Introduction to UAS

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

UAS technology has advanced to play a key role in today's world, and the uses for UA systems, while already numerous, will continue to evolve.

ESSENTIAL QUESTIONS

1. How have drones developed over time, and how are they currently used in today's world?

LEARNING GOALS

Students Will Know

- A brief history of unmanned aerial systems (UAS), and how their technology has evolved over the years.
- Fundamental differences and similarities between the three categories of drone: fixed-wing, helicopter, and multicopter.
- The missions likely to be carried out by different UAS airframe categories.

Students Will Be Able To

- *Identify* the differences between categories of unmanned aerial systems (UAS). [DOK-L1]
- *Compare* the types of missions that might be flown by both fixed-wing and multicopter drones. [DOK-L2]

ASSESSMENT EVIDENCE

Warm-up
Students will be exposed to an overview of drone technology and applications.

Formative Assessment
Students will be queried on their knowledge of the basic types of drones and basic recall of drone technological advances over the years.

Summative Assessment
Students will be asked to demonstrate knowledge of factors that affect flight and the manner in which different drone technologies and configurations can compensate for these.

LESSON PREPARATION

MATERIALS/RESOURCES

- Introduction to UAS Presentation
- Introduction to UAS Student Activity 1
- Introduction to UAS Student Activity 2
- Introduction to UAS Teacher Notes 1
- Introduction to UAS Teacher Notes 2

LESSON SUMMARY

Lesson 1: Introduction to UAS
Lesson 2: How Drones Fly

The lesson begins with a warm-up to introduce students to basic types of drones and their applications; a video provides context, and the activity concludes with a discussion in which students are invited to suggest additional uses for drones. Students will also be introduced to different types of drones and the terminology used to describe them, including sUAS, UAV, and drone.

The lesson will then focus on the history of drone innovations and applications from the Wright Brothers era through the present. The value of unmanned aircraft will be presented and given context.

Finally, students will consider the pros and cons of fixed-wing and multicopter craft; this information will help students understand why these two main types will be the focus of future lessons. Students will also be given context on differentiation of these basic types. The lesson concludes with a summative assessment in which students demonstrate what they have learned.

BACKGROUND

Unmanned aerial vehicles (UAV)—commonly known as "drones"—were a key factor in the development of early flying experiments. They have evolved over time to include not just the flying machine itself but also an entire system of software, ground controller peripherals, and communication technology, better known as unmanned aircraft systems (UAS). UAS have changed our lives and societies in many ways, and missions that were once performed by manned aircraft have begun to be carried out by unmanned systems.

The Federal Aviation Administration (FAA) is currently writing regulations and working to stay ahead of evolving technology and safety standards due to the fact that the National Airspace System (NAS) was created for manned aircraft. While regulatory efforts are in place, integrating drone operations into the NAS in a way that enables them to operate safely and effectively without compromising national security or private interests represents an ongoing challenge.

MISCONCEPTIONS

Many people think of unmanned aerial systems (UAS) as a recent invention. It is true that their popularity has soared in recent years, but in fact drones have existed throughout most of aviation history. This lesson will explore different advancements in UAS technology over the years.

Although many people see UAS as merely toys or nuisances, they are, in fact, sophisticated aerial platforms capable of a wide range of missions and useful applications. These missions, as well as the different types of UAS that fly them, will be discussed within this lesson.

In everyday conversation, "UAS," "UAV," and "drone" are often used interchangeably. In the world of unmanned aviation, however, these terms describe specific systems and/or components, and using them appropriately is important.

DIFFERENTIATION

To support student comprehension of the differences between multicopter and fixed-wing aircraft, provide them with a copy of the Summary Comparison Chart on slide 25. Encourage students to take more specific notes on how these two categories of drones differ.

To support student comprehension of the learning objectives, create a visual wall of UAS categories and types of aircraft. Allow students to organize information they have learned in the lesson on notecards to place on the wall under the appropriate category, as well as images of various drones.

