Flight Controls for Unmanned Aircraft

Session Time: One, 50-minute session

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The principles of aerodynamics allow an aircraft to fly, yet those same principles limit its ultimate performance and capabilities. (EU2)

A deep understanding of how an aircraft operates enables a pilot to fly the aircraft to its maximum capabilities in both normal and abnormal situations. (EU5)

ESSENTIAL QUESTIONS

1. How have the flight controls of unmanned systems evolved from manned systems?
2. Do unmanned systems still need a human in the loop to operate? Why?

LEARNING GOALS

Students Will Know

- The processes that must be handled by technology in the absence of a pilot
- How to control a multirotor unmanned system around the three axes of flight
- The relationship between the flight controls and the stability of a multirotor system

Students Will Be Able To

- *Identify* the flight control components of a UAS quadcopter. (DOK-L1)
- *Explain* the actions of a quadcopter's motors that cause it to move. (DOK-L2)

ASSESSMENT EVIDENCE

Warm-up
Students will activate prior knowledge from previous lessons and explain what a flight control system must provide in an unmanned aircraft.

Formative Assessment
Students will identify parts of a quadcopter controller, as well as the axes represented by each direction on the left and right controllers.

Summative Assessment
Students will analyze changes in rotor speed to predict how a drone will maneuver and they will predict the resulting movement of a drone if two of the motors spin faster than the other two.

LESSON PREPARATION

MATERIALS/RESOURCES

- Flight Controls for Unmanned Aircraft Presentation
- Flight Controls for Unmanned Aircraft Student Activity 1
- Flight Controls for Unmanned Aircraft Student Activity 2
- Flight Controls for Unmanned Aircraft Teacher Notes 1
- Flight Controls for Unmanned Aircraft Teacher Notes 2
- Flight Controls for Unmanned Aircraft Teaching Aid

Drone Flying Challenge! Activity (one per class)

- Quadcopter drone and controller (with standard controls if possible) - drone options provided in Unit 2, Section A, Lesson 2
- 2 hula hoops (optional)

LESSON SUMMARY

Lesson 1 - Primary Flight Controls
Lesson 2 - Secondary Flight Controls
Lesson 3 - Flight Controls for Unmanned Aircraft

This lesson begins with a discussion of the role of pilots in controlling aircraft. Students will think about what functions a computer would need to perform in order to control an unmanned aircraft. They will then examine how unmanned quadcopters are controlled.

Students will learn about the parts of a quadcopter and how these parts contribute to flight. In a formative assessment, students will identify the parts of a quadcopter controller.

Next, students will learn how a quadcopter maneuvers in the absence of conventional flight control surfaces, with a detailed discussion of how the electronic components interact with each other to provide maneuverability. A summative assessment will have the students look at diagrams of a quadcopter and predict how it will move based on changes to the rotor speeds.

If time allows and if a quadcopter is available, students will take turns flying a drone using a standard controller and the control inputs they have learned in this lesson.

As a summative assessment, students should recall what they have learned about how the rotors of a quadcopter generate lift and maneuver a drone. They will analyze changes in rotor speed to predict how a drone will maneuver. A final question asks students to predict the result if two of the motors spin faster than the other two.

BACKGROUND

Unmanned aircraft or drones come in two basic designs: fixed-wing and rotary. Flight controls on large military drones and small fixed-wing drones are very similar to those found on manned aircraft. The main difference is that the pilot controlling the aircraft is at a remote location on the ground instead of in the aircraft.

Rotary drones rely on variable-speed propellers to allow them to maneuver in all three axes of motion. The operator commands a direction of motion, and the software working inside the device speeds up or slows down the appropriate blades, thus allowing the platform to move as commanded. The most common rotary drone seen today is the quadcopter, available for both recreational and commercial/industrial applications. This design has proven to be the most stable and versatile rotary design.

The methods used to control quadcopters are very different from those used to control helicopters. Where helicopters control movement by varying the pitch angles of the rotor blades, the quadcopter features four fixed-pitch rotors arranged in a symmetrical pattern around the frame. Each rotor has its own motor. To change the amount of lift being produced by a rotor, its speed is altered. By changing the speed of different combinations of rotors, the pilot can turn or tilt the quadcopter to make it move in the desired direction. Since a pilot can't feasibly monitor four separate motors, the motors are controlled by a computer that translates the directional commands being given by the pilot into movement of the rotors.

