The Right Drone for the Job

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The many types of UAS available, along with their different capabilities, means that remote pilots must be familiar enough with technology and systems to determine a drone's appropriateness for a given mission.

Primary considerations when deciding upon a UAS for a mission should include airframe type, requirements of the flight controller, and the capabilities of the payload.

ESSENTIAL QUESTIONS

1. How does the technology available on a given UAS (e.g., sensors, payload) affect its ability to perform an operation?
2. Why are some UAS better suited to a particular mission (e.g., agricultural operations, search and rescue) than others?

LEARNING GOALS

Students Will Know

- How different sensors available within a UAS flight controller lend capability for different modes of flight.
- Flight modes common to most UAVs, as well as some others that are available with specific aircraft.
- That the mission being flown should always be considered when selecting both a drone and its payload.

Students Will Be Able To

- *Summarize* common sensors that can be found in flight controllers, as well as the flight modes that they make possible. [DOK-L2]
- *Relate* the appropriateness of a drone's payload to the operation it will be performing. [DOK-L2]
- *Draw conclusions* about the type of UAS that would be ideal, given a specific mission to be flown. [DOK-L3]

ASSESSMENT EVIDENCE

Warm-up
Students will analyze the basic factors that go into drone payload and mission considerations.

Formative Assessment
As a class, students will summarize the content of the lesson with guided questions.

Summative Assessment
Students will take on the role of a consultant using given mission scenarios to apply the concepts from the lesson and demonstrate the ability to choose the right drone and equipment for a given job.

LESSON PREPARATION

MATERIALS/RESOURCES

- The Right Drone for the Job Presentation
- The Right Drone for the Job Student Activity
- The Right Drone for the Job Teacher Notes

LESSON SUMMARY

Lesson 1: The Right Drone for the Job
Lesson 2: Expert Mode
Lesson 3: UAS Classroom Safety
Lesson 4: Learning to Fly: Fundamentals of Control

The lesson begins by discussing the concept of the right drone for the job.

During the next part of the lesson, students watch a video of an underground surveying drone. They discuss the purpose of a flight controller and various components that interface with it. Then, they examine types of imaging sensors and the purposes and benefits of each. Next, they consider flight modes, including those that are common to most controller systems and additional modes available for certain vehicles.

Finally, the lesson introduces key mission types and the payloads that would be suitable for each. Students then apply what they have learned by choosing the best drone and components for each of several missions: first as a class, and then individually in the Summative Assessment.

BACKGROUND

There are a multitude of components, including a wide range of cameras, accessories, and electronics, with which an operator could equip a drone.

When choosing a payload (or loadout) for a mission, it is important to use a minimalist approach. Generally, the more that is attached to a drone, the more inherently unstable the drone will be. The motors will also have to work harder to compensate for the extra weight, which results in a loss of flight time.

There are other things to consider, such as budget, mission goals, and other necessary capabilities. This lesson will focus on common components that are either built into a drone or part of a mission-specific payload. With this knowledge, a pilot can more readily tailor the drone to the mission—saving resources and time and creating a safer flight.

MISCONCEPTIONS

Students may believe that while UAS vary in complexity, their systems—and the information the flight controller uses to maneuver them—are largely the same. This is not the case, however, because sensors that provide information can vary from drone to drone, meaning that different UAS can have vastly different capabilities.

For example, UAVs might contain GPS, internal measurement units (IMU), optical sensors, or other components. The parameters of each of these systems and the capabilities they provide are specific to that component.

Emphasize to students the importance of understanding the systems and technology on every drone that they fly. The more they know about the technology, the more proficient and safe they will be as remote pilots.

DIFFERENTIATION

To support students with low working memory, set up a place on the board or use chart paper to capture notes during the **ENGAGE** and **EXPLORE** sections of the lesson plan. Headings could include "Types of Missions" and "Characteristics of and Technologies Used on a Drone." Then, continue to add to students' initial ideas as the class works through the **EXPLAIN** section of the lesson plan. You may or may not decide to keep the notes displayed during the Formative Assessment at the end of Session 1, as well as the Summative Assessment at the end of Session 2.