LEARNING PLAN

ENGAGE

Teacher Material: Introduction to UAS Presentation

Session 1

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

Slides 4-5: Conduct the **Warm-Up**.

Warm-Up

Many students likely already have some familiarity with drones; they may even own and fly them. Ask students whether they have any experience with drones, and—if so—what that experience entails. This will be a good way for teachers to get a handle on the level of knowledge some students might already possess.

Ask students to list some of the different applications/industries in which drones are currently used. This will get them thinking about the various ways that we currently interact with drones in the world.

Common answers will likely include the following:

- *Agriculture*
- *Infrastructure maintenance/inspections*
- *Construction*
- *Entertainment*
- *Utilities*
- *Forestry*
- *Insurance claim inspection*
- *Surveying*
- *Mining*
- *Military*
- *Public safety*
- *Delivery*

In addition to their roles in these industries, people are finding new and creative ways to use drones. The following video is an excellent example of such a mission, as a UAS is used to capture and transmit live feed during a flight over the Holuhraun volcano eruption in Iceland.

- DJI Stories – Live Broadcast From a Volcano
  https://video.link/w/OsGw (Length 3:34)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/Pav-10YEIEE

Finally, ask students how they think drones might be used to help people in the future.

Answers will vary. If students struggle to think of ideas, remind them of the current applications for drones and ask them to brainstorm how these applications might be improved.

EXPLORE

Teacher Material: Introduction to UAS Presentation

Slide 6: Drones are becoming more common every day. Even so, many people remain confused by the terminology used to identify and describe drones. What exactly is the difference between various kinds of unmanned vehicles? For example, what differentiates a "UAS" from an "sUAS" or a "UAV"? How do these terms differ from the "drone" nomenclature we so commonly see in headlines, social media, and YouTube?

Teaching Tips

Before they watch the videos, ask students as a class to define terms such as UAV, sUAS, and UAS, based on their background knowledge.

- UAV = unmanned aerial vehicle
- UAS = unmanned aircraft system
- sUAS = small unmanned aircraft system

Students should watch the following videos, which explain some of the differences between these terms:

- What is the Difference Between a Drone, UAS, SUAS, and UAV
  https://video.link/w/U2Gw (Length 1:30)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/TMX7wCbWGac

- What is a Drone? Where did the words Drone, UAV, and UAS come from?
  https://video.link/w/o6Gw (Length 0:50)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/ent5CBPFCHM

Slide 7: Explain that the FAA classifies a small UAS (sUAS) as any system that has a UAV with a takeoff weight of less than 55 lbs.

Teaching Tips

"Drone" is simply commonplace slang. It is not truly specific to any aspect of a UAS or sUAS, though colloquially it typically refers to the UAV itself.

Slide 8: Based on the information in these videos, students as a class should complete a 3-circle Venn Diagram that defines, compares, and contrasts the terms UAS, sUAS, and UAV. Then, discuss the following questions as a class. Make sure that students have a basic understanding of the differences before moving on to **EXPLAIN**.

Questions

- What is the maximum weight for the aircraft of an sUAS?
  The maximum weight of an aircraft as part of an sUAS is 54.999 lbs. Remind students that "less than 55 lbs" does not include 55 lbs.

- What is a GCS?
  GCS is an abbreviation for "ground control station," and includes the remote controller, goggles, screens, software, and any connecting wires.

- What key devices can a UAS consist of?
  A UAS consists of a GCS (which includes the controller, any goggles or screens, software, and any connecting wires), the UAV or drone, and the system of communication between them. (Variations of the GCS description are acceptable, but the "system of communication" aspect should be reiterated as a mandatory part of the UAS.)

