writing to the address listed on the back cover or by faxing your name, school name, and address to (202) 357-2116.

LESSON PLAN Step 1
Look Mom, No Wings!

In this lesson, you'll introduce your students to the four forces of flight—drag, lift, thrust, and weight—through a variety of fun-filled flight experiments. Students will "fly" for short periods and then evaluate factors that might either increase or decrease their "flight" duration.

You might begin the activity by asking your students the following questions:

☐ Can you fly? How high do you think you can fly? How long do you think a very good jumper (e.g., Michael Jordan) can stay in the air?

☐ Have your students complete the "How High Can You Fly?" and "How Long Can You Fly?" activities on page 6. Ask them to examine the duration and height of their flights. Are they surprised at the results?

☐ Refer to the "Think About It" activity on page 6. Ask your students to observe each of the cartoon figures. What are they doing? How might the cartoon figures' actions and environments allow them to jump higher and for longer periods than anyone in class? What else could students do to make their jumps last longer?

Possible observations of the cartoon figures

Parachute figure—This figure can stay airborne longer because the parachute slows the person's fall. Demonstrates *drag*.

Helmeted figure—This figure can jump higher because the sleek helmet decreases air resistance. Demonstrates drag.

Figure with springy shoes—This figure can jump higher because the springy shoes provide a power boost. Demonstrates *thrust*.

Moon-walking figure—This figure can jump higher on the Moon than on Earth. The smaller gravity on the Moon means that the figure weighs less there. Demonstrates the force of *weight*.

Figure with propeller hat—The spinning propeller creates a difference in air pressure, which pushes the figure upward. Demonstrates *lift*.

Some other possible actions to make jumps last longer

Lift—Wear wings.

Thrust—Jump off a trampoline or diving board; launch yourself with a pole vault, catapult, or rocket; or exercise to get stronger muscles.

Weight—Wear lighter clothing, lose weight, or travel to a planet with smaller gravity than Earth's.

Drag—Wear skin-tight clothing.

Students may suggest other methods to make their jumps last longer. You may wish to organize their thoughts by drawing a simple chart on the chalkboard (see below).

Drag	*Lift*
Thrust	*Flight*

Definitions

Drag—The resistance caused by the shape of an object and its movement through the air.

Lift—The upward force created by a difference in air pressure. Moving air creates this difference as it moves around an airfoil (e.g., a wing).

Thrust—The force developed by a propeller or jet engine that drives an airplane through the air. (*In the jumping activity, students' leg muscles provided thrust.*)

Weight—A measure of the heaviness of an object.

Direct your students to the "What's Going on?" section on page 7. (*You may wish to have several students alternately read this section to the class.*) Conclude the activity by reinforcing the concept that on Earth four forces work together to make things fly: thrust, drag, weight, and lift.

LESSON PLAN Step 2
Bernoulli Brain-Teasers

In this lesson your students will conduct a series of hands-on experiments that will help them to understand the role of lift in fixed-wing flight. Students will observe the flow of air and water around several surfaces and then consider the dynamics of airflow around an aircraft wing.

You may wish to begin the activity by telling your students that, although air is invisible to the human eye, it is made up of physical matter—real "stuff." This means that air exerts a force that helps to keep an airplane up in the air.

Tell your students that the experiments in this lesson will demonstrate what Swiss mathematician Daniel Bernoulli discovered in the early 1700s: When flowing air or water changes speed, its pressure also changes.

With each activity, ask your students to consider what is going on. Is air slowing down or speeding up? How might air pressure be changing? How might the flow of air (and its changing pressure) help to keep an aircraft up in the air?

Direct your students to the "Use Your Lips to Levitate" and "Balloons That Boggle" activities on page 8. What happens when air is blown over the paper or between the balloons? Ask students what they think causes the paper and balloons to move.

After your students have finished the activities, direct them to the "What's Going On? The Simple Explanation" section on page 10. (*You may wish to have several students alternately read this section aloud.*) Use the questions in the text as the basis for a class discussion. Be sure that students understand that air loses pressure when it speeds up.