The precise commands necessary to stabilize and maneuver a rotary drone require small computers, gyroscopes and motors. The fact that these have only recently become widely available helps account for the exploding numbers of capable, low-cost drones.

MISCONCEPTIONS

Students may assume that flying a drone is similar to flying an airplane or helicopter, where the pilot is required to make constant control inputs to maintain stability in flight. In fact, many drones have built-in auto-stabilization which reduces pilot workload and makes the drone easier to fly.

DIFFERENTIATION

To support student comprehension of new information in the **EXPLORE** section, provide an actual quadcopter and sticky notes for students to label the parts. This will allow students to better understand the structure of new information and also connect working and long-term memories.

To support learning in the **GOING FURTHER** section, model for students the best practices and safety considerations that should be followed for flying the drone. Walk through the process and verbalize your thoughts and demonstrate what learners are expected to do when operating the drone.

LEARNING PLAN

ENGAGE

Teacher Material: Flight Controls for Unmanned Aircraft Presentation

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up.**

Warm-Up

Students will activate prior knowledge from previous lessons and explain what a flight control system must provide in an unmanned aircraft. Divide the class into pairs and present the following question.

- A manned aircraft relies on a pilot's inputs for completing its mission. But what if the aircraft is unmanned? With a partner, discuss and write down what a flight control system must provide when a pilot is not board an aircraft.

Give students several minutes to determine their answers. Lead a class discussion and ask each pair of students to provide at least one item a flight control system must provide when a pilot is not board an aircraft.

[DOK-L2; *explain, predict*]

Questions

What must a flight control system provide when a pilot is not on board an aircraft?

Answers could include: Ensure the aircraft's safety, maintain control and stability, navigate the sky and around obstacles, monitor systems like fuel or battery power available, maintain a real-time radio communication link, complete the mission or objective of the flight

EXPLORE

Teacher Material: Flight Controls for Unmanned Aircraft Presentation

Slide 5: To follow-up on the warm-up discussion, review some of the tasks that a pilot does while controlling an aircraft.

Ensures safety - The most important job of a pilot is to maintain the safety of the aircraft and flight crew, as well as the safety of those on the ground. The pilot maintains separation from other aircraft and objects in the sky. The pilot also avoid dangers such as weather, terrain, and obstructions that can increase flight risks.

Maintains positive aircraft control - Part of ensuring the safety of the aircraft involves maintaining positive aircraft control during all flight conditions. The pilot responds to changing conditions, such as wind or turbulence, by modifying control inputs to ensure that the aircraft flies within its limitations and along the desired flight path.

Navigates - It is the pilot's responsibility to get the aircraft from one point to another, taking into account such factors as terrain and obstacles, controlled and prohibited airspace, and weather.

Monitors systems - A pilot monitors aircraft systems to ensure that everything is operating as expected, such as fuel quantity, engine operating temperature, performance information, and electrical load and voltage.

Makes mission-related decisions - While on a mission, the pilot of an aircraft makes decisions to ensure completion of the mission. On a surveillance mission, for example, the pilot maneuvers the aircraft to maintain contact with the subject.

Handles contingencies - An aircraft can encounter many unexpected events during a mission, such as changing weather or mechanical failure. In these cases, a pilot makes decisions about how to best handle the contingencies in the safest manner.

Communicates with the ground - In controlled airspace, an aircraft needs to maintain communication with the ground. When landing, for example, it is the pilot's responsibility to coordinate with air traffic control to ensure that the aircraft has clearance to enter airspace or land.

Slide 6: Unmanned aircraft do not have on-board pilots. Discuss with students how an unmanned aircraft handle all the tasks that pilots would traditionally do.

Explain that some of the work can be handled automatically by a computer. For example, many drones have systems on board that can track the GPS position of a drone and maintain its position without any human intervention. This lets the drone hover automatically.

Other tasks can be handled by a remote pilot. A remote pilot on the ground can manipulate controls whose commands are transmitted to the aircraft.