EXPLAIN

Teacher Materials: Introduction to UAS Presentation, Introduction to UAS Teacher Notes 1
Student Material: Introduction to UAS Student Activity 1

Slide 9: Before diving deeper into the role drones play today, it is useful to look at the role they have played throughout human history. A common belief is that drones have only been around since the 21st century; while it is true that the affordability of drones has enabled consumers to take part in something that was previously inaccessible due to price, the earliest recorded use of drones can be dated to 1849.

Slides 10-11: In 1849, primitive unmanned implements were used by the Austrians to wage war. In this first recorded use of an unmanned platform, the Austrians laid siege to the city of Venice using over 200 of what they called "pilotless balloons," which carried bombs controlled by timing fuses over the city. A sketch of one of these balloon-like devices is shown on slide 10.

Accuracy issues were a factor in the Austrian operation over Venice. While one bomb did detonate over St. Mark's Square, the mission was severely hampered due to the influence of wind on the flight path and the resulting course deviation. The image on slide 11 is an artist's depiction of the event, showing the large array of Austrian balloons scattered off-target above the city of Venice.

Slide 12: In the 1890s, German pioneer Otto Lilienthal used unmanned gliders on test flights while conducting experiments for his lightweight airframes and wing designs. An important advantage of this process is that the flights did not pose a risk to human life. A downside was a lack of controllability, which limited Lilienthal's ability to test the frames and wings more dynamically. The control surfaces on Lilienthal's gliders could not be moved from the ground; consequently, his experiments involved a process similar to throwing a paper airplane.

Slide 13: In 1916, during World War I, the U.S. Navy conducted the first flight of what we would consider a modern-type drone. This machine consisted of an airframe with batteries, electrical actuators, and a mechanical 3-axis gyro stabilization unit that allowed the drone to fly in a controlled manner and carry a warhead payload. In other words, inputs from gyros were converted into magnetic signals, and those signals were used to manipulate actuators of flight controls.

Slide 14: In the late 1930s and early 1940s, World War II would prove to be a further catalyst for UAS technological advancements. Notably, the German V-1 "Buzz-Bomb," an early cruise missile and the only production aircraft powered by a pulse jet engine, utilized a barebones compass and timer guidance system that would terminate the device's rocket engine when it reached the target area.

Essentially, the V-1 was given a "heading," or direction, and then set to a timer before launch. At the end of the time allotted to reach the target, the system locked the flight control surfaces and terminated the engine, sending the V-1 into a deadfall; an impact sensor would then detonate the warhead when it struck the ground. The V-1 was produced at mass scale and would have a lasting impact on post-war UA systems.

Slide 15: From the late 1940s to the late 1960s, UAS were typically used as live-fire targets or for reconnaissance. One notable example was the Lockheed D-21. The D-21 was a long-range, ramjet-powered UAS launched from the SR-71 Blackbird or B-52 aircraft. The D-21 could fly at speeds in excess of Mach 3 and at high altitudes. It was designed to carry a single high-resolution photographic camera over a preprogrammed path, then release the camera module into the air for retrieval, after which the drone would self-destruct. These deployment capabilities made it an invaluable reconnaissance tool and steppingstone for drone innovation.

Slide 16: After 1975, following the U.S. withdrawal from Vietnam and the winding down of the Cold War, UAS technological gains experienced diminishing returns, largely due to dwindling budgets. In the 1990s, however, new technologies such as digital electronics, satellites, and GPS entered the technological landscape. These technologies are still in use today with practically all consumer drones. Microelectronics are a part of every drone no matter the price point; in mid-level consumer or prosumer models, they allow for spatial navigation, flight tracking, telemetry (flight data recording), GPS-powered stability controls, onboard autopilot computers, and predictive flight path capabilities.

