UNIT 3: BREEZY BLIMPS

IN THIS UNIT, students explore force, Newton's laws, air pressure, and buoyancy by making blimps out of helium-filled balloons.*

UNIT TABLE OF CONTENTS

- **Overview:** Students make a helium-filled Mylar® balloon hover by adding weight and making it neutrally buoyant. They move the balloon around the room without touching it by using a sheet of cardboard to make small pockets of low-pressure air into which the balloon moves.
- **Learning outcomes:** Students will be able to make a floating object neutrally buoyant and explain how a balloon moves in response to differences in air pressure. They will also use the design process to achieve neutral buoyancy and perfect a technique for moving the balloon.

- **Overview:** Students apply all they learned in *Sky Floater* to design and build a blimp that glides efficiently on a straight course across a room.
- **Learning outcomes:** Students will be able to explain how drag affects a blimp's flight, how its length affects its axis of rotation, and how blimps demonstrate Newton's 1st Law. They will also use the design process to design and build a neutrally buoyant blimp that has a long axis of rotation, is aerodynamic, and is able to travel in a straight path.

- **Overview:** Students add a balloon-powered propulsion system to their blimps to make them fly across the room under their own power.
- **Learning outcomes:** Students will be able to explain how a blimp demonstrates Newton's 3rd Law and describe how they used the design process to get their "jet" to propel their blimps along a straight course.

- **Overview:** Students present their blimps and discuss the science and engineering behind their designs. They also watch two short videos: They meet a young engineer who keeps a large blimp running smoothly, and they see how the *Design Squad* teams use the design process to redesign the blimps they made to film a rock concert from above.
- **Learning outcomes:** Students will be able to identify the science concepts exhibited in their work (e.g., force, Newton's laws, mass, buoyancy, aerodynamics, axis of rotation, friction, and air pressure), explain how the design process encourages them to think creatively to tackle a challenge, point out how they are thinking and working like engineers, and cite examples of how engineering is a profession centered on improving people's lives.

PLANNING YOUR TIME

Only have one class period available? Do *Sky Floater*.

Two class periods? Do *Sky Floater* and *Making It Real*.

Three class periods? Do *Sky Floater*, *Sky Glider*, and *Making It Real*.

Four? If your students are very engaged with this unit and are able to work with patience and precision, include *Blimp Jet*.

"As a teacher for 31 years, the only thing that really excited middle school students is hands-on activities."

Bill D.
Fairgrounds Middle School
Nashua, NH

* For specific standards, see Appendix, page 48.

SKY FLOATER CHALLENGE

The Challenge: Make a balloon hover at eye level for five seconds, and then make it move by creating air currents.

Preparation

- ☐ Copy the *Sky Floater* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Band Cam Challenge*** (1 minute) and ***Buoyancy*** (1½ minutes). Be prepared to project them.
- ☐ Gather these materials (per student):
  - 1 helium-filled Mylar balloon
  - paper
  - large garbage bags for storing the balloons (12 fit in a 42-gallon bag)
  - paper clips of various sizes
  - large binder clip for anchoring a balloon (optional)
  - scissors
  - clear tape
  - corrugated cardboard (about 8 inches square)
  - If you have high ceilings, use 2 brooms as "jaws" to capture escaped balloons.

NOTE: *You can get Mylar balloons at party stores, florists, dollar stores, drug stores, and supermarkets, often for a dollar each. However, multiple class sections can use the same balloons for Sky Floater. Have students clean off their balloons at the end of the period so they're ready for the next class. If you plan to do Sky Glider as well, stagger the unit with your different sections since the first class will need their balloons for at least two days. Helium-filled Mylar balloons reliably provide lift for a week. In our testing, over half our balloons maintained excellent lift for up to two weeks.*

The first task is to weight a balloon to make it neutrally buoyant.

1. **Introduce the challenge** (5 minutes)
   - Tell students today's challenge is to first get a helium-filled balloon to hover and then to move it around the room without anyone touching it. Mention that this challenge is similar to one that the kids did on the *Design Squad* TV show.
   - Show ***Band Cam Challenge***, in which the *Design Squad* teams build a blimp to film a stage concert. Point out that in both the classroom and *Design Squad* challenges, kids need to control and direct their balloons.
2. **Do Part 1 of *Sky Floater*** (10 to 15 minutes)
   - Show students the materials. Ask: How can you stop a balloon from floating upward? *(Add weight.)*
   - Distribute the handout and have students do Part 1. Tell them to tie the balloon ribbon in a bundle close to the neck of the balloon so it doesn't drag on the floor or catch on things.
   - If drafts are an issue, have students use their bodies to block currents, not move around too much near the balloon, and work away from air vents, doors, and windows.
   - Part 1 takes anywhere from 5 to 15 minutes. Stop everyone after 15 minutes.
3. **Process the science and engineering** (10 minutes)
   Show the ***Buoyancy*** video, which describes how a helium-filled balloon floats. Ask:
   - What are the forces affecting this balloon? *(Gravity and lift)*
   - What do you know about these two forces when a balloon is ***neutrally buoyant*** (i.e., when it hovers)? *(The force of gravity equals the force of lift.)*

