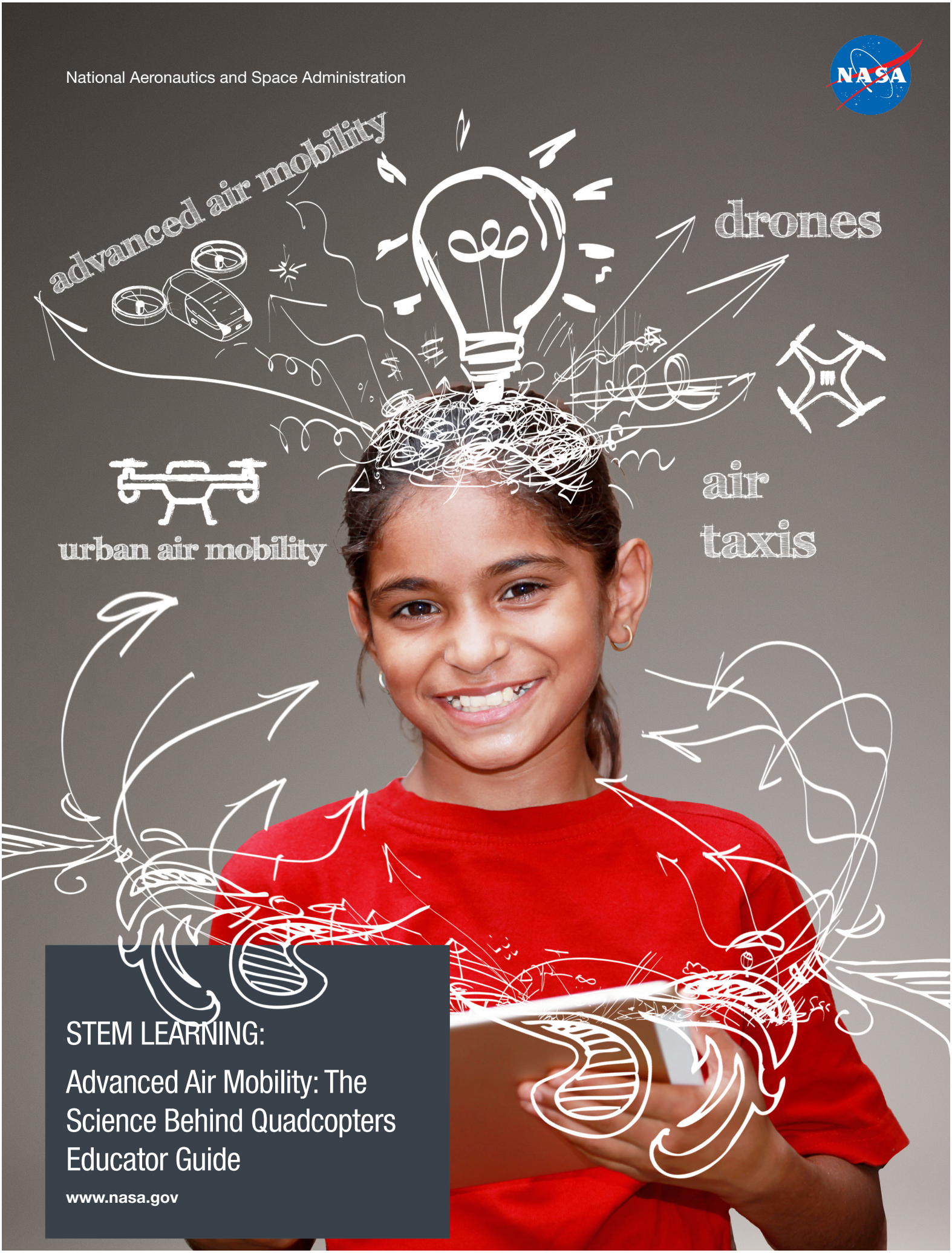
National Aeronautics and Space Administration




# STEM LEARNING:

# Advanced Air Mobility: The Science Behind Quadcopters Educator Guide

www.nasa.gov

# OVERVIEW

This activity explains the science behind controlling the movement of a quadcopter. In doing so, Newton's third law of motion, torque, and the fundamentals of rotary flight are introduced. Made for a middle school audience (grades 6 through 8), the guide includes comprehension questions, activities, and a glossary of scientific terms used in the text. This activity can also be completed without the activities, allowing it to be used as a standalone, informational text.

## Standards

### Next Generation Science Standards

**NGSS.MS.PS2.A:** Motion and Stability: Forces and Interactions

- Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Crosscutting Concepts

Patterns

- Using mathematical and computational thinking

Science and Engineering Practices

- Analyzing and interpreting data

### Common Core Standards, English Language Arts

**Craft and Structure**

**CCSS.ELA-LITERACY.RST.6-8.4:**

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context (relevant to grades 6–8 texts and topics).

**Integration of Knowledge and Ideas**

**CCSS.ELA-LITERACY.RST.6-8.7:**

- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

## Optional Teaching Strategies

- Use literacy tactics to help students make sense of the text, such as numbering paragraphs, circling unknown words, and underlining main ideas.
- Have students read the comprehension questions first, before reading the text, so that they have a purpose for reading.
- Have students work with a partner or in a small group when completing the activities.
- If students have the option to read this article digitally, use a screen reader or text-to-speech application to assist English language learners and/or special education students.