EXPLAIN

Teacher Materials: Flight Controls for Unmanned Aircraft Presentation, Flight Controls for Unmanned Aircraft Teacher Notes 1
Student Material: Flight Controls for Unmanned Aircraft Student Activity 1

Slide 7: Students learned the difference between a UAS and a UAV is the first unit. Ensure that students remember that the acronym UAS stands for "unmanned aircraft system." The term UAS involves all of the components that are involved in the flight of an unmanned aircraft, including the aircraft itself and its control system. The control system includes communication datalinks, controllers, sensors, and the human operator. The term drone, or unmanned aerial vehicle (UAV), refers to the unmanned aircraft itself. Emphasize that a UAV is part of a UAS.

Slide 8: Introduce the flight controls on unmanned aircraft. Flight controls on large military drones, such as the Predator and Reaper, are very similar to those found on manned aircraft. Small fixed-wing UAVs also have flight controls similar to those of manned aircraft. The main difference is that the pilot controlling the aircraft is at a remote location on the ground instead of in the aircraft.

The flight controls on multi-rotor UAVs, on the other hand, are very different. This is primarily because these UAVs use different control surfaces from those found on other aircraft. The design of these control surfaces make the aircraft inherently unstable and requires the assistance of computers.

In a typical quadcopter, the four rotors, each of which can be controlled individually, are the control surfaces. (We'll get more deeply into how they work a little later.) Because the forces exerted by the four individual rotors must exactly balance each other to maintain the stability of the aircraft, it would be difficult for a human pilot to effectively control the motors directly. Instead, the pilot uses the controller to issue instructions that are processed by onboard computers that, in turn, control the motors. These systems are similar to "fly-by-wire" systems that are found on the most large, modern aircraft. The pilot inputs the command for the desired movement, and the computer adjusts the control surfaces as necessary to achieve that movement. As a result, these multi-rotor drones are a technological innovation made possible by microprocessors, solid state gyroscopes and accelerometers, and brushless motors.

Teaching Tips

Brushless motors, in particular, help improve the performance of multi-rotor UAVs. Brushless motors consist of three or more coiled electromagnets. Permanent magnets are placed on the rotor. A computer controls the flow of current through the electromagnets one after another, driving the rotor to turn. Because brushless motors are controlled by current regulated by a computer, they can be operated more precisely and efficiently.

Slide 9: Most drones are controlled using radio-based controllers. Understanding a drone's position is vital to controlling it properly. Pilots of small drones operated within line of sight can simply look at the drone to understand its position. When a drone is operated from a greater distance, beyond the pilot's line of sight, the drone must transmit data back to the pilot and control station so they have the information necessary to understand the drone's position and control it. Sometimes video is transmitted from the perspective of the drone cockpit. This method, known as "first person view" (FPV), is the method used for drone racing.

Whether the drone is controlled by external viewing or FPV, certain functions, such as stability, can be provided by computers on board the drone.

The ground controller must normally stay in radio contact with the drone at all times. If the ground controller is close to the drone, WiFi or bluetooth radios can be used to maintain the communications link. If the ground controller is far away, more powerful radio signals are required. For example, unmanned military aircraft operated by the U.S. Air Force can use satellite links so that controllers on the ground in the United States can fly missions throughout the world.

Because these radio signals can sometimes be unreliable, all drones must have some sort of backup system in case communications fail. Usually, this means that the drone will either land itself and cease operations, or will return to the base until communications can be reestablished.

Review the standard joystick controller layout for rotary drones using the illustration on the slide.

Roll – Push the right stick to the left or right. Rolls the quadcopter, which maneuvers the quadcopter left or right.

Pitch – Push the right stick forwards or backwards. Tilts the quadcopter, which maneuvers the quadcopter forwards or backwards.

Yaw – Push the left stick to the left or to the right. Rotates the quadcopter left or right. Points the front of the quadcopter different directions and helps with changing directions while flying.

Throttle – To increase, push the left stick forwards. To decrease, pull the left stick backwards. This adjusts the altitude, or height, of the quadcopter.

Teaching Tips

Many drone remotes allow the user to customize what each stick and button does. For the purpose of this course, industry standard control configurations are used. If flying drones in the classroom with students, refer to the individual user control instructions for the available drone.

Slide 10: Students learned in the first unit that quadcopters are drones with four rotors that provide both lift and aerodynamic control. These are a popular design for drones, and they can be widely seen in operation. Quadcopters have very similar internal components.