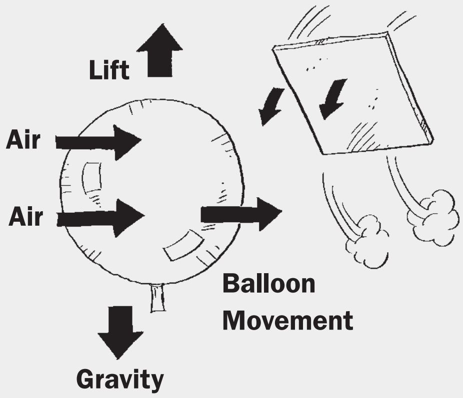
Students make their balloons hover at face level for at least five seconds.

Students move their balloons around the room. They use cardboard to create a low-pressure air pocket. Nearby air moves into these air pockets, carrying the balloon with it.

Once they learn how to move their balloons, students step them around a partner, one low-pressure air pocket at a time.

- Why do the balloons rise? *(Air is denser than helium—it has more particles per unit volume than helium does. The denser air pushes the less-dense helium aside, producing an upward force called a **buoyant force**. In our testing, kids called air a "bully.")*
- How is neutral buoyancy an example of Newton's 1st Law? *(If the forces of lift and gravity are equal and opposite, the balloon won't rise or fall.)*
- When will the balloon stop rising? *(When it hits the ceiling or rises to a point where the density of the air outside the balloon equals the density of the helium inside the balloon. When these two densities are equal, there is no longer a buoyant force.)*
- What steps of the design process did you use to make the balloon neutrally buoyant? *(Identified the problem; brainstormed how to make the balloon hover; tested different ways to weight the balloon; refined our systems; shared solutions; etc.)*

4 **Give the class a "driving" lesson** (5 minutes)
Borrow a neutrally buoyant balloon from one of your students. Ask the class to predict*: How will this balloon move when I fan a piece of cardboard next to the balloon but not at it?* Demonstrate by taking a square of cardboard and sharply sweeping it alongside the balloon in one swift motion (i.e., no fanning back and forth). Surprise! The balloon moves unexpectedly *toward* where you swept the cardboard. Repeat on the other side, and above and below the balloon.



Explain that the balloon is surrounded by air. When you sweep the cardboard beside the balloon, you temporarily remove some of the air, producing an area with fewer air molecules (i.e., lower pressure). Surrounding air molecules rush in to equalize the pressure, carrying the balloon with them. By creating a succession of low-pressure air pockets, kids can move the balloons around the room a few inches at a time. End by demonstrating that rapid fanning at a balloon makes it hard to control the balloon's movement. Fanning results in chaotic air currents. They will move a balloon, but in an unpredictable way.

5 **Do Parts 2 and 3 of *Sky Floater*** (10–15 minutes)
Have students experiment with different techniques for moving a balloon in a circle around a partner. If time permits, they could also do an obstacle course or race other teams.