## Teacher Directions for Activities Version

1. This activity is designed to be completed individually or in small groups. The entire activity should take approximately 90 minutes, but this can vary depending on the students.

2. Before class, make copies of the student guide for each student/group. Optionally, the student guide can be used digitally with answers entered on a separate piece of paper or in an electronic document.

3. Gather all materials needed for activity 2.

4. Prior to working on this activity, introduce students to quadcopters. This can be done with a video showing a quadcopter-style drone, by showing them a quadcopter, or by discussing what quadcopters are and any experience students have with them.

5. Activity 1 requires no special materials and should take approximately 10 minutes to complete.

6. The materials required for activity 2 are listed in the activity description. This activity should take approximately 15 minutes.

7. Activity 3 requires no special materials. An explanation of how to complete the chart is included in the activity description. The student guide contains the rules for how to complete the chart. This activity should take approximately 20 minutes.

8. All or some of the reading comprehension and “Going Further” questions can be assigned.

## Teacher Directions for Reader Version

1. This activity is designed to be completed individually, but can be completed in small groups. The entire activity should take approximately 30–45 minutes, but this can vary depending on the students.

2. Before class, make copies of the student guide for each student/group.

3. Prior to working on this activity, introduce students to quadcopters. This can be done with a video showing a quadcopter-style drone, by showing them a quadcopter, or by discussing what quadcopters are and any experience students have with them.

4. Before having students begin, point out that there is a glossary at the end of the document which provides definitions for the bolded words throughout the guide.

5. All or some of the reading comprehension and “Going Further” questions can be assigned.

# ANSWERS FOR ACTIVITIES VERSION

**ACTIVITY 1:**
Designs and explanations will vary, but should include some way to attach the package to the drone and a method for detaching during delivery.

**ACTIVITY 2:**
5. Students' hypotheses will vary, but should include what they expect to happen and why they expect this to happen.

8. Observations will vary.

9. When you blow up the balloon, it makes the air pressure inside the balloon greater than the air pressure outside it. When you let it go, the air pushes its way out of the balloon. As the air escapes from the straw, it creates a force. According to Newton's third law of motion, for every action there is an equal and opposite reaction. This means that a force is applied on the straw/balloon and that is what causes it to rotate (with the pin at the center).

**ACTIVITY 3:**

| Lift Produced (N) | | | | Vertical Movement (None, Up, or Down) | Lateral Movement (None, Right, Left, Forward, or Backward) | Rotational Movement (None, Clockwise, or Counterclockwise) |
|---|---|---|---|---|---|---|
| Propeller 1 | Propeller 2 | Propeller 3 | Propeller 4 | | | |
| 1.25 | 1.25 | 1.25 | 1.25 | Up | None | None |
| 1.2 | 1.2 | 0.8 | 0.8 | None | Backward | None |
| 0.25 | 0.25 | 0.5 | 0.5 | Down | Forward | None |
| 1 | 1.5 | 1 | 1.5 | Up | None | Clockwise |
| 1.5 | 0.5 | 1.25 | 0.75 | None | Right | Counterclockwise |
| 0.5 | 1.5* | 0.5 | 1.5* | None | None | Clockwise |
| 2 | 1 | 1 | 1 | Up | Right and Backward | Counterclockwise |
| 0.25 | 1 | 1 | 0.25 | Down | None | None |

**Reading Comprehension Questions:**
1. According to recent NASA-commissioned market studies, there will be millions of AAM aircraft flights each year. Many of these flights will be in densely populated areas at low altitude. AAM will ensure they operate in a safe and efficient manner.

2. Without a good control system, there's a chance they would cause damage to people and/or property.

3. If the force of gravity was greater than the force of lift, the quadcopter would be pulled downward. Conversely, if the force of lift was greater than the force of gravity, the quadcopter would be pushed upward. When the two forces are equal, they are balanced and the quadcopter does not move up or down.

# ANSWERS FOR READER VERSION

**ACTIVITY 1:**

1. According to recent NASA-commissioned market studies, there will be millions of AAM aircraft flights each year. Many of these flights will be in densely populated areas at low altitude. AAM will ensure they operate in a safe and efficient manner.

2. Without a good control system, there's a chance they would cause damage to people and/or property.

3. If the force of gravity was greater than the force of lift, the quadcopter would be pulled downward. Conversely, if the force of lift was greater than the force of gravity, the quadcopter would be pushed upward. When the two forces are equal, they are balanced and the quadcopter does not move up or down.

4. Yes, you could create a drone with three propellers, but it would require some engineering. To balance out the torques, you would need to have two of them rotate slower than the third. This could create other issues that would have to then be addressed by the placement of the propellers.

5. It would move straight down (i.e., no lateral movement) while rotating clockwise.

6. Propellers 1 and 4 are on the left side of the quadcopter. If they are spinning faster than propellers 2 and 3, there will be more lift on the left side, thereby lifting that side up. This then causes the quadcopter to tilt, causing the force of lift to act both upward and to the right. Because of this, the quadcopter moves to the right.

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