EITC Engineers in the Classroom

NATIONAL GEOGRAPHIC + LOCKHEED MARTIN

Level E Elementary | Grades K-4

# Forces of Flight

Image credit: NASA/Lockheed Martin

## ACTIVITY: FORCES OF FLIGHT

### Big Idea
Show students how engineers design aircraft for different flight speeds and uses.

### Guiding Question
What are the four attributes of flight that influence high-speed aircraft and low-speed aircraft?

### Materials
1. Paper clips: 1 box per kit
2. Scissors: 1 pair for every 4 students (Most students in elementary classrooms have scissors or the teacher has a classroom set.)
3. Projector: a way to share the online videos and key image
4. Paper airplane template #1 (1 printed template per student)
5. Paper template airplane #2 (1 printed template per student)
6. Paper template airplane #3 (1 printed template per student)
7. Model of an airplane (optional)

### Set up
Arrange the desks so students can alternate between small-group work and all-class discussions and demonstrations.

TIPS:
- Practice folding all of the airplanes using the tutorial videos and provided templates before your classroom visit.
- Begin paper airplane construction by placing the dotted lines of the template face down.
- Bring 4 sets of pre-assembled paper airplanes with you to class in case students have a hard time folding.

### Introduction
Teacher introduces the engineer/classroom visitor.

### Setting the Stage
- Show the introductory video.
- Tell students who you are, what you do, and what it's like to work in your career (3 mins).
- Tell them a story about how you got interested in engineering/your career or something that happened in your work that was really exciting—something that truly made a difference in your life (3 mins).

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## Hands-on Activity

Ask: *Have you ever wondered exactly how airplanes stay in the air—how they fly?* Tell students that the whole science of flight is pretty cool—and that they know more about it than they think they do. Ask: *Have you ever made and flown a paper airplane?* Tell students that the way that paper airplane flies is exactly the same way a huge jet airplane flies.

Introduce students to the flight terms *drag, thrust, lift,* and *gravity (weight)*, and ask them if they have heard those terms before. Students may be familiar with the terms used in different ways. For example, they may have heard of drag racing, and they surely know the term *weight* or *weigh.* Encourage students to give their ideas of what these words may mean in relation to flight and aircraft capabilities (high speed and low speed). Explain to students that for this activity *drag* is described as the slowing down force exerted on an airplane by a fluid medium such as air or water. *Thrust* is the aerodynamic force that pushes or pulls the airplane forward through space using a propeller or a jet engine. *Weight* is the force of gravity. *Lift* is the force available for overcoming the force of gravity. Engineers have to consider these forces when they design airplanes if the planes are going to stay in the air and fly.

Tell students that engineers also design planes with certain capabilities in mind. High-speed planes can be used for military purposes and civilian business jets. Low-speed planes can be used for fighting forest fires, surveying land, and dusting crops.

**Demonstration**

Use the key image projected on the classroom screen or a model of an airplane—paper or otherwise—to identify the forces of drag, thrust, lift, and weight (gravity). Encourage student volunteers to step forward and identify the forces for their classmates. Demonstrate how to construct the first paper airplane template. Carefully model each fold and step for the students. You might use a document camera to show the specific folds enlarged for the students. Using the completed paper airplane to engage student volunteers to once again identify the four forces of flight. Demonstrate how to safely throw the paper airplane within the classroom environment.

**Construct Paper Airplanes**

Explain to the students that engineers make models of airplanes to test their ideas before building a real one. They run models through thousands of tests. Tell students that they will mimic engineers by constructing and flight-testing a few paper airplanes, changing their designs to meet different criteria.

Follow these steps to guide students through the activity.

1. Have students construct paper airplane #1 as demonstrated by the professional. The template shows specific steps and the associated fold lines. This particular template was chosen for its relatively straight glide profile—the classic paper airplane.
2. Move students into small groups in designated areas of the classroom to flight test their #1 paper airplanes. Students will notice that there is a certain speed required to throw the airplane. Tell students that an airplane that is thrown too fast will create too much lift and stall; thrown too slowly the airplane will not create enough lift and nosedive.
3. Have students modify paper airplane #1 to allow for faster flight using their new knowledge of balancing forces (faster flight creates more lift). Ask the students for suggestions about how the airplane could be modified for faster flight. Because the airplane thrown fast tends to create too much lift leading to a stall, the two possibilities are balancing the lift with more weight (paper clips) or reducing lift (reducing wing area by folding the wing). Note that the paper clips should be positioned toward the nose of the airplane; the ends of the wings can be folded up or down to reduce the wing area contributing to lift. Give the students a few minutes to flight test their modified airplanes; allow them to test their design then change it and test it again.
4. Have students modify paper airplane #1 to allow for slower flight (slower flight creates less lift). Ask the students for suggestions about how the airplane could be modified for slower flight. Because the airplane thrown slowly creates less lift leading to a very short flight, the two possibilities are balancing the lift with less weight (cut away material from the airplane body/fuselage) or increase lift (increase wing area by fully unfolding the wing). Note that the material should be removed in small sections along the length of the fuselage. Give the students a few minutes to flight test their modified airplanes; allow them to test their design then change it and test it again.

