FUTURE U.

CAV Aid

Objectives

Students will be able to:

- **Construct** their own helicopter
- **Consider** the forces of flight acting upon their helicopter, as well as its energy sources
- **Perform** research in order to understand how the CAV functions and why it is unique
- **Develop** a proposal that articulates how the CAV's functionality would make it a good candidate to assist communities in need

Overview

Students will join Boeing's community engagement team as they investigate how the Cargo Air Vehicle (CAV) could be used to help relief organizations. In order to gain a better understanding of the CAV and its mechanics, students will first explore energy and the forces of flight as they build their own helicopter. Students will then incorporate what they learn from this activity, as well key readings and videos about the CAV and additional research about where aid is needed most as they develop a proposal for using the CAV to help the greater good.

This lesson focuses on the following

Engineering Design Process

- Defining the problem
- Designing solutions

21st-Century Skills

- Communication
- Collaboration
- Critical thinking
- Creativity

Timing

Two 60-minute class periods

Materials

Day 1

- Device with ability to project, one for the teacher
- Devices with Internet access, at least enough for half the class
- Handout 1: Build a Helicopter, one per student
- Helicopter supplies, enough of the following for groups of four students:
    - nose-hook propeller (similar to this)
    - popsicle sticks
    - large rubber bands

  - paperclips
  - cardboard or stiff paper
  - pennies
- Handout 2: Power Optimization (half sheet), one per student

Day 2

- Devices with Internet access, at least enough for half the class
- Cargo Air Vehicle Outdoor Flight video, to project
- Handout 3: CAV Research and Humanitarian Aid, one per student
- Handout 4: CAV Aid Proposal (half sheet), one per student
- Notebook paper, at least one sheet per student

Have you ever wondered…

What is Boeing's Cargo Air Vehicle (CAV)?

The Boeing CAV is a drone. It is also an electric vertical takeoff and landing (eVTOL) unmanned aerial vehicle (UAV) designed to carry a payload of up to 500 pounds. It can carry this amount of weight thanks to an electric propulsion system powered by six dual rotor systems and 12 propellers. It is 17.5 feet long, 20 feet wide, five feet tall, and weighs 1,100 pounds. The CAV is currently still in its testing phase, but it has demonstrated the ability to take off, hover, fly forward, and land.[1]

How does the CAV differ from other drones?

Most delivery drones, including ones used by companies such as Amazon or those used for medical supplies, are designed to carry small loads and packages. Boeing's CAV, while it has the same functionality of a drone in its ability to take off, hover, fly, and land, is unique in the amount of weight that it is able to carry. As Boeing Chief Technology Officer Greg Hyslop said upon unveiling the CAV prototype: "This flying cargo air vehicle represents another major step in our Boeing eVTOL strategy. We have an opportunity to really change air travel and transport, and we'll look back on this day as a major step in that journey."

Make Connections

How does this connect to students?

Drones are changing the landscape in commercial and nonprofit sectors. So far, they are credited with being able to "increase work efficiency and productivity, decrease workload and production costs, improve accuracy, refine service and customer relations and resolve security issues."[3]

As drones change the world around us, universities are beginning to offer training and resources to help students investigate drones—including how they can be used for social good. In 2018, the University of Southern California began conducting the country's first college course in using drones for public health. The course explores how drones are currently used, as well as models for success and their potential.[4]

As drone technology advances and they become more and more integrated into different aspects of daily life, it is important for students to understand their functionality, how they already help society, and how they may impact the future.

How does this connect to careers?

Aerospace Engineer: Aerospace engineers design aircraft, spacecraft, drones, and satellites. These engineers have specific standards and goals that their designs must meet depending on the industry that their design will service.

Software Engineer: Software engineers develop software and systems for everything from games and business applications to drone operating systems. They work with others to determine their software needs, and then they design, develop, and test their system according to the user's specifications.[5]

Public Health Professional: Public health professionals develop and analyze programs that protect the health of individuals around the world. They may work for federal, state, local, private, or non-governmental organizations focusing on a wide range of issues, including those in which drones could be used—such as emergency preparedness, disaster response, remote healthcare, and more.

How does this connect to our world?

The uses of drones in today's world is ever-expanding. While their commercial potential is huge, it's also important to note the ways in which drones can make a difference. UNICEF, for example, segments the potential of drones into four main categories: transport efficiency, supply chain management, rapid response in emergencies, and medical diagnostic kits—all of which will help UNICEF better care for children in remote areas around the world.[6]

Public health experts and people involved in humanitarian aid are now using drones to deliver supplies (medical and otherwise) to remote areas and monitor disaster-stricken areas.