Slide 17: At the turn of the 21st century, GPS-based autopiloting systems, mini-avionics, electric propulsion, and inflight reconfiguration technology led to major advancements in the UAS world. An example of this is trilateration; the following video shows how GPS uses satellites to pinpoint locations using trilateration:

- How Does GPS Work?
  https://video.link/w/c5Qw (Length 4:50)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/FU_pY2sTwTA

Teaching Tips

- Triangulation = working with angles
- Trilateration = working with distances

Slides 18-19: In today's UAS landscape, the popularity of unmanned systems has increased dramatically. As mentioned earlier, the FAA defines an sUAS as any aerial platform that weighs under 55 pounds. As manufacturing has become more widespread, drones have diversified to fill a wide variety of roles.

The key distinguishing features of a UAS are an onboard flight controller and a two-way transmission system. (This includes both remotely piloted aircraft and autonomous aircraft.) In future lessons, students will go into more depth as to the different drone components and systems. As the cost of drones (particularly sUAS) has come down, they have become affordable purchases for many.

In today's world, for example, UAS are used by real estate agents to survey properties, companies to inspect assets, farmers to inspect crops, public safety officials to perform search and rescue missions, and scientists to monitor the environment. Even first-person view (FPV) drone racing has emerged as a sport that is attracting an increasing amount of coverage, as shown in this video.

- Dunkan, Fastest Lap, Boston | Drone Racing League
  https://video.link/w/yPQw (Length 1:16)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/8C2C1E7vpMM

Slide 20: Many people use the terms "drone" or "UAV" interchangeably. As mentioned earlier, these terms may be referring to several different types of aircraft: "drone" and "UAV" are general terms that can refer to various kinds of remotely controlled aerial platform. Different categories of drone include airplane, helicopter, and multicopter (also termed multirotors, these drones have more than two rotors). The most common consumer types are fixed-wing or multirotor. The following video compares and contrasts these types.

- What is a Drone? Fixed Wing Drones vs. Multirotor Drones • DARTdrones Flight School
  https://video.link/w/C6Qw (Length 1:30)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/2TFzMC4VBIA

Slides 21-22: These categories differ in appearance and generate lift differently as well, which makes them suitable for different applications.

Fixed-wing drones have a much greater endurance than multicopters; they are less complex, with simpler controls. They don't have great maneuverability, however, and require more room to operate (for takeoff and landing). These drones use longitudinal thrust to stay aloft, which means the long axis of the aircraft is the direction of thrust.

Multicopters, by contrast, are highly maneuverable and can take off and land vertically. They are also mechanically simple, compact, and relatively low cost. They have greater electronic complexity, however, as well as low endurance. Multicopters utilize vertical thrust to stay aloft, which requires more power, but they can hold a 3-dimensional spatial position with millimeters of accuracy.

Similarities exist between fixed-wing and rotorcraft, despite the physical differences in appearance. In both cases "servos," or control surfaces, control the aircraft. In rotorcraft however, these control surfaces are usually fixed blades, and the rate of blade spin, specific to each individual motor in microseconds, is used to maneuver the aircraft.

Helicopters are not ideal autonomous platforms due to the large amount of maintenance required. They are naturally unstable due to the physics of lift and torque, and the carbon fiber construction can cause interference with RF (radio frequency) signals. In addition, the overhead rotor blocks the clear view of the sky needed for reliable GPS. Therefore, this semester's lessons will focus on fixed-wing and multirotor drones.

Session 2

Slide 23: Complete the **Formative Assessment**.

Formative Assessment

Students will answer five written questions. Provide students with **Introduction to UAS Student Activity 1**. Correct answers and guideline responses are provided in **Introduction to UAS Teacher Notes 1**.