Ask your students to begin the "Squeeze the Stream" activity. Explain that this activity is more complex than the previous two activities and will require teamwork. (*You may wish to have three or four experiments going simultaneously, so that all students can observe the water movement first-hand.*) Stress that although this experiment uses water, air flows in a similar manner.

Direct your students to the "What's Going On? The Advanced Explanation" section on page 10. (*You may wish to have several students alternately read this section to the class.*) Conclude the activity by reinforcing these important concepts: (1) Air speeds up as it moves around an object. (2) When air moves faster, its pressure drops and it pushes less. (3) When an airplane flies, air speeds up more above the wing than below it. As a result, the air above an airplane wing pushes less than the air below the wing. The higher pressure below the wing pushes the wing (and the airplane) up.

LESSON PLAN Step 3
Flying through Time

Some possible aircraft observations
(*For more detailed information on each aircraft, refer students to a school or local public library or to the National Air and Space Museum's World Wide Web site,* **http://www.nasm.si.edu.**)

Wright Flyer (1903)—two wings (biplane), wooden frame with stretched fabric, small piston engine, pilot lies on wing, no landing gear, two propellers

Vega (circa 1930)—single wing (monoplane), tapering wooden fuselage, fixed landing gear, engine in front, streamlined covering (cowl) over engine, wing over cockpit

Boeing 727—(first produced in 1964 and still in service)— swept-back wings, retractable landing gear, three jet engines attached to tail of aircraft, streamlined metal fuselage, large in size.

X-15 (circa 1960)—fuselage shaped like a rocket, rocket engine at the back of the aircraft, short wings.

In this lesson, your students will observe photographs of selected twentieth-century aircraft at the National Air and Space Museum and note differences in the design of aircraft wings, fuselages, and engines.

Begin the activity by telling your students that they'll be looking at photographs of twentieth-century aircraft at the Smithsonian's National Air and Space Museum in Washington, D.C. Stress that these photographs will help them to understand some of the many approaches to aircraft design.

Direct your students to the Take-Home Page activity on pages 11–14. (*Depending on time and resource availability, you may complete the lesson as either a take-home or in-class activity.*) Tell them to observe carefully each aircraft. How are the wings shaped? How is the aircraft's body (fuselage) shaped? What type of engine does the aircraft appear to have? Is there any evidence of *streamlining* (designing the body of an aircraft so that it moves easily through the air)?

After your students have completed their observations, begin a class discussion about their findings. Ask them to consider if any of the aircraft display evidence of streamlining. Answers may vary, but students will probably note the wheel coverings and engine cowling of the Vega as well as the retractable landing gear and long, narrow fuselages of the 727 and the X-15.

Next, direct your students to a comparison of the X-15 and the Vega. How do their wings differ? Students will probably conclude that the X-15 has shorter, thinner, and more swept back wings. Emphasize that airplanes designed to fly faster than the speed of sound use wings like these to reduce the substantial force of drag in supersonic flight.

Conclude the activity by asking your students to evaluate the type of materials used in each aircraft. Students will likely conclude that cloth, wood, and metal have been used in the example aircraft. Emphasize that the choice of materials depends largely on the desired speed and performance of an aircraft and that each plane featured in the activity was designed around the engine power available during the time when it was built.

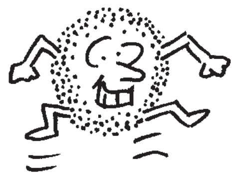
Stress that the Wright Brothers chose large wings and a lightweight frame for their Flyer to compensate for their relatively weak engine. Alternately, the designers of the Vega concentrated on reducing drag by removing wires and struts and encasing a much more powerful engine within a streamlined cowling.

The high-powered jet engines available by the 1960s allowed the engineering team of the Boeing 727 airliner to use high-strength materials and thin, swept-back wings that reduced drag and increased speed to nearly 600 miles per hour.

Engineers at the National Aeronautics and Space Administration (NASA) who worked on the X-15 project had even more available power in the form of rocket engines. The focus of their experimental work was to develop the highly streamlined fuselage, short wings, and heat-resistant materials necessary for supersonic flight.

ACTIVITY SET 1
Look Mom, No Wings!

Do you ever dream of being able to fly? The good news is, you probably can! The bad news is, you cannot fly very high or stay up very long.