SKY FLOATER

DESIGN SQUAD

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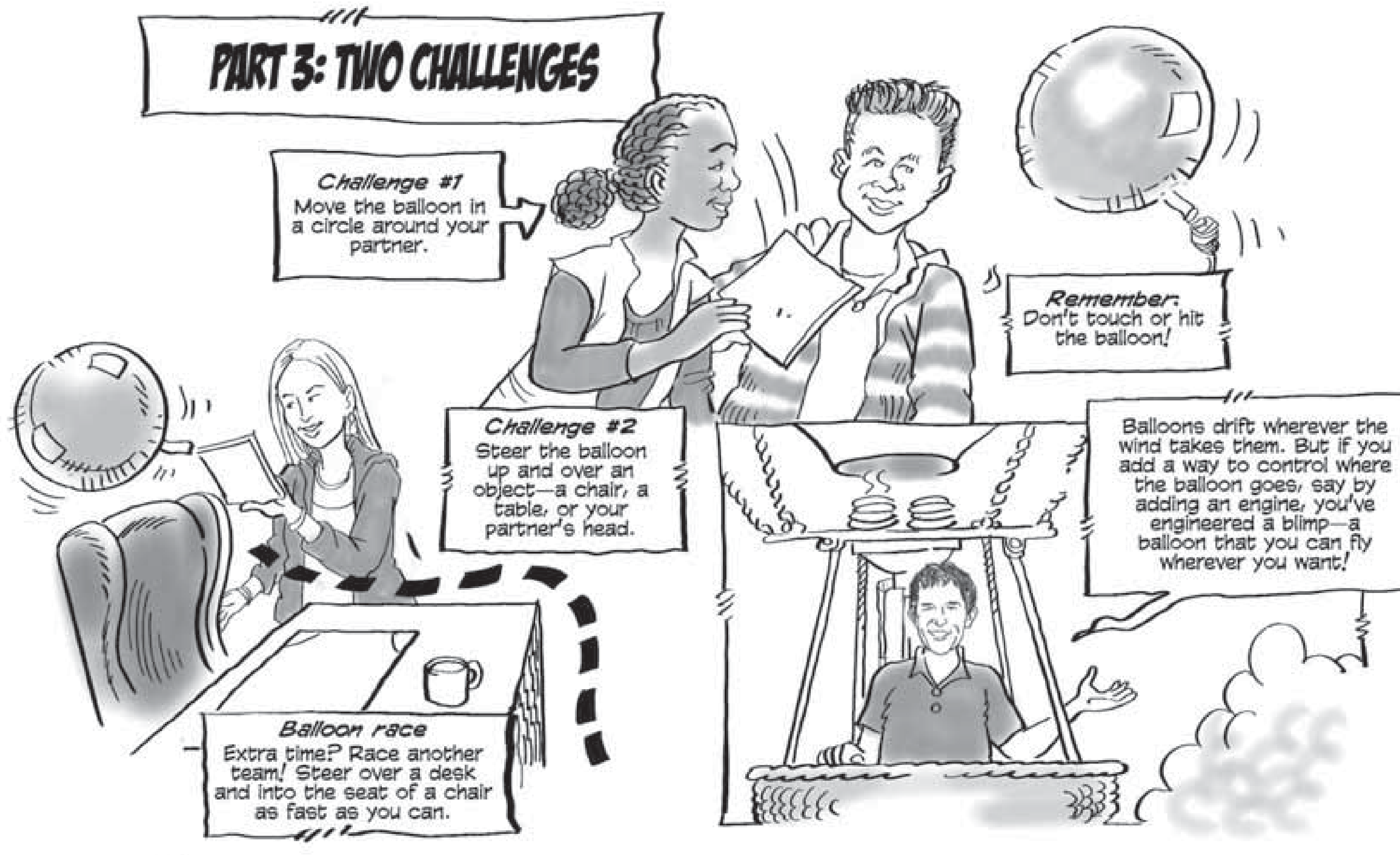

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Major funding for *Design Squad* provided by

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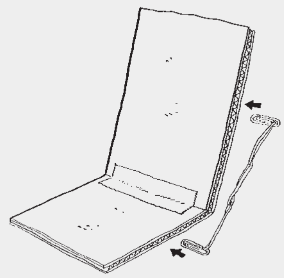
SKY GLIDER CHALLENGE

The Challenge: Build a blimp that travels in a straight path across the room.

Preparation

- ☐ Copy the *Sky Glider* handout (one per student).
- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Air Resistance*** (1 minute), ***Axis of Rotation*** (1 minute), and ***Design Process: Testing the Axis** of Rotation* (1½ minutes). Be prepared to project them.
- ☐ Set up 3–4 launching stations. For each station, you'll need 2 sheets of corrugated cardboard (approx. 11x17 inches), duct tape, rubber bands, and paper clips.
- ☐ Gather these materials (per team of two):
  - *Sky Floater* balloons
  - clear tape
  - copier paper
  - scissors
  - small paper clips



Launching Station
Insert the paper clips so the rubber bands gently lift the launcher's back.

1 Introduce the challenge (5 minutes)

- Tell students that today's challenge is to build a blimp that can travel a straight path across the room. Point out how this activity is similar to the *Band Cam* challenge: The blimp must be neutrally buoyant and travel in a predictable way.
- Ask: Who might be interested in using blimps? *(People interested in moving heavy loads and using energy-efficient transportation. Blimps also make excellent eyes-in-the-sky for things like filming sporting events, TV broadcasts, surveillance, search-and-rescue missions, and observing wildlife.)*

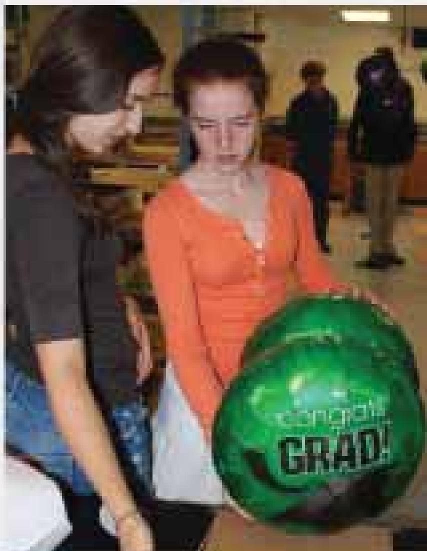
2 Brainstorm (10 minutes)

Brainstorm air resistance

Tape together the wide faces of two balloons. Set them in motion using the launcher. Point out that the device launching the balloons is an example of one object transferring its kinetic energy to another.