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5. Have students construct paper airplane #2, the high-speed template. This particular template was chosen to show an example of a product that evolves from the engineers' work of modifying and testing to create a high-speed airplane. It was designed and tested to perform in a certain way to meet specific criteria.
6. Have students flight-test paper airplane #2. Does it fly like a high-speed airplane? How does it compare to your modified flight test in step 3?
7. Have students construct paper airplane #3, the low-speed template. This particular template was chosen to show an example of a product that evolves from the engineers' work of modifying and testing to create a low-speed airplane. It was designed and tested to perform in a certain way to meet specific criteria.
8. Have students flight-test paper airplane #3. Does it fly like a low-speed airplane? How does it compare to your modified flight test in step 4?

## Wrap-Up

Ask the students to reflect on what they learned. What are the four aerodynamic forces of flight? How did the first airplane fly? What happened if you flew it too fast? Too slow? What was out of balance for the airplane to fly this way? How did you modify the airplane so that it could successfully fly faster? Slower? How did the airplanes that were designed to fly fast and slow compare to the modified one?

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## SUPPORT MATERIALS – FOR THE CLASSROOM VISITOR

### Background Information

How Do Paper Airplanes Fly?
Paper airplanes are gliders. The basic shape includes wings and a body (fuselage). The wings allow the plane to "sit" on the air. The wings create a pressure differential (higher below, lower above). This pressure differential creates lift. The lift must balance the airplane weight to allow the airplane to glide smoothly. Thrust happens when the airplane is thrown. Drag slows the airplane throughout its glide. Drag is created in two ways; the lift induces drag and the friction of the air on the paper creates drag.

### National Standards Alignment

- National Science Education Standard: (K-4) Standard A-1: Abilities necessary to do scientific inquiry
- National Science Education Standard: (K-4) Standard E-2: Understandings about science and technology

### Preparation For Your Classroom Visit

Once a classroom visit has been established, check in with the host educator to make sure students are prepared and have some prior knowledge about the topic you have selected to share with the class.

An educator guide has been created for you to share with the host educator before your classroom visit. This guide includes pre- and post-visit resources and suggested activities that support the content you will be presenting during your classroom visit. Some of the information in the educator guide has been provided in the "Support Materials—For the Educator" section at the end of this document. Share the educator guide for this activity with the classroom educator as soon as you have a date for your visit. The educator guide can be found in the educator version of the Engineers in the Classroom website (www.classroomengineers.org)

### Prior Knowledge

Familiarize yourself and the educator with the following terminology: lift, drag, weight, gravity, thrust, aerodynamics, force, criteria, fuselage

### Other Resources To Explore

NASA: The Four Forces of Flight
http://www.nasa.gov/audience/foreducators/k-4/features/F_Four_Forces_of_Flight.html

Teach Engineering: Resources for K–12
http://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_airplanes/cub_airplanes_lesson06.xml

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## Classroom Management Tips

1. **Use a normal, natural voice:**

   The students will mirror your voice level, so keep it neutral and soft. If you want students to talk at a normal, pleasant volume, you must do the same. You also want to differentiate your tone. If you are asking students to put away their notebooks and get into their groups, be sure to use a declarative, matter-of-fact tone. If you are leading a classroom discussion, use an inviting, conversational tone.

2. **Use hand signals and other non-verbal communication:**

   Holding one hand in the air and making eye contact with students is a great way to quiet the class and get their attention on you. Have the students raise their hand along with you until all hands are up. Then lower yours and talk.

   Flicking the lights on and off is a helpful cue to let the students know a transition is coming up. At that point let them know they have 3-5 minutes to finish up their current task.

   Another helpful tool to gather attention is to clap or sing a certain rhythm for the students to repeat.

3. **Address attention needs quickly and wisely:**

   Always take a positive approach while addressing an interruption to your instruction. Say, “It looks like you have a question,” or, “Is there something that I might clarify for you?”

   When students have conflicts with each other, use neutral language as you guide the students to a solution.