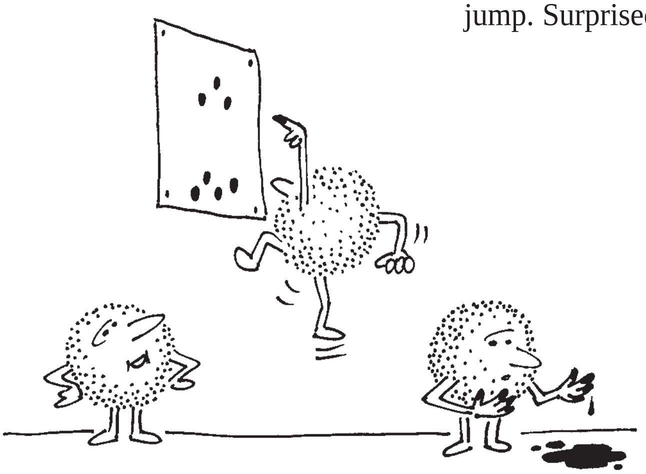
HOW HIGH CAN YOU FLY?

Materials

- Large sheet of paper
- Tape
- Dirt or stamp pad
- Ruler or meter stick

How high do you think you can you jump? Get some of your friends together to find out.

- ☐ Tape a large piece of paper to the wall. (Brown wrapping paper or sheets of newspaper will do.) The shortest person in your group should be able to reach the bottom of the paper without standing on tiptoes.
- ☐ Dip one finger in dirt or ink. While standing with your feet flat on the floor, stretch your arm as far as you can and mark the highest point you can reach on the paper.
- ☐ Now jump and mark the paper by touching it at the top of your jump. Try it a few times and challenge your friends to jump higher. (Label each person's standing and jumping marks with initials or have each person use a different color of ink or dirt.)
- ☐ Use a ruler or meter stick to measure the vertical difference in height between your standing and jumping marks. This is how high you can jump. Surprised?

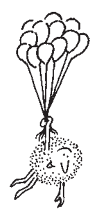


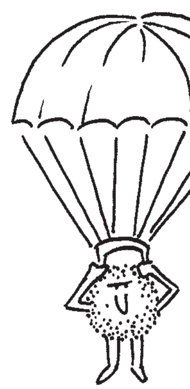
HOW LONG CAN YOU FLY?

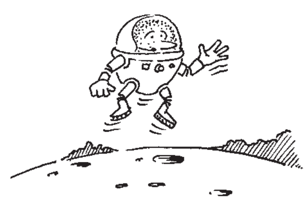
Materials

- One helper
- Stopwatch or watch with a second hand

How long can you stay in the air when you jump? Ask someone to time you with a stopwatch or a watch with a second hand. (It won't be easy!) You can also time jumping athletes who are playing sports such as basketball or volleyball.

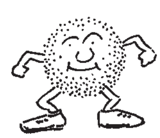






THINK ABOUT IT

These characters can jump higher and longer than you can. What are they doing that makes a difference? What else could you do to jump higher or make your jump last longer?



WHAT'S GOING ON?

You probably noticed that taller kids didn't necessarily have higher jumps. Remember, you measured the jump height from your reach (the standing mark) and not the ground. The best jumpers in the world can clear heights up to 2.4 meters (8 feet), but they lift their center of mass considerably less than that distance.

Did you have a hard time measuring your time in the air? You're not alone. Even the best jumper remains airborne for less than one second. Still, you can compute your airborne time by using the table below. Look down the first column for your jump height and read across to find your time.

Is jumping really flying? Yes and no. Some things like rockets, cannonballs, and baseballs fly like jumping kids: They are pushed into the air by engines or muscles. Airplanes are more complex: Engines push them forward, and air pushes and holds them up.

Thrust, drag, weight, and lift are the four forces that work together to make things fly. You already know something about each of them, although you might not have called them by their names. If you thought that having stronger muscles, springy shoes, or a rocket booster might help your jump, then you were thinking about thrust (the force that pushes you during flight). If you thought that a slick suit or helmet would make you jump higher or that a parachute would keep you in the air longer, then you were thinking about drag (the resistance of air against things that fly). If you thought about jumping higher by losing weight, changing clothes, or visiting the Moon, you were thinking about weight (the force that holds you to the ground).