- What keeps this pair of balloons from going across the room? *(Air resistance)*
- Drop a sheet of paper, first with the wide face perpendicular and then with it parallel to the floor. Ask: Which has the most ***drag*** (i.e., a force that resists an object's movement)? *(There is more drag when the wide face is parallel to the ground, and the paper falls more slowly.)*
- What are some things that are streamlined to cut easily through air or water? *(Sports cars, blimps, submarines, planes, fish, birds, etc.)*
- To reduce drag and move efficiently through the air, which face of a balloon should face forward? *(The narrowest one, so that it can slice through air)*
- What could you use to firmly hold two balloons in this orientation? *(A paper tube or tubes)*
- Show ***Air Resistance*** in which the *Design Squad* teams discuss how drag slows down flying objects.

First, students make a neutrally buoyant blimp out of two balloons. Many used a paper tube to connect their balloons.



Then, students use a rubber band-powered launching station to gently set their blimps in motion.

Next, students get their blimps to “fly” straight and far by streamlining them and lengthening their axis of rotation. Some students used fins to help their blimps travel straight.

Finally, in *Making It Real*, students discuss the science and engineering behind their designs and describe how they are thinking and working like engineers.

Brainstorm axis of rotation

- Show ***Design Process: Testing the Axis of Rotation.*** Point out how the Purple Team’s blimp is held at just one point, making it easy for the blimp to spin.
- Spin the two balloons with your hands. Ask: Why do they spin so easily? *(They have a short **axis of rotation**—the point around which an object spins. Also, there is little force, such as air resistance, stopping the spin.)*
- What shape do objects that must travel long distances through the air—such as javelins, footballs, arrows, and rockets—have in common? *(They are much longer than they are wide.)*
- Show ***Axis of Rotation,*** in which the *Design Squad* teams stabilize a boat by lengthening its axis of rotation. In *Sky Glider*, students will lengthen the axis of rotation to help their blimps travel straight.

Brainstorm the design process

- Brainstorm ways to make a blimp from two balloons so it will have low air resistance. *(Students should suggest designs that have as little material as possible hitting the air as the blimp moves forward.)*
- Brainstorm ways to make a blimp from two balloons so it will travel straight and not spin. *(Students should suggest designs where there is a wide separation between the balloons.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you’ll need to figure out as you make your blimp? *(How to: attach the two balloons; make them neutrally buoyant; launch them gently; keep them on a straight course; streamline them so they fly far; etc.)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways of turning the materials into a blimp that can glide straight and far. Distribute the handout and have them sketch their ideas.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Travel far:** Have students make streamlined designs to reduce air resistance.
- **Travel straight:** In our testing, students found that fins helped a blimp glide straight. As a blimp begins to veer from a straight course, the fin’s wide side begins to hit a lot of air, taking advantage of drag and producing a force that helps the blimp resist turning. (NOTE: Wings only provide lift at high air speeds. Buoyant, lighter-than-air craft, such as blimps, go too slowly to make use of wings, so wings just add unnecessary, burdensome weight.)
- **Launch the same way:** Remind teams to launch their blimps the same way every time (i.e., use the same launcher, start from the same position, etc.). Otherwise, it’s hard to know what affects a blimp’s flight—a design change, the launcher, or the launching technique.
- **Record data:** Have teams record the distance traveled and keep track of any rising, falling, spinning, or traveling in an arc.
- **Storage:** Keep blimps intact until you finish the *Making It Real* session.