To promote collaboration and critical thinking during the **EXTEND** and **EVALUATE** sections of the lesson plan, have students attempt to complete the activities individually, then work in pairs or small groups to evaluate their answers. Groups must come to a consensus about the best type of drone, given the mission.

LEARNING PLAN

ENGAGE

Teacher Material: The Right Drone for the Job Presentation

Session 1

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

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

Warm-Up

To start class, ask students the following:

- What are the most important aspects in choosing a drone to use on a mission?
  Answers may vary, but students should realize that the mission itself would be the primary consideration.

Follow up by asking:

- What are some different types of missions, and what type of drone would be suitable for each?
  No need to correct students at this point, but examples include the following:
  Multicopter for short range or maneuverability
  Fixed wing for long range or pattern flight missions like land surveying
  Cameras or imaging for surveillance or surveying
  Other electronics or mounts for specialized missions

The lesson will focus on factors to consider when choosing a type of drone for a mission and deciding among payloads or attached equipment.

EXPLORE

Teacher Material: The Right Drone for the Job Presentation

Slide 5: Students will watch a video that demonstrates how an Elios drone is being used to map areas in mines that miners will excavate. The video discusses the relative ease with which the drone can be flown and the value of the information it provides.

While they watch the video, have students consider the following question: *What characteristics of and technologies used on the drone make it suitable for operating in an environment that has limited lighting and cramped spaces?*

- “Underground Mining Drone: Stope Photogrammetric Mapping” (Length 6:00) https://video.link/w/NHn3

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/e8UVLwRfRdg?start=0&end=360

Slide 6: After the video, discuss the following question as a class:

Questions

What technologies did the Elios drone likely use?
Answers will vary but could include proximity sensors, inertial (motion) and/or optical sensors, and sonar. If GPS is mentioned, however, the teacher should remind students that this type of technology is not available underground because it requires a line of sight to satellites.

Explain that this lesson will explore technologies, including sensors built into a drone and those that are part of a payload, such as a camera, that can make missions like the one in the video a success.

EXPLAIN

Teacher Material: The Right Drone for the Job Presentation

Slide 7: Remind students that a flight controller takes inputs from the pilot and sensors and interprets them into outputs for the drone’s motors. Although flight controllers can be used on fixed-wing drones, they are rare and are not required. Fixed-wing drones receive incoming control commands for each axis and output them directly to the flight control servos. In contrast, some form of flight controller is required in a multicopter.

Slide 8: Multicopters are inherently unstable in flight. Micro-adjustments are needed to keep a multicopter stable under windy conditions or during flight maneuvers. An onboard computer, or flight controller, is required to adjust the RPM for each motor without affecting the overall position of the UAS. In addition to adjusting the RPM for each motor, the computer must translate control inputs from the UAS operator.

In short, it would be impossible for a human alone to safely manage the micro-adjustments required for each motor; a flight controller is necessary to augment human inputs.

Slide 9: To reiterate key points and to check retention, discuss the following questions as a class:

Questions

What does a flight controller do?
Answers will vary, but they should resemble the following:
Converts sensor inputs to motor outputs
Monitors stability and helps maintain it

Do fixed-wing drones require a flight controller? Why or why not?
No. While flight controllers can be used on fixed-wing drones, they are not required because these drones are inherently stable.

Slide 10: Advanced flight controller systems have capabilities beyond flight control input management. Advanced systems can manage failsafes such as Return to Home (RTH) and other features like auto-landing, autopilot, and obstacle avoidance. They accomplish this by using the inputs from various sensors and onboard electronics.

Onboard components vary widely. Memory, for example, can either be built-in or card-supported. It can be used to store media or to conduct automated flights. Components could also include extra sensors, such as an inertial measurement unit (IMU), GPS hardware, a digital compass, and optical or sonar-based proximity sensors.