Most people have experienced how thrust, drag, and weight can help them jump higher, or "fly," but few people are familiar with lift. Lift is a push that comes from the air. You were thinking about this force if you decided that wearing wings or holding helium balloons would help you jump higher. While planes and birds have to be moving to get enough of this push to fly, hot-air balloons are light enough for their size that the air will lift them up whether or not the balloon is moving.

Does everything that flies use all four forces? Nope. Only two forces, weight and thrust, act on spacecraft. Lift and drag are not factors in spacecraft flight, because there is no air in space.

This was a quick overview of the forces of flight. Don't stop here, though. Ask your teacher for help in finding more information about how high you can fly.

Jump Height		Time in Air
(centimeters)	(inches)	(seconds)
25	10	0.4
50	20	0.6
75	30	0.8
100	39	0.9

ACTIVITY SET 2
Bernoulli Brain-Teasers

To pilots, *lift* means the way that air holds up airplanes and other flying objects. These activities will show you how this force works—and they don't require a pilot's license.

USE YOUR LIPS TO LEVITATE

Materials

- Piece of paper

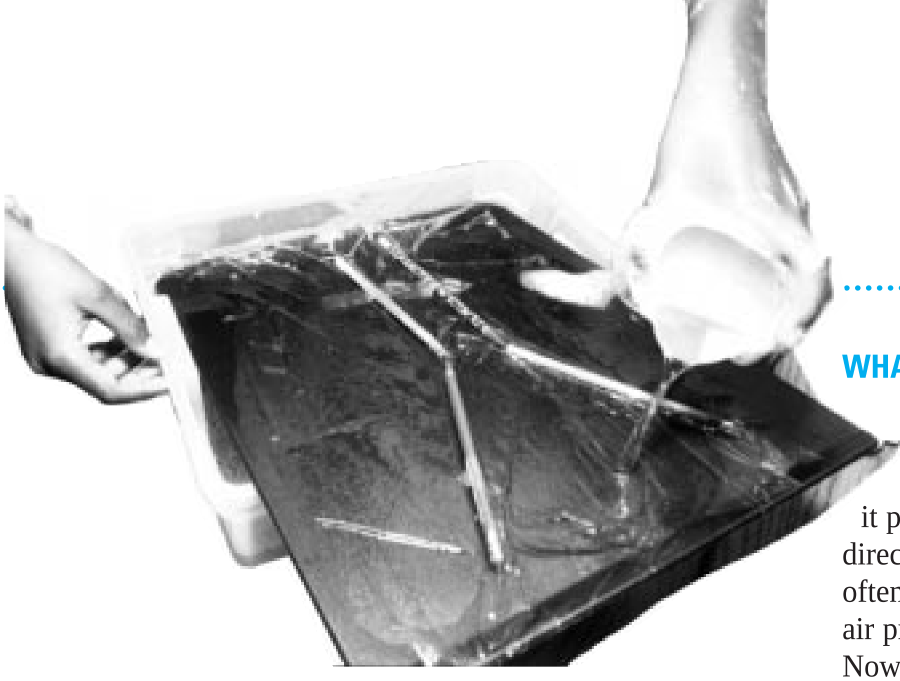
Hold a piece of paper between your thumb and forefinger, as shown in the picture below. Now blow over the paper. What happens?

BALLOONS THAT BOGGLE

Materials

- Balloons
- String
- Water

Try this activity with a friend. Blow up two balloons and tie each one to a string. Hold the balloons a few inches apart and try to blow them together. Can you do it? What happens? Try different ways of blowing on the balloons to see what happens. (*Hint: Squirt a little water into the balloons before you blow them up. This will help steady them.*)



SQUEEZE THE STREAM

Materials

- Cookie sheet
- Pencils
- Tape
- Plastic wrap
- Sink or tub
- Water
- Small scraps of paper or Styrofoam (optional)

Fluids, such as air and water, change speed as they flow between and around objects. To see how this happens, build a tiny stream channel. Tape pencils to a cookie sheet so that they make a channel that starts out wide and then narrows. Drape the pencils and cookie sheet with plastic wrap; this creates a waterproof channel. Now barely tilt the cookie sheet against the sink and slowly pour soapy water into the channel. Does the speed of the water change? How? When? (*Hint: You may want to add small scraps of paper or Styrofoam to the water to help you observe the current's flow.*)

SO WHAT'S A BERNOULLI?