SKY GLIDER

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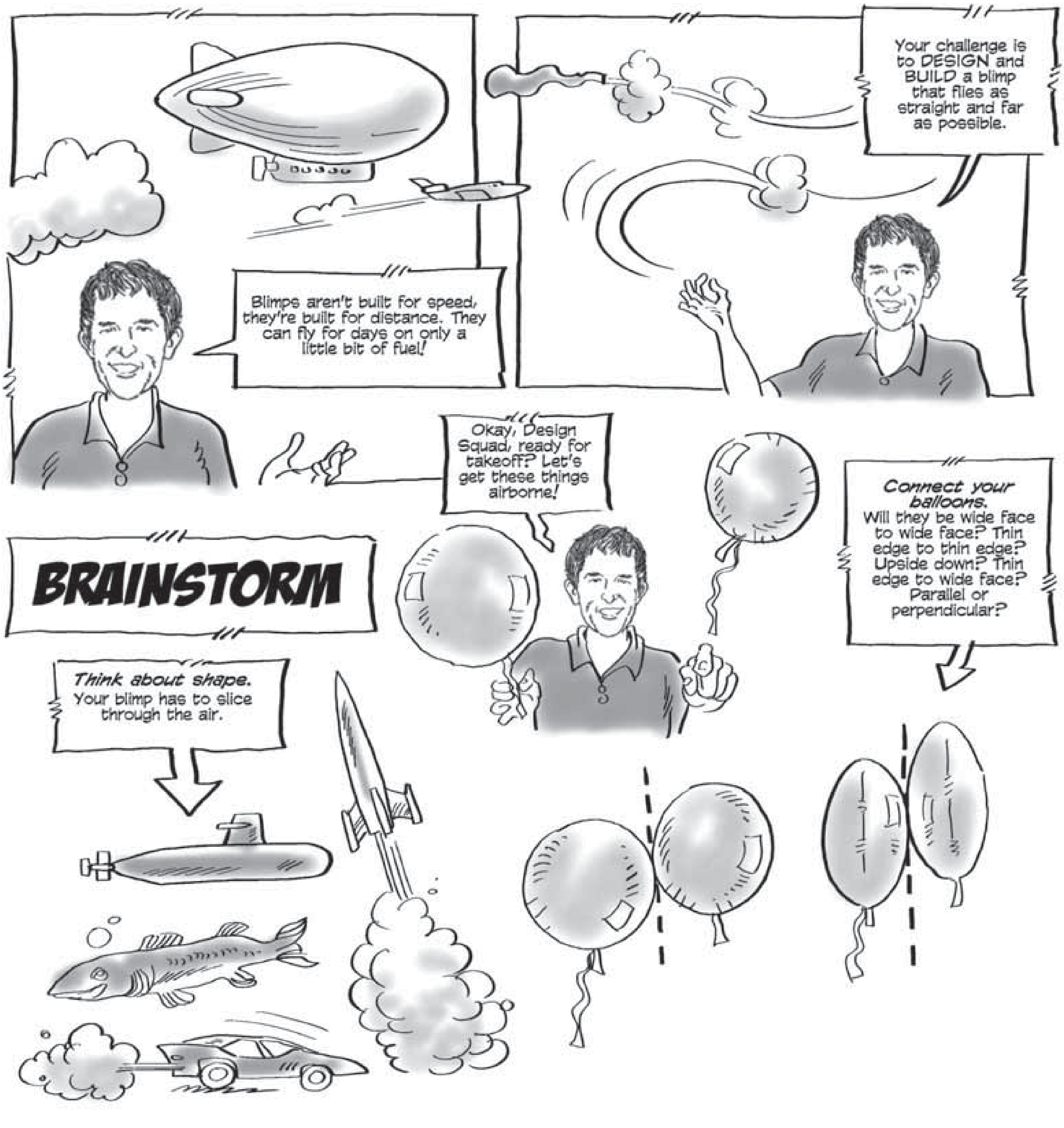