4. **Use Reflective Questioning:**

   Paraphrase and restate comments. By repeating or reflecting the student’s statement in the form of a question, you will help them gain valuable insight and they will know you are listening to them.

5. **Emphasize Safety:**

   The most important component of any environment is safety. Let the students know it is your job to keep them safe and it is their job to help keep it that way.

   Review classroom safety rules:

   - Keep hands to self.
   - Use the correct voice volume for the task (0-5 scale):
     0=silent, 1=whisper, 2=conversational, 3=small group, 4=presentation, 5=outside
   - Listen to the speaker.
   - Share when it’s your turn.

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## SUPPORT MATERIALS – FOR THE EDUCATOR

### Tips

- Additional relevant concepts and physical properties that could be presented before/after the activity include lift, drag, weight (gravity), thrust, aerodynamics, force, criteria, and fuselage.
- Read a book about forces of flight to introduce the topic and familiarize the students with relative terminology: *The Wright Brothers for Kids: How They Invented the Airplane, 21 Activities Exploring the Science and History of Flight* or David Darling's—*Up, Up, and Away: The Science of Flight.*

### Pre-Visit Resources and Activities

- *Pre-teach relevant vocabulary: aerodynamics, force, criteria, fuselage*
- Show video that explains the four forces of flight: https://archive.org/details/NasaSciFiles-TheFourForcesOfFlight
- Additional forces of flight information: https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/dynamicsofflight.html

### Post-Visit Resources and Activities

- Review the National Geographic Education activity Pterosaur Glider Experiment to discuss comparisons between animal and aircraft flight: http://education.nationalgeographic.com/education/activity/pterosaur-glider-experiment/?ar_a=1
- Review relevant vocabulary/concepts: lift, drag, weight (gravity), thrust, aerodynamics, force, criteria, and fuselage.
- Possible extension: Discuss Angle of Attack as a means of increasing lift and drag. Angle of Attack is the angle of the airplane wing with respect to the relative wind. Nearly all airplanes increase their angle of attack before landing so that they can fly slower yet still have enough lift to keep the airplane flying.

This video shows the space shuttle orbiter on the shuttle-carrier aircraft landing; notice 3 minutes, and 26 seconds into the video when the airplane clearly increases its angle of attack to increase lift (to slow its descent) just before touching the ground. http://www.youtube.com/watch?v=caKrNA1l1MI

Demonstrate flying the paper airplane with increased angle of attack. This is easiest with the airplane model #1. This can be done in two ways. First, attach a paper clip to the fuselage toward the tail of the airplane. Second, bend the trailing edge of each wing up (this is the more challenging approach). The airplane must be thrown slowly; otherwise, it will create too much lift at the increased angle of attack and will likely stall. With a little experimentation, a slow glide with the airplane at a noticeable angle of attack is achievable.

### For Further Exploration

- NASA: The Four Forces of Flight
  http://www.nasa.gov/audience/foreducators/k-4/features/F_Four_Forces_of_Flight.html
- Teach Engineering: Resources for K–12
  http://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_airplanes/cub_airplanes_lesson06.xml
- Paper Airplane Construction tutorials
  http://www.10paperairplanes.com/