In the early 1700s, a Swiss mathematician named Daniel Bernoulli discovered that when flowing air or water changes its speed, its pressure also changes.

As you do these activities, can you figure out how the pressure changes? How does this help airplanes stay in the air?

WHAT'S GOING ON?

The Simple Explanation…

Air is pretty pushy stuff. It never pulls or sucks; it pushes. Air is pushing on you right now from every direction. We're so used to air being around us that we often don't notice it. This constant push of air is called air pressure. It allows us to breathe—not a bad thing! Now think about what was happening in the activities you just finished. Why did the balloons come together when you blew between them? Why did the paper lift up when you blew over it? Air must be pushing these things, but how?

Even before you blew at the balloons, they were surrounded by air pressure. If you tried blowing between them, you disturbed this push in a very special way. How? Think about this: Either the air between has stopped pushing as hard or the air on the outer sides is pushing harder. Which do you think happened? Which air did you disturb, the air between the balloons or on the outer sides of the balloons?

Can you figure out what happened with the paper? Now you know that the paper was surrounded by air pressure. How did you change the air when you blew over the paper? Remember, air can't suck up anything, but it can push. Did you change the push of air on the top or the bottom of the paper?

Okay, enough questions! Here's what was going on: In both the balloon and paper activities, air lost pressure and stopped pushing as hard. This happened because you blew the air, and it had to "squeeze" between or around the objects. As it "squeezed" through, it sped up, lost pressure, and stopped pushing as hard.

The Advanced Explanation...

Now that you know about push and lift, can you see how these forces might relate to airplanes? If we can make air speed up over a wing, the pressure of the air over the wing will drop. The higher pressure air below the wing then pushes the airplane up. How would you shape a wing so that the air moves more quickly over the top than under the bottom?

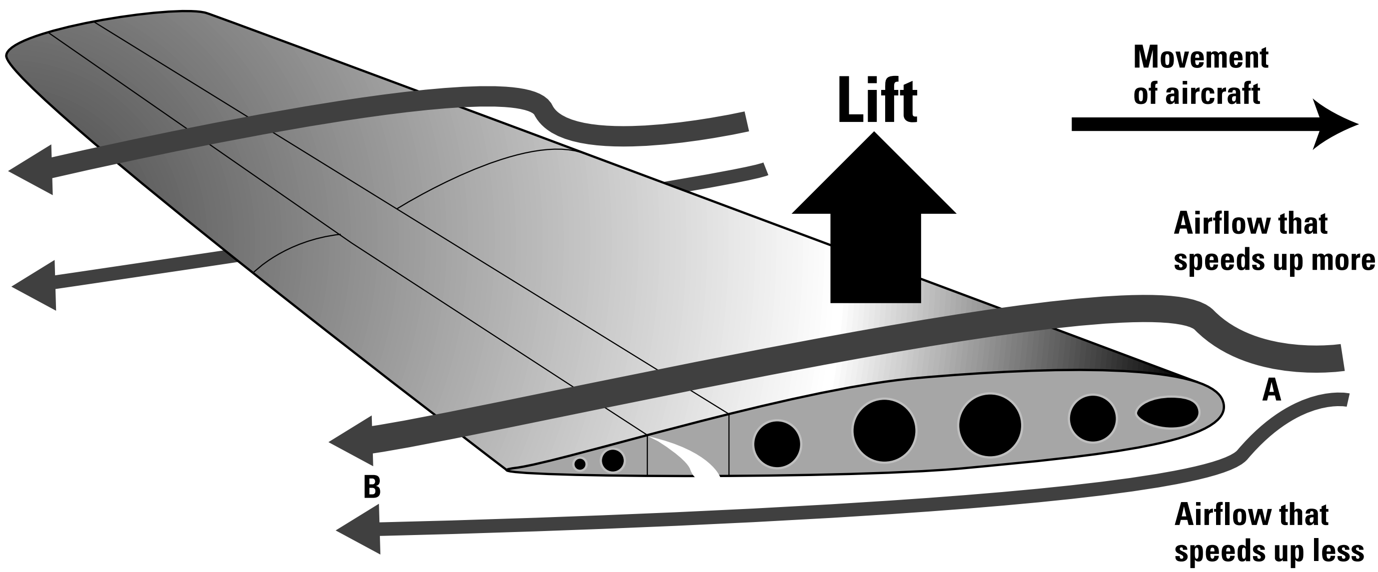
The "Squeeze the Stream" activity shows what happens when a fluid is forced to flow from a wide space through a narrower channel. For the water to squeeze through a thinner space, something must either compress the water (think of pulling a sponge through a bottle neck) or speed it up. Freely flowing water does not compress easily. Instead, it speeds up as the channel narrows. Water also speeds up as it moves around an object, such as a rock in a river. Air is a fluid, too, and it behaves like water when it moves through a narrow channel or around an object: It speeds up. As you saw with the other activities, when air moves faster, its pressure drops and it pushes less.