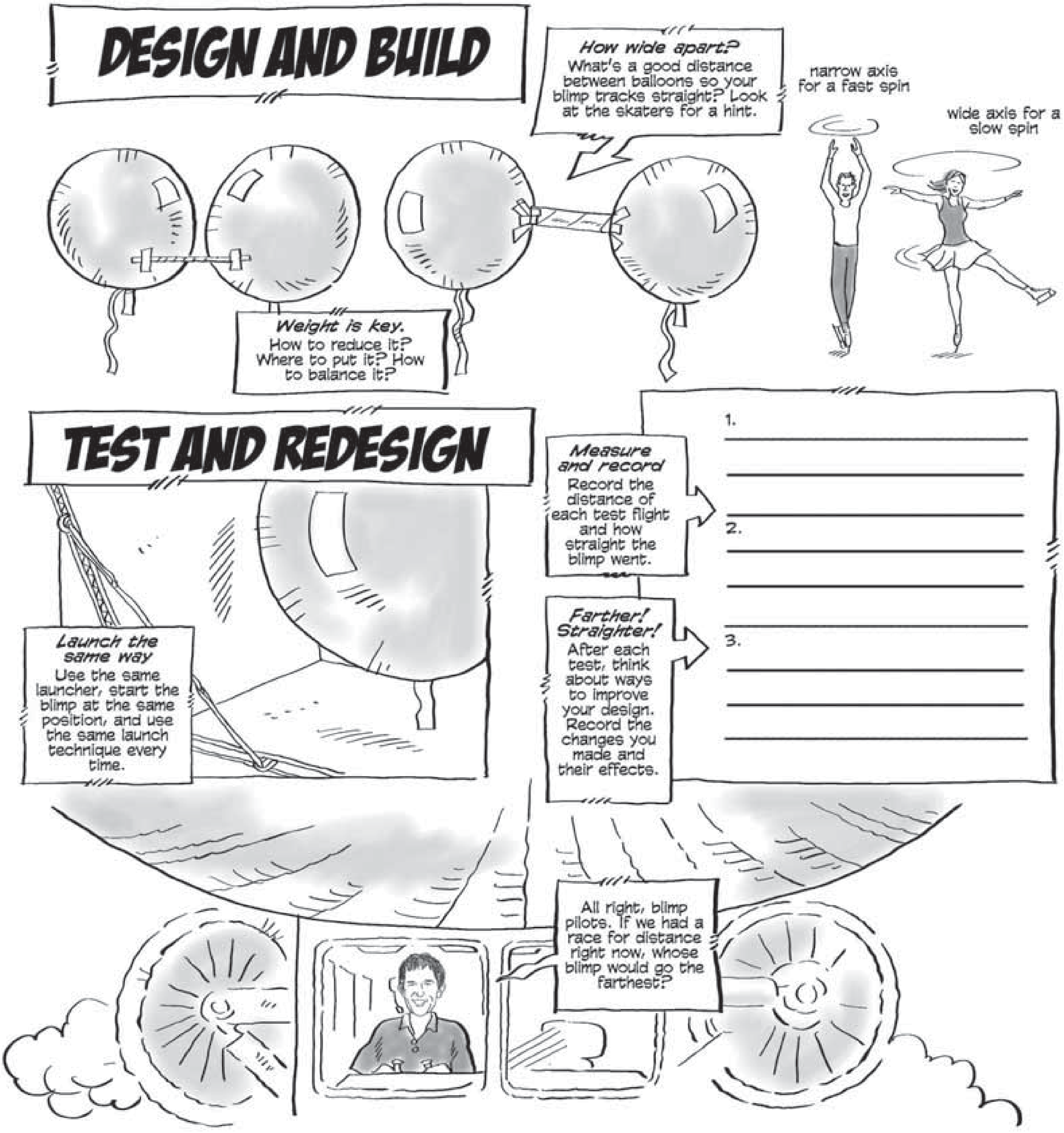

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Major funding for *Design Squad* provided by

NSF, Intel Education, the Lemelson foundation — improving lives through invention

Additional funding for *Design Squad* provided by

Noyce Foundation, UEF, NCEES National Council of Examiners for Engineering and Surveying, ASME, IEEE Celebrating 125 Years, Northrop Grumman Foundation

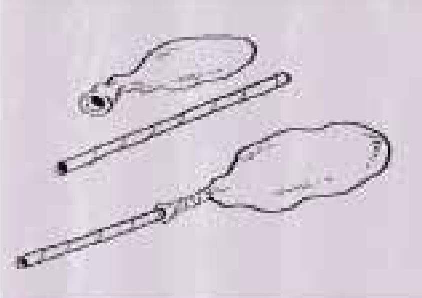
BLIMP JET CHALLENGE

The Challenge: Add a jet-propulsion system (i.e., a balloon) so that a blimp flies straight and far under its own power.

NOTE: *In Blimp Jet, there are many more variables than in Sky Glider. Because it can take many rounds of testing to get a blimp to travel a straight path, students must be patient and be able to work precisely.*

Preparation

- ☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Newton's 3rd Law*** (1 minute) and ***Thrust & Newton's Laws*** (1 minute). Be prepared to project them.
- ☐ Gather these materials (per team of two). See page 44 for suppliers.
  - blimps from previous challenge
  - 4 sheets of paper
  - clear tape
  - balloon pump
  - scissors
  - 6 drinking straws (narrow and wide)
  - 12- to 16-inch latex party balloon (Long "rocket" balloons also work but hang down awkwardly.)



Make a blimp jet
To propel a blimp, make a "jet." Fit a straw into the balloon's neck. Seal it tightly with tape.

1 Introduce the challenge (5 minutes)

- Tell students that today's challenge is to add a jet propulsion system (in this case, a party balloon) so their blimps fly under their own jet power. Hold up a latex party balloon and a straw and make a jet. (See illustration.) *(Mention that the straw can help control how fast air escapes from the balloon.)*
- How can you use this jet to provide ***thrust***—a pushing force—to a blimp? *(Attach the jet to the blimp. To assure that the end of the jet stays pointing exactly where students want it to point, they should attach it to a stable, easy-to-access place, such as the frame connecting the two Mylar balloons. Demonstrate how to use a pump to inflate the balloon. Point out how the straw lets you inflate the balloon without having to detach the jet from the blimp.)*
- What force does the jet's thrust overcome? *(Inertia and air resistance [i.e., drag])*