For instance, a company called Zipline uses drones to deliver medical supplies and products to remote areas around the world, flying over 25,000 miles each day from various global distribution centers.

Governments are also beginning to recognize drones' humanitarian potential. In 2017, the government of Malawi, in partnership with UNICEF, launched the world's largest flight-testing area dedicated especially to development and humanitarian uses. Norway is testing how drones can be

used to quickly get defibrillators on the scene, and Nepal has used drones to get an aerial view of disaster areas in order to help search and rescue operations.[4]

These are just a few examples of how drones can be used for global good. As they become more powerful and autonomous, their uses will only continue to evolve and grow.

Sources

1 "Watch: Cargo Air Vehicle Completes First Outdoor Flight." boeing.com/features/2019/05/cav-first-flight-05-19.page.

2 "Boeing Autonomous Passenger Air Vehicle Completes First Flight." boeing.mediaroom.com/2019-01-23-Boeing-Autonomous-Passenger-Air-Vehicle-Completes-First-Flight.

3 "Drone technology uses and applications for commercial, industrial and military drones in 2020 and the future." Business Insider. businessinsider.com/drone-technology-uses-applications.

4 "Drones that Save Lives? Meet humanitarian aid's newest tool." USC News. https://news.usc.edu/143636/drones-humanitarian-aid-can-save-lives-usc-experts-online-class.

5 "Learn About Being a Software Engineer." Indeed Careers. indeed.com/career-advice/careers/what-does-a-software-engineer-do.

6 "Drones." UNICEF. unicef.org/innovation/drones.

7 Zipline. flyzipline.com.

Blueprint for Discovery

DAY 1

1. Begin the class session by welcoming students to Boeing's Global Engagement team. Explain that the goal of the team is to strengthen ties between Boeing and communities—both locally and globally. Tell the class that over the course of the next few class sessions, they will be considering how Boeing could help deliver aid to communities in need.

2. Explain that Boeing has decided to focus on vehicles with rotors and propellers, such as helicopters, as they consider how to deliver aid.

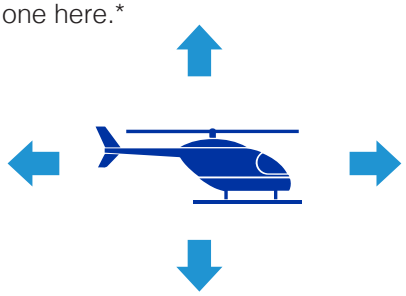
   Ask students: Why may these kinds of vehicles be better for accessing communities in need?

   Explain that vehicles with rotors and propellers can be much more useful in remote areas because they don't need a long runway to take off and land. Instead, they can rise straight up and then lower straight down. This means they can access just about anywhere!

3. Tell the class that in order to gain a better understanding of these kinds of vehicles and how they fly, student groups will spend the first part of the session constructing their own helicopter. Prepare students for the activity by performing the following steps:

- Divide students into teams of four.
- Distribute one *Handout 1: Build a Helicopter* to each student.
- Review the directions provided on the handout.
- Show students where they can find the materials needed for the activity.
- Explain that they will have about 20 minutes to follow the instructions and complete the activity with their groups.
- Answer students' questions as needed, and then encourage groups to begin!

4. Rotate around the classroom as students work and provide assistance as needed. When 15 minutes have passed, provide a five-minute warning.
5. Then bring the class back together, and call on a few groups to demonstrate how their helicopter works. As groups share, ask them to describe how/why they believe their helicopter is able to stay in the air.
6. After two or three groups have shared their helicopters, draw a diagram on the board or a piece of chart paper that similar to the one here.*



*Note: Keep this diagram in a safe place so it can also be referred to next class session.

7. Help student understand the forces of flight by discussing the following:
    - Point to the downward-facing arrow and ask students: What force is pulling down on the helicopter at all times? Call on a student to share their thoughts, and then explain that weight, which is the force of gravity, pulls the helicopter down toward the center of the Earth. Write "weight" under the downward-pointing arrow.
    - Next, point to the upward-facing arrow and write "lift." Explain that lift is the force that causes a flying object to rise into the air and stay there. Lift must overcome the weight of the flying object and the downward force of gravity. Ask students: What created lift in your helicopter? Be sure students understand that the rotating blades created lift and helped their helicopter rise off the ground.
    - Then point to the forward-facing arrow and label it "thrust." Ask students to demonstrate with a head nod or shake whether their helicopter moved forward. Explain that, while their helicopters were not able to, actual helicopters can move forward thanks to their engines. Engines produce thrust, which is the force that propels the vehicle forward.
    - Finally, point to the backwards-facing arrow and label it "drag." Explain that drag is a force that acts against the direction of motion, and it is caused by air resistance. In order for a helicopter to fly, the thrust must overcome the drag.
8. Then shift the discussion to the helicopter's power. Ask: Where did your helicopter get the energy it needed to create lift, or stay in the air, while holding the penny?