[DOK-L1; *identify*, DOK-L2; *compare*]

EXTEND

Teacher Material: Introduction to UAS Presentation

Slides 24-25: The categories of drone missions flown by the two main types of UAS differ:

- Fixed-wing drones can fly higher than multicopters. Their greater endurance makes them ideal for surveying large areas and collecting data. They can also fly in inclement weather; by contrast, a multicopter's high RPM can create rotor icing as the air gets colder at higher altitudes. The lower air density at high altitudes would also inhibit effective lift. Fixed-wing drones can be used for cargo operations if air drop is acceptable.
- Multicopters, however, are more agile and maneuverable. They have lower endurance, though high-end prosumer multicopters can average a flight time of around 30 minutes on a single battery. They are ideal for low-altitude missions and suitable for cargo delivery, provided the cargo is not large. Sometimes they are flown in multiples or "swarms" as a group. The advantages of swarms are that a wider area can be covered visually with the onboard cameras, and that multiple items can be carried at once that would normally be too much for a single UAV.

The table on slide 25 compares and contrasts the main characteristics of fixed-wing and multicopter drones.

Slide 26: The following video shows how drones—specifically, multicopters—can be used in search-and-rescue operations:

- DJI Stories – Search and Rescue
  https://video.link/w/h9Qw (Length 5:33)

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/IbkTzDchrzE

Questions

After the video, ask students the following questions:

- Why do you think these drones were likely suited for this particular mission?
  Sample response: Multicopters provide a more stable platform for a particular area, and can get better sightlines.
- What other specific missions might multicopters be used for?
  Sample response: Land surveying, package delivery, photography
- What about fixed-wing drones?
  Sample response: Surveying large areas, national defense, reconnaissance

EVALUATE

Teacher Materials: Introduction to UAS Presentation, Introduction to UAS Teacher Notes 2
Student Material: Introduction to UAS Student Activity 2

Slide 27: Conduct the **Summative Assessment**.

Summative Assessment

Students will answer written questions. Provide students with **Introduction to UAS Student Activity 2**. Correct answers and guideline responses are provided in **Introduction to UAS Teacher Notes 2**.

[DOK-L1; *identify*, DOK-L2; *compare*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Postings show evidence of one or more of the following:
  - Knowledge of flight paths and basic instruments
  - Provides details about the factors that affect flight path
  - Provides explanation of actions pilots can take to account for wind and other factors while flying
- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points	Performance Levels
9-10	The student shows strong objective understanding; Answers 23-25 questions correctly.
7-8	The student shows sufficient objective understanding; Answers 18-22 questions correctly.
5-6	The student shows a struggle with objective understanding; Answers 13-17 questions correctly.
0-4	The student shows a lack of objective understanding; Answers 12 or fewer questions correctly.

STANDARDS ALIGNMENT

COMMON CORE STATE STANDARDS

- **RST.11-12.2** - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.4** - 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 11-12 texts and topics*.
- **WHST.11-12.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
- **WHST.11-12.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research

REFERENCES

Innovations Through History of Unmanned Aircraft Systems (pp. 1-5): https://bit.ly/2Ks1EID

The Droner's Manual (Kevin Jenkins) (pp. 11-31): https://amzn.to/2CSRInq

The Complete Remote Pilot (Bob Gardner and David Ison) (1-1–1-11): https://amzn.to/2XkayNO

FAA DroneZone: https://faadronezone.faa.gov/#/

V-1 Flying Bomb: https://en.wikipedia.org/wiki/V-1_flying_bomb

FAA e-CFR Part 107: https://bit.ly/32VJUMm

FAA e-CFR Part 101: https://bit.ly/2CSdB6q

DJI Stories – Search and Rescue: https://video.link/w/h9Qw

Lockheed D-21, Wikipedia https://en.wikipedia.org/wiki/Lockheed_D-21

How Does GPS Work?: https://video.link/w/c5Qw

What is a Drone? Fixed Wing Drones vs. Multirotor Drones • DARTdrones Flight School: https://video.link/w/C6Qw

What is the Difference Between a Drone, UAS, SUAS, and UAV: https://video.link/w/U2Gw

What is a Drone? Where did the words Drone, UAV, and UAS come from?: https://video.link/w/o6Gw

Dunkan, Fastest Lap, Boston | Drone Racing League: https://video.link/w/yPQw