2 Brainstorm (10 minutes)

Brainstorm Newton's 3rd Law

- How is this jet an example of Newton's 3rd Law? *(Inside a sealed balloon, the air pushes out equally on all sides, so there is equal force on all parts of the balloon. But when you open the neck of the balloon, the air rushes out of the hole. When this happens, one area of the inside surface—the area with the hole—has less pressure on it than the other parts. The forces inside the balloon are now unbalanced—there is a greater force pushing on the area opposite the hole. So, the balloon moves in the direction of the greater force—the area opposite the hole. Since the balloon is attached to the blimp, this unbalanced force also pushes the blimp forward.)*
- Which way should the straw point? *(Opposite the direction students want the blimp to travel. Very small adjustments of where the straw points have a noticeable effect on how the blimp travels. This is why students must be willing to work carefully and precisely.)*

An inflated jet makes a blimp look ungainly, but it doesn't significantly impair the blimp's flight.

Students attach paper fins to help a blimp fly straight. This particular design won't travel as far as a more streamlined blimp, due to air resistance.

- Watch both ***Newton's Laws*** videos. In one, the *Design Squad* teams use Newton's 3rd Law to propel and steer a fan-propelled boat. In the other, they build a flying football goalpost and grapple with balancing gravity and thrust. Discuss how their blimp jet similarly provides thrust using an action-reaction principle. Also point out the importance of reducing weight.

Brainstorm the design process

- Brainstorm good places to attach the jet. *(A bottom-heavy blimp is more stable; make sure the air stream flows freely and is not blocked by blimp parts.)*

3 Summarize the problem to solve (5 minutes)

- Break the larger challenge into its sub-challenges. Ask: What are some of the things you'll need to figure out as you add a jet to your blimp? *(Decide how to: mount the jet; inflate the balloon; make minor adjustments easily; document each test flight to understand how to modify the blimp and jet; etc.)*
- To promote creative thinking and foster a sense of ownership, have students pair up and brainstorm their own ways to add a jet.

4 Build, test, and redesign (30 minutes)

Here are some strategies for dealing with issues that may come up during building:

- **Modify the balloon pump:** Tips on commercial balloon pumps are too big to fit into straws. Insert a thin straw into the pump tip and seal it with tape. Now the thin straw can slip into a balloon jet's straw.
- **Make blimps neutrally buoyant:** To compensate for the added weight of the balloon jet, students will need to adjust their blimps to make them neutrally buoyant again.
- **Orient the blimp:** Top-heavy blimps don't stay level. Encourage students to tape the balloon jet toward the bottom of the blimp.
- **Tape the jet firmly in place:** The balloon jet wiggles if kids tape it in only one place. To anchor it well, students should tape it to the frame in at least two places.
- **Control the jet power:** The amount of air leaving the balloon jet makes a difference. If air escapes too quickly, the initial thrust is powerful, but it rapidly peters out. If the air escapes too slowly, there's too little thrust to overcome inertia and air resistance. Students might need to modify the straw to adjust the rate of the escaping air. Just make sure that the end of their straw still fits into the pump. Overfilling balloons will, of course, pop them. More air is not always the answer!
- **A second class period?** Students can achieve success in one class period and have a fun, memorable experience with Newton's 3rd Law. But devoting two sessions to *Blimp Jet* will really let students refine their systems.

Accomplishing the challenge—getting a blimp to travel straight and far—gives kids a real sense of achievement.

MAKING IT REAL:
DRIVING HOME THE BREEZY BLIMPS UNIT

Overview: Students take their work beyond the walls of the classroom, using a combination of presentations, videos, and discussion. They present their blimps, discuss how they demonstrate the unit's science concepts, point out how they are thinking and working like engineers and discuss how engineering is a field centered on making the world a better place.

Preparation

☐ Visit pbs.org/designsquad and download the following video clips from the "Teacher's Guide" page: ***Design Process: Teamwork*** (1½ minutes), ***Design Process: Testing & Redesign*** (30 seconds), ***Band Cam Judging*** (4 minutes), and the ***Mark Caylao*** engineer profile (2½ minutes). Be prepared to project them.