Flight controller - This is the on-board computer of a quadcopter. It is responsible for translating the flight commands from the ground controller to changes in motor speed that determine the flight path of the drone. The flight controller also usually contains gyroscopes, accelerometers, and barometers that help determine the aircraft's position, direction, and stability. Because quadcopters are inherently unstable, the flight controller contains algorithms that automatically adjust the motors to keep the aircraft level, based on these sensors.

Power distribution board (PDB) - This component distributes power from the battery to all of the electric components of the aircraft. The flight controller, motor, and electronic speed controllers all require electricity to operate. In addition, if the quadcopter is carrying electronic payloads such as cameras, these would also be connected to the power distribution board.

Global positioning system (GPS) - The onboard GPS receiver determines the position of the aircraft. The GPS module is integrated with the flight controller and provides the drone's location. This data can be relayed to the ground controller so that the controller knows where the drone is flying. This data can also be used by the flight controller to know when the aircraft moves into restricted flying areas.

Battery - The battery is responsible for supplying electric power to the drone. Drones require lightweight but energy-dense batteries. Lithium polymer batteries are the most popular type of batteries because they are rechargeable and can have expansive discharge rates so they can turn the motors very quickly when needed.

Electronic speed controllers (ESC) - These control the rate at which the motors spin based on the commands of the flight controller. Each motor is connected to an electronic speed controller, which is connected to the flight controller. Because each motor is connected to a separate ESC, each motor can turn at different rates, allowing the aircraft to turn and accelerate as needed.

Radio - The radio allows the ground controller to communicate with the drone. The radio needs to operate on at least four channels because the controller needs to control throttle, left and right, forward and back, and yaw. More channels are required for additional functionalities, such as transmitting aircraft location and status.

Slide 11: Quadcopters also possess very similar external components.

Propellers - The rotor blades are the primary lifting surface for the drone. They can spin at different speeds to allow the drone to be maneuvered.

Motors - The motors provide the force that enable the quadcopter to fly. They convert the electrical energy of the battery to mechanical energy that turns the propellers. The motors on the quadcopter are controlled by the electronic speed controller that determines how quickly the motors turn.

Camera - The camera is capable of sending live images back to the operator. From this perspective, the operator can see what the drone sees. The camera can also capture still photos or flight video via commands from the operator's controller.

Antenna - The antenna receives commands from the operator's controller and transmits those commands to the flight controller. The antenna also transmits information back to the operator, such as altitude, airspeed, and position. Oftentimes, the antenna is located inside the drone body. In the case of the drone on the slide, the antenna is located inside the landing gear.

Landing gear - The landing gear allows the drone to takeoff and land without causing damage to the camera, engines, and rotors. In the event of a hard landing, the landing gear takes the brunt of the impact to offer protection to the drone itself.

Slide 12: Complete the **Formative Assessment**.

Formative Assessment

Students will identify parts of a quadcopter controller, as well as the axes represented by each direction on the left and right controllers.

Provide each student with **Flight Controls for Unmanned Aircraft Student Activity 1**. Students will identify parts of a quadcopter controller. Answers are included in **Flight Controls for Unmanned Aircraft Teacher Notes 1.**

[DOK L1; *label*]

EXTEND

Teacher Materials: Flight Controls for Unmanned Aircraft Presentation, Flight Controls for Unmanned Aircraft Teaching Aid

Slide 13: Quadcopters, like all aircraft, are controlled by altering the forces of flight. In the case of a quadcopter, lift and thrust are manipulated to change the altitude and direction of the vehicle. The same principles of physics that govern flight in airplanes and helicopters govern the flight of unmanned aircraft. The lift required to fly a quadcopter relies on Bernoulli's principle. The rotors on the quadcopter behave as rotating airfoils (like a helicopter rotor) to generate lift.

However the configuration of a quadcopter means some of the forces involved affect the aircraft differently. For example, because a quadcopter has four rotors that sit on opposite sides from each other and spin in opposite directions, the torque forces cancel out.