When an airplane flies, it pushes air out of the way. That air must go somewhere—so it "squeezes" between the wings and the surrounding air. The wings are shaped and tilted so that the air moving over the top has less room than the air moving below the wings. Because it has less room, the air moving over the top must speed up more than the air below the wing. As it moves faster, the air on top of the wing also loses pressure and push. The slower moving air below the wing maintains more of its pressure, which pushes the wing, and the plane, up.

An airplane wing affects moving air much like a rock in a stream affects moving water. Remember that the space around the wing is already jammed full of air, so there's no empty space for more air to move into. As oncoming air hits the wing and moves either over or under it, it speeds up and "squeezes" between the wing and the surrounding air.

The Wrong Explanation...

Many books state that air speeds up over a wing because it has further to travel than air moving under the wing. This explanation implies that air separates at the front of the wing (point A) and rejoins behind the wing (point B), but this isn't true. Air moving over the top of a wing speeds up so much that it arrives at point B sooner than air that travels beneath the wing.



TAKE-HOME PAGE
TRABAJO PARA HACER EN LA CASA

Observe and Describe
Observa y Describe

Aircraft body (fuselage)
El cuerpo de la aeronave (el fuselage)

Streamlining
La aerodinámica de la nave

The Wright Flyer (1903)

Wing shape
La forma del ala

Engine
El motor

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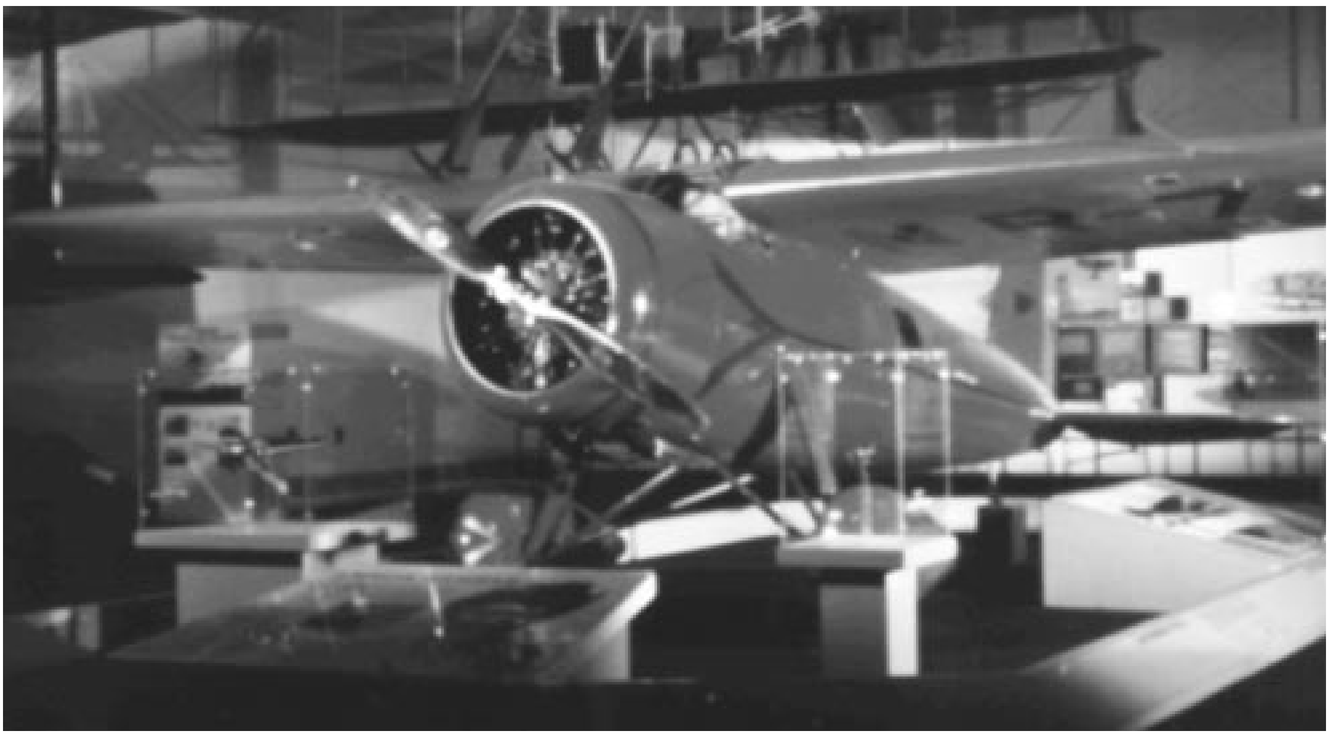