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## FOUR FORCES OF FLIGHT

Lift - upward
Drag - backward
Weight - downward
Thrust - forward

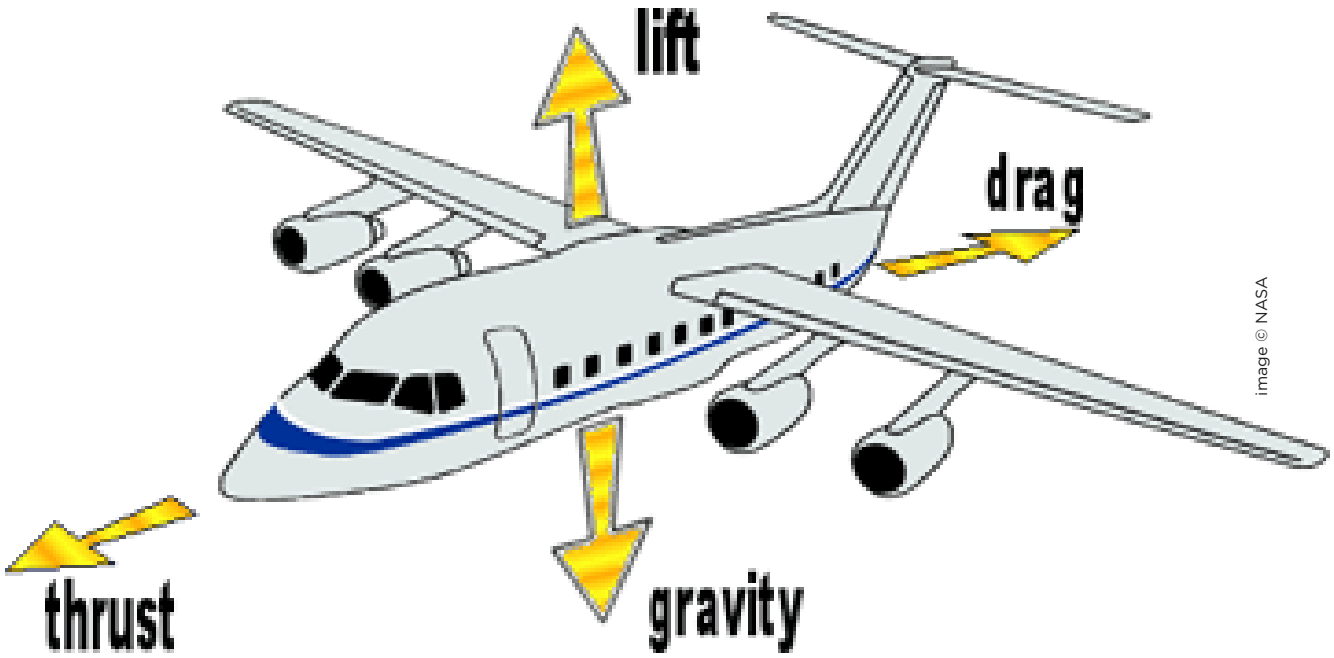
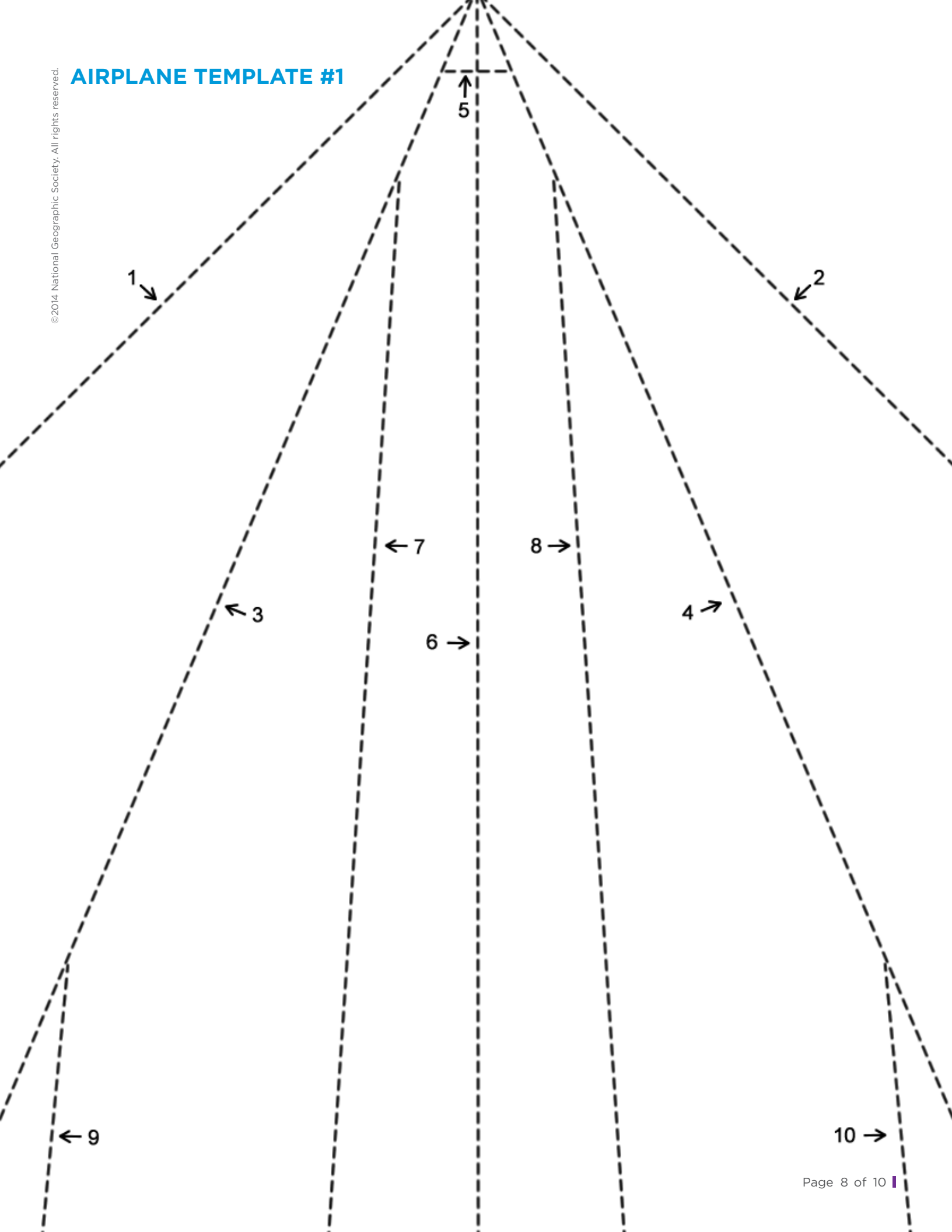