1 **Raise student awareness of engineering** (5 minutes)
Our world is molded by the engineering that surrounds us. Yet, many students are unaware of what engineers do. Probe students' ideas about engineering. Ask:

- What do engineers do? *(List students' ideas.)*
- Then ask: What things in this room were probably designed or made by engineers? *(There is very little in the room other than the people, plants, and dirt that does not bear the mark of an engineer.)*

2 **Relate students' work to science and engineering** (25 minutes)
View ***Band Cam Judging***, in which team members discuss how to meet the *Band Cam* challenge. Then ask:

- How did the teams create lift? *(Varied the amount of helium; reduced the frame's weight; added propellers; redesigned based on testing; etc.)*
- How could the teams redesign their faulty blimp? *(Balance the weight better; adjust propellers to provide more balanced thrust; make sure it's neutrally buoyant; increase the axis of rotation to reduce spin; lighten the load; etc.)*
- How is the process you followed similar to the one the kids on *Design Squad* did? *(Both the students and the teams brainstormed lots of ideas, then built, tested, and revised their blimps, and presented their designs to others.)*

Show ***Design Process: Teamwork***, in which the *Design Squad* teams discuss frustrations inherent in teamwork. Then show ***Design Process: Testing & Redesign***, in which the Green Team, formerly at odds in *Teamwork*, works together to come up with an effective solution to a problem. Have students present their blimps. Use the following questions to explore key points in the video and unit:

- What could you suggest to help the Green Team work effectively together? *(Listen to each other; adjust one's style to help things work smoothly; get input from each team member; agree on a plan; choose roles; assign tasks; use people's strengths; etc.)*
- What were some problems you solved as you built and tested your blimp?
- Was it harder to get a blimp to travel straight or to travel far? Why?
- What are some general characteristics that help a blimp work well? *(Lightweight; neutrally buoyant; long axis and fins to prevent spinning; streamlined to minimize air resistance; etc.)*

SHOW KIDS THE RELATED TV EPISODE

Show students *Band Cam*, the full-length *Design Squad* TV episode related to the *Breezy Blimps* unit, where the *Design Squad* teams design and build a remote-controlled aerial camera system to film a live concert. Watch it online at: **pbs.org/designsquad**.

"My students loved the hands-on aspect of this and really rose up to the challenges. I learned that I should not be afraid to challenge my kids, and I should do more open-ended projects with them."

Harini A.
Belle Haven Elementary School
Menlo Park, CA

Students develop a working knowledge of force in *Sky Floater*, take their understanding further in *Sky Glider*, and explore the relevance of the science and engineering in *Making It Real*.

3 Meet an engineer (10 minutes)

- View the ***Mark Caylao*** video to introduce students to an engaging young engineer involved in designing, building, and running one of the world's largest blimps. Of engineering, he says, "It's the best job you can have. I love it!"
- Mark mentions that every day he uses things he learned in high school. Ask: What subjects might you study to prepare to do the things Mark does? *(Math, science, and tech. ed. would help you understand how blimps work, and how to design, build, operate, navigate, and maintain one.)*
- What were some of the things Mark mentioned liking about being an engineer? *(He calls it the perfect job because he likes the traveling; being able to fly; being part of the team that designs, builds, and operates blimps; and doing important work, such as testing air quality and monitoring whales.)*

4 Make the engineering real (10 minutes)

Use the following questions to help students see how the work they did relates to engineering and see that engineers design things that improve people's lives.

- Who might be interested in using blimps? *(Blimps provide quiet, energy-efficient transportation and can carry heavy loads and hover easily. They can be used in logging operations, in search-and-rescue missions, and to carry cameras to observe wildlife, conduct surveillance, and film TV broadcasts.)*
- How might engineers be involved with blimps? *(Designing sturdy, aerodynamic blimps and efficient propulsion systems; inventing new, sturdy, lightweight materials for making blimps; designing blimp-based transportation systems and infrastructure, such as terminals, hangars, and manufacturing systems; finding sources of gas to fill blimps; etc.)*
- In what ways did you think and work like an engineer as you made your blimp? *(Used creativity; followed the design process to design, build, and test an aerodynamic blimp that travels a straight path; applied science concepts—buoyancy, force, and Newton's laws; made a prototype of something people want—an efficient mode of transportation; etc.)*

Extension Ideas

- Share photos of your students' designs and see what others have made. Visit DS XCHANGE, *Design Squad*'s online community at **pbs.org/designsquad**.
- Using photos, contrast the design—the form and function—of a stunt plane (built for sharp turns and quick maneuvers), supersonic jet (speed), and blimp (distance, hovering, fuel economy). Focus on overall shape, axis of rotation (short for stunts, long for steady flight), streamlining, fins and wings, and the size and location of the cockpit or cabin.

Interdisciplinary Connections

- *Math:* Calculate how big a spherical balloon has to be to lift a pound, given that the lift of helium is one ounce per cubic foot. Since the volume of this sphere must be at least 16 cubic feet, then: $\frac{4}{3}\,r^3 = 16$ cubic feet; $r = 1.56$ feet. *(The diameter must be at least 3.12 feet.)*
- *Social Studies:* Research the history and current use of blimps in travel, law enforcement, warfare, wildlife studies, search and rescue, and other fields.

TELL US WHAT YOU THINK

Take our quick online survey, and we'll send you a *Design Squad* class pack (while supplies last—see back cover for details).