Lockheed Vega (circa 1930)
Lockheed Vega (alrededor de 1930)

Wing shape
La forma del ala

Engine
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C

TAKE-HOME PAGE
TRABAJO PARA HACER EN LA CASA

Observe and Describe
Observa y Describe

Aircraft body (fuselage)
El cuerpo de la aeronave (el fuselage)

Streamlining
La aerodinámica de la nave

Boeing 727 (first produced in 1964 and still in service)
Boeing 727 (Este tipo de avión fue manufacturado por primera vez en 1964. Este tipo de avión aun sigue en servicio.)

Wing shape
La forma del ala

Engine
El motor

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D

TAKE-HOME PAGE
TRABAJO PARA HACER EN LA CASA

Observe and Describe
Observa y Describe

Aircraft body (fuselage)
El cuerpo de la aeronave (el fuselage)

Streamlining
La aerodinámica de la nave

X-15 (circa 1960)
X-15 (alrededor de 1960)

Wing shape
La forma del ala

Engine
El motor

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RESOURCES

BOOKS AND TEACHING GUIDES

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PERIODICALS

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ELECTRONIC RESOURCES

These comprehensive sites provide links to hundreds of the major aviation-related pages on the World Wide Web.

National Air and Space Museum
http://www.nasm.si.edu
The Smithsonian's National Air and Space Museum features online exhibitions (including the *How Things Fly Gallery*) as well as links to many of the sites below.

The Air Affair
http://www.airaffair.com/hotlist.html

Aviation Laboratories
http://www.avlab.com/link.html

Embry-Riddle Aeronautical University
http://macwww.db.erau.edu

Landings: Aviation's Busiest Hub in Cyberspace
http://www.landings.com/aviation.html

Michele's Virtual Hanger
http://rampages.onramp.net/~micheleb/hanger.html

ACKNOWLEDGEMENTS

National Air and Space Museum
Barbara Brennan
Clare Cuddy
David Romanowski

PHOTOGRAPHS

All photographs in this issue are from the collections of the National Air and Space Museum.

ILLUSTRATIONS

Cover, page 6
Chris Major

Page 10
Alan Smigielski

Pages 2, 15
Stan Stokes, courtesy of NASA Dryden Flight Research Center

SMITHSONIAN IN YOUR CLASSROOM

Smithsonian in Your Classroom is a publication of the Smithsonian Office of Education, Smithsonian Institution, Washington, DC 20560.

Writers
Carolyn Balch
Alan Smigielski

Editor
Douglas Casey

Translator
Sarita Rodriguez

Designer
Karlic Design Associates
Baltimore, Maryland

Publications Director
Michelle Knovic Smith

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