    Be sure students understand that the helicopter's energy was stored in the rubber band as potential

(or stored) energy, which then converted to kinetic energy (or energy of motion) as it rotated, turned the propeller, and created lift.

9. Wrap up the class session by challenging students to consider how they would change the design of their helicopter if they wanted it to be capable of achieving greater lift and carrying a heavier load.

   Distribute one *Handout 2: Power Optimization* to each student, read the instructions aloud, and encourage the class to work on their sketches until the end of the class session. When the session is complete, you may either collect the students' work or ask them to save it in a safe place so they can refer to it when you see them next.

DAY 2

1. Begin the session by welcoming students to the second day of their new job on Boeing's Community Engagement team. Explain that now that they have a basic understanding of the fundamentals of helicopter flight, they are going to learn more about a recent Boeing innovation *and* consider the role it may be able to play in delivering aid to communities in need.
2. Tell the class that you are going to share a video clip of one of Boeing's most recent innovations. As they watch, they should observe how the vehicle appears to achieve lift and thrust. Then show the Cargo Air Vehicle Outdoor Flight video.
3. When the video is complete, encourage students to share their observations. Ask:
   a. At first glance, how is this vehicle different from the helicopter you built during the first class session?
   b. Does this vehicle have anything in common with your helicopter or the optimized helicopter that you sketched?
4. Once students have shared their observations, tell the class that the vehicle in the video is called a Cargo Air Vehicle or CAV. In other words, it is a drone designed to carry cargo or heavy loads.

   Tell the class that, as members of the Global Engagement Team, they are about to start their first real assignment: With a "coworker," they will research this CAV in order to develop a proposal for the United Nations* that explains how the CAV could benefit a cause of their choice. Their proposal must: 1) Explain how the CAV functions and 2) Describe how it could be used to effectively deliver aid.

   *If needed, explain that the United Nations is an international organization committed to promoting and maintaining peace, social progress, human rights, and decent living standards around the world.

   - Divide students into pairs and distribute one *Handout 3: CAV Research* and *Humanitarian Aid* to each student. Then prepare the students for the work session by completing the following steps:
     - Explain that the class session will be divided into two parts: research and proposal writing.
     - Review the directions provided on Handout 3.
     - Explain that students should spend about half of the class period on this research. When they are done, they should raise their hand to let you know they are ready for the next step.
     - At this point, you will give them *Handout 4: CAV Aid Proposal*. After reading the directions carefully, they may work individually or with their partner to write their aid proposal.
5. Once you have answered any student questions, encourage students to begin. When the class session is about halfway over, distribute *Handout 4: CAV Aid Proposal* to any students who have not yet started it and encourage them to begin this next step.
6. Give students a five-minute warning when there are 10 minutes left in the session.

7. When there are five minutes left in the class session, reassemble the community engagement team. Ask each pair to briefly share the cause they selected and explain how the CAV could effectively be used to help.

   Then wrap up by thanking the students for their hard work. Encourage them to remember the activity that they completed today and always question how innovations can be used to help the greater good.

Extend

Students can perform Internet research about organizations that are using drones to deliver aid. After learning more about the drones that these organizations are using, students can consider if any optimizations could be made to the CAV to help it deliver aid to their cause more effectively or efficiently.

National Standards

Next Generation Science Standards

Forces and Interactions

- MS-PS2-2: 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.
- Disciplinary Core Idea:
  - PS2.A: Forces and Motion: The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

Energy

- Disciplinary Core Ideas:
  - Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1)
  - A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)

Common Core State Standards for English Language Arts

- CCSS.ELA-LITERACY.CCRA.SL.4: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.
- CCSS.ELA-LITERACY.CCRA.W.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Design a Helicopter

Directions: Your goal is to design and construct a helicopter that can hover in the air for at least three seconds while carrying a penny! The steps below will guide you through the building process, but think of these steps as suggestions. You may follow each step or you can make changes if you have other ideas.