image © NASA

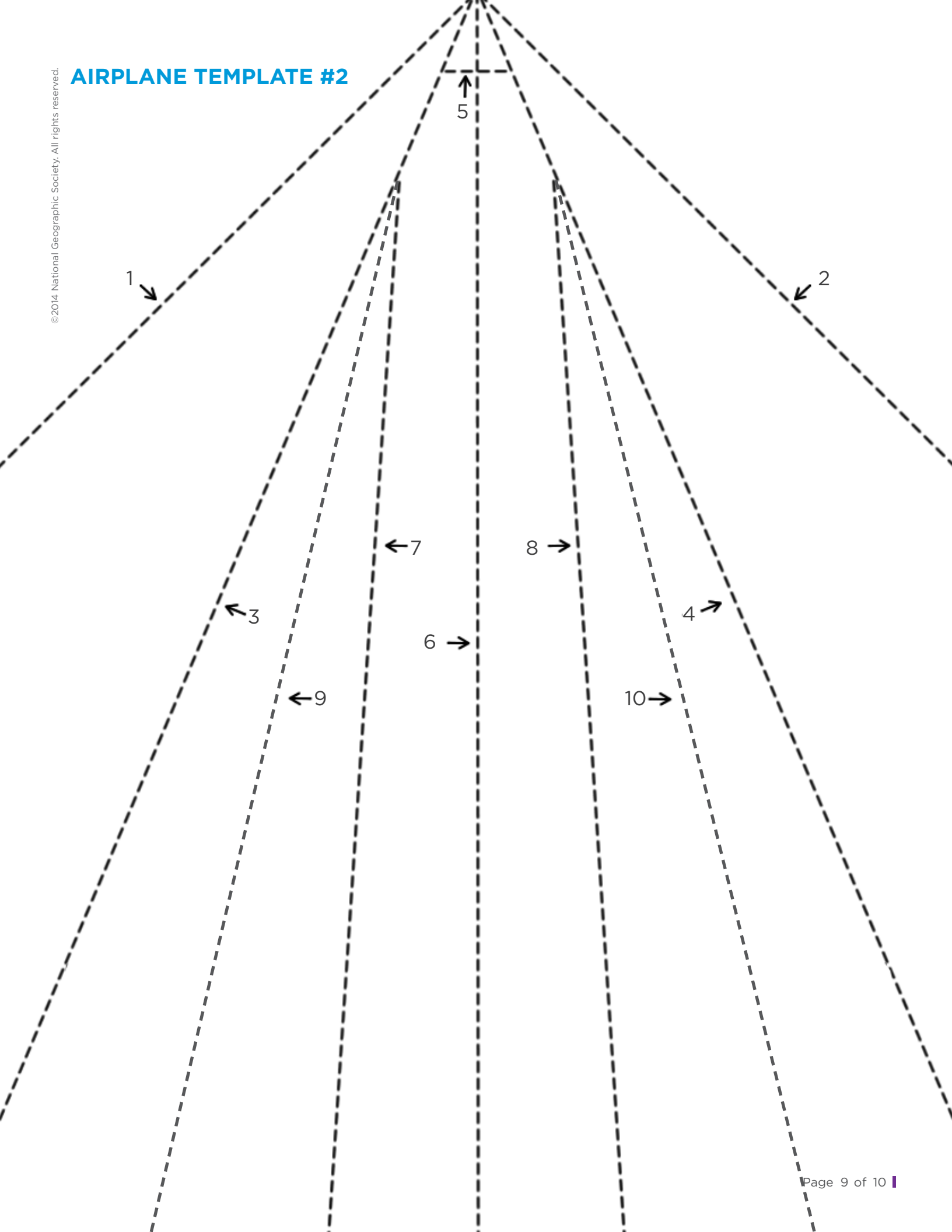
# AIRPLANE TEMPLATE #1





# AIRPLANE TEMPLATE #2





## AIRPLANE TEMPLATE #3

1

2

3

4

6 5 7