As students learned in the second unit, a multirotor uses counterrotating propellers to counteract the twisting motion of torque. For example, a fourmotor quadcopter has two clockwise and two counterclockwise rotating motors. A clockwise spinning motor twists the drone in a counterclockwise motion, while a counterclockwise spinning motor does the opposite. On a multirotor, pairs of motors spinning in opposite directions cancel the effect of torque on the drone when they are running at equal power.

Multirotor drones can move horizontally by tilting their rotors so that the thrust is created in a diagonal direction. That way some of the thrust is creating lift upwards and some of the thrust is creating a forward push. Drones are tilted by decreasing the thrust on one side (causing it to descend slightly) and increasing thrust on the opposing side (causing it to climb slightly). Power is then stabilized in the motors and the forward or sideways tilt can be maintained and horizontal motion achieved.

Show students the following video on how the motors of a quadcopter adjust to achieve each movement.

- "How Do Quadcopters and Multicopters Fly?" (Length 6:25)
  http://video.link/w/SH5e

Teaching Tips

Many drone remotes allow the user to customize what each stick and button does. For the purpose of this course, industry standard control configurations are used. If flying drones in the classroom with students, refer to the individual user control instructions for the available drone.

Slide 14: Proceed through the next several slides to explain how to control a quadcopter.

For a quadcopter to hover, all four rotors must provide the same amount of upward thrust to overcome weight. According to Newton's First Law, since there is no net force on the drone, it will act as an object at rest and will stay at rest. For level hovering in calm air, all four rotors turn at the same speed. There is no lateral motion since all four blades are turning at the same speed and directing their force straight downward to overcome the quadcopter's weight. If they provide the right amount of thrust, but it is unequally distributed among the blades, the quadcopter will yaw. If they all provide the same thrust but it is too much, the quadcopter will climb. If they all provide the same thrust but it is too little, the quadcopter will descend. Because of the precision involved, the operator needs to rely on the onboard flight controller to equalize the required thrust. From an operational standpoint, this typically means centering the controls on the controller.

More advanced systems feature gyro-stabilization. In these platforms, if something disturbs the equilibrium (e.g. light breeze, operator input), a gyroscope communicates the change, prompting the computer to send a signal to the ESCs to alter the speed on one or more of the rotors to compensate for the upsetting force and return the quadcopter to a stabilized hover.

Slide 15: The standard control input to make a quadcopter climb or descend is to push the left stick forward to climb and pull it back to descend. To alter the altitude of the quadcopter, all four rotors on the drone must increase or decrease their thrust in equal amounts. The additional lift produced by faster rotors causes the quadcopter to climb straight up and gain altitude. Once the desired altitude is achieved, the flight controller must decrease the thrust to stop the climb. Once the velocity of the drone reaches zero, the flight controller can go back to maintaining the hover. Level descending flight works much the same way, except that the speed of the rotors is decreased to produce less lift. It is virtually impossible for a human to directly control the rotor speeds this precisely, so the ground controller relies on the flight computer to do this.

Slide 16: Changing pitch causes the quadcopter to move forward or backward. Because there is no propeller mounted to the front or back of the quadcopter, and because the rotor blades have a fixed pitch, the airframe must be tilted to generate this movement.

For a quadcopter to exhibit level forward motion, some of the rotors' force must be directed rearward; per Newton's Third Law, this creates an equal and opposite force that pushes the quadcopter forward. To achieve this effect, the forward two rotors slow, creating less lift than the back two rotors; this causes the quadcopter to tilt slightly forward (nose down). This downward tilt directs some of the rotors' force rearward, which pushes the quadcopter forward.

Increasing this downward tilt at the front increases the rearward force vector and with it the quadcopter's speed. However, something else happens at the same time. Because the front two rotors slow to produce the downward tilt on the frame, the total lift produced by the rotor system decreases. Left unchecked, this would result in the quadcopter descending. To offset this imbalance and keep the quadcopter in level flight, the back two rotors must speed up, creating enough additional lift to counteract the loss of lift at the front two rotors.

Level backward motion works in exactly the same way as level forward, except that the back two rotors slow; this causes the back of the quadcopter to tilt downward and ultimately pushes the aircraft rearward. The standard control input for these movements is pushing the right stick forward or back.

The section of the video "How Do Quadcopters and Multicopters Fly" from 1:30 to 2:52 illustrates these concepts.