Suggested Steps

1. Read through all of the steps below once.
2. Then visit youtu.be/DwHyk4V2w5Y to watch the steps in action before you begin. As you build, refer back to the video if you have any questions.
3. Design and cut out the body shape of your helicopter from a piece of thick paper.
4. Bend a paperclip so the small inner part bends out 90 degrees from the larger outer part, like an "L." The paperclip should now form the shape of an "L."
5. Tape the outer part of the paper clip to one end of a popsicle stick. The small inner part of the paper clip should still bend outward like a hook. *(Video Demo: 38 seconds)*
6. Tape the body of your helicopter to the stick at the same end as the paperclip. The other end of the stick should stick out about 2 inches from the helicopter's body. *(Video Demo: 46 seconds)*
7. Attach the penny to the helicopter near where the stick meets the bottom of the body. You don't want the penny to change the balance of your helicopter, so think carefully about where you place it. *(Video Demo: 1 minute 2 seconds)*
8. Grab your propeller and loop the rubber band through its hook. *(Video Demo: 1 minute 10 seconds)*
9. Attach the propeller to the other end of the stick. *(Video Demo: 1 minute 18 seconds)*
10. Loop the rubber band that is on the propeller hook through the paper clip too. *(Video Demo: 1 minute 22 seconds)*
11. Spin the propeller so the rubber band twists and tightens. This may take 50 or more turns! *(Video Demo: 1 minute 26 seconds)*
12. To fly the helicopter, hold the propeller with one hand and hold the other end of the helicopter with your other hand. Let go of the propeller first, and then wait about two seconds before letting go of the helicopter's body. *(Video Demo: 1 minute 53 seconds)*
13. If you have time, experiment to see:
    - What happens if you hold on to the helicopter's body for longer?
    - What happens if you let go of the helicopter's body first?

Power Optimization

Directions: Imagine that you wanted your helicopter to transport something heavier than a penny. In order to do this, it must have more lift than it does now. What could you change about your helicopter's design to achieve more lift? Sketch a new design below.

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CAV Research and Humanitarian Aid

Part 1: CAV Research

Background: A drone is any kind of aircraft or spacecraft that does not have a pilot. Boeing's CAV, or Cargo Air Vehicle, is a drone. In technical terms, the CAV is also called an electric vertical takeoff and landing (eVTOL) unmanned aerial vehicle (UAV).

The CAV has several qualities that make it stand out from other drones and eVTOLs. These unique qualities also make it better suited to provide aid to areas in need.

Directions: Review the sources below to learn more about the development of the CAV from 2018 to today. Then answer the research questions.

- 2018: youtube.com/watch?v=EWQdWUtKSro
- 2019: boeing.com/features/2019/10/cav-flight-testing-10-19.page
- 2020: boeing.com/features/highlights/2020/cargo-air-vehicle

Research Questions:

How is the CAV powered? (For instance: Is it solar-powered, battery-powered, fuel-powered, etc.)

How large is the CAV?

How does it create lift?

What qualities make the CAV unique from other drones?

Which of these qualities may also make it well-equipped to deliver aid to communities in need?

CAV Research and Humanitarian Aid

Part 2: Humanitarian Aid

Directions: Now that you know how the CAV functions, complete the steps below to find a cause that you believe could benefit from the CAV's assistance.

1. Visit news.un.org/en/news/topic/humanitarian-aid and review some of the causes around the world that could benefit from aid. As you do, consider if the CAV could help provide some of this assistance.
2. Select one cause that you believe the CAV could best assist, and reread the summary on the UN website. You may also perform brief additional research about the cause, if needed. Then write a summary of the problem and what kind of aid this cause needs.

3. Next, jot notes below as you consider the following:
    - How could the CAV help the cause you describe above?
    - What exactly would the CAV do? What would it be responsible for?
    - Why is the CAV well-designed to provide this assistance?

CAV Aid Proposal

STUDENT HANDOUT 4

On a piece of lined paper, write a proposal letter addressed to the United Nations. The goal of your letter is to introduce the CAV the United Nations and explain how and why it could help solve a humanitarian problem.

- Introduce yourself and your profession
- Introduce the CAV, including:
    - What is it?
    - How does it work?
    - What makes it unique?
- Describe the cause you have identified, including:
    - Where is it?
    - What kind of help is needed?
- Clearly explain and illustrate how the CAV would be able to help.
    - Include a labeled sketch in your proposal to support your explanation
- Include any additional information that you may need before you can prepare the CAV to help this cause.

CAV Aid Proposal

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