Slide 17: Roll is the movement of the quadcopter either to the left or the right. Because a quadcopter is symmetrical, moving left and right is essentially the same as changing pitch, except a different set of rotors are tilted. Slowing the left two rotors will cause the aircraft to roll to the left, and the direction of flight will change 90 degrees.

The standard control input for these movements is pushing the right stick to the left or right.

The section of the video "How Do Quadcopters and Multicopters Fly" from 0:39 to 1:29 illustrates these concepts.

Slide 18: Yaw rotates the quadcopter either clockwise or counterclockwise. Note that this is different from roll because the quadcopter stays over the same place while rotating. To rotate the quadcopter, the front-left and back-right rotors will rotate in one direction while the front-right and back-left rotors will rotate in the opposite direction. The rotors moving in opposite directions will provide equal but opposite lift forces that cancel each other out. This means that the altitude of the quadcopter will not change. However, because the angular momentum of the four rotors is no longer balanced, the aircraft will rotate, changing the direction of flight.

The standard input for these movements is pushing the left stick left or right.

The section of the video "How Do Quadcopters and Multicopters Fly" from 2:53 to 5:04 illustrates these concepts.

Teaching Tips

It may be difficult for students to visualize the movement of the rotors of a quadcopter during flight. If students are flying a quadcopter, they can use slow motion video to record the drone during flight. This will show that the opposite rotor pairs turn in opposite directions and that the speed of the rotors changes to allow the drone to maneuver.

Slide 19: If time allows and if a quadcopter is available, have students take turns flying a drone using a standard controller and the control inputs they have learned in this lesson. Before flying, reference the "Know Before You Fly" website for safety information. Take proper precautions as to flying venue, location of obstacles, and positioning of students and observers.

Refer to **Flight Controls for Unmanned Aircraft Teaching Aid** for instructions for this flying activity. The activity describes three different flying challenges: flying point-to-point, flying in a square, and flying in a circle.

EVALUATE

Teacher Materials: Flight Controls for Unmanned Aircraft Presentation, Flight Controls for Unmanned Aircraft Teacher Notes 2
Student Material: Flight Controls for Unmanned Aircraft Student Activity 2

Slide 18: Conduct the **Summative Assessment.**

Summative Assessment

In this activity, students should recall what they have learned about how the rotors of a quadcopter generate lift and maneuver a drone. They will analyze changes in rotor speed to predict how the airframe will move. A final question asks them to predict the result if two of the motors spin faster than the other two.

Provide each student with a copy of **Flight Controls for Unmanned Aircraft Student Activity 2**. Answers are included in **Flight Controls for Unmanned Aircraft Teacher Notes 2.** This assessment may be given to students as homework if time is limited.

Summative Assessment Scoring Rubric

Follows assignment instructions

Writing shows evidence of the following:

An understanding a drone flight control and stabilization systems

An assessment of how the flight control system works with the propeller

Student work shows overall understanding of the concepts covered in the lesson

Points	**Performance Levels**
9-10	Student responses show a clear understanding how changes in rotor speed impact the movement of a quadcopter.
7-8	Student responses show a sufficient understanding how changes in rotor speed impact the movement of a quadcopter with minor gaps in understanding.
5-6	Student responses show a partial understanding how changes in rotor speed impact the movement of a quadcopter with some gaps in understanding.
0-4	Student responses show little to no understanding how changes in rotor speed impact the movement of a quadcopter.

[DOK-L2; *Explain*]

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, it mass, and its acceleration

Science and Engineering Practices

Analyzing and Interpreting data

Constructing explanations and designing solutions

Disciplinary Core Ideas

PS2.A: Forces in Motion

PS2.B: Types of Interactions

ETS1.A: Defining and Delimiting an Engineering Problem

Cross Cutting Concepts

Cause and Effect

Structure and Function

COMMON CORE STATE STANDARDS

- **RST.9-10.1** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- **RST.9-10.4** - 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 9-10 texts and topics.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.
- **W.9-10.2F** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic)

REFERENCES

http://www.droneybee.com/how-quadcopters-work/
https://www.dronezon.com/learn-about-drones-quadcopters/how-a-quadcopter-works-with-propellers-and-motors-direction-design-explained/
http://www.extendingbroadband.com/aerial-tracking/drone-communication-systems/
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