Devices like these provide a UAS with ways to monitor and maintain its own stability. The next sections will break down the components that can help an operator determine the best drone for the task, beginning with the flight controller sensors.

Slide 11: GPS receivers use three satellites as points for *trilateration* in order to determine the UAV's position. Trilateration is the use of time, speed, and distance calculations to calculate an accurate position.

Teaching Tips

- Triangulation measures angles, not distance.
- Trilateration measures distances between GPS satellites that are broadcasting their locations and time.

Civilian GPS is typically accurate within 3 meters or less. However, GPS cannot determine the orientation of the drone or heading, just the ground speed and vector (direction of movement).

Fixed-wing drones require an airspeed indication to avoid stalling. Instead of using the GPS to measure this, fixed-wing drones use a pitot tube system, similar to that used in manned aircraft. A pitot tube is a forward-facing, right-angled tube that measures the pressure of air in flight.

Slide 12: A compass or magnetometer manages the heading of the drone, calibrated to magnetic north. When flying in new areas with different magnetic influence or metallic proximity, it is a good practice to calibrate this onboard compass to avoid drifting and flyaways.

Slide 13: An IMU, or accelerometer, measures the relative movement and velocity changes around the axes of the UAV; that is, it monitors the stability of the UAV in physical space. This component gives flight data to the flight controller which is continuously making minor adjustments to maintain the UAV's stability. In a multicopter, for example, the flight controller uses IMU data to control the rotors in order to stabilize the UAV while in flight. Data may be used to display an artificial horizon or attitude indicator on a ground control station (GCS).

Slide 14: A power management unit (PMU) provides the flight controller with information about power consumption of the aircraft, motors, and components. It also regulates the flow of power to the flight controller. It is used to predict flight time and manage voltage resources.

Telemetry units are the modular two-way radio components that allow the GCS to communicate with the UAV and obtain flight data or video or send commands.

Slide 15: Range sensors, or sonar modules, can be used to calculate the height of a UAV above or next to obstacles or the ground using a send-and-receive method and timing the travel of the signal. They help the UAV avoid obstacles and assist in landing and descent control. When they are integrated into the auto-landing system, they allow a UAS to automatically terminate the motors upon landing.

Slide 16: Optical flow sensors are low-resolution cameras with a processor that can be leveraged by the flight controller in tandem with or without an IMU to help maintain position when hovering. These sensors are typically only effective at lower altitudes, and the reliability of the information they provide varies based on the patterns, lighting, or surfaces observed. By using a low-altitude snapshot at takeoff to guide the UAS in for landing later, these sensors can also enable the UAS to autoland on high-contrast landing pads.

Slide 17: Imaging sensors are the most common form of payload on a drone. These imaging sensors typically take the form of cameras. The configuration of imaging sensors depends on their application; for example, surveying, reconnaissance, or first-person view (FPV) piloting. FPV is the forward view from the perspective of the UAV, and it enables someone on the ground to view live video from the vehicle as though they were a pilot inside the aircraft. Typically, FPV is used in drone racing.

Cameras vary widely in price and versatility, but the main things to keep in mind besides budget are the types of data that need to be collected, size of the camera body, resolution, infrared or other imaging specializations, triggering rate (that is, how quickly they can take photos), and how many photos they can store.

Slide 18: Photos need to be taken with some sort of trigger mechanism. Depending on the specific setup, this can be a timer or a radio-controlled mechanical device, or it can be done wirelessly with software.

When triggering mechanisms are not integrated in the UAS to be triggered wirelessly with software, they will likely need to use a connector cable routed from the main UAS fuselage (body) or to an externally mounted transmitter. In some cases, a mechanical device may need to be used to physically trigger a button. This could be a purpose-built device from the manufacturer or a custom radio-controlled device fabricated to fit the UAS.

Slide 19: Mounts can be fixed or articulating, and come in three main types: gimballed, movable, and fixed.

Gimballed mounts are shock-isolated articulating mounts that use gyroscopes to steady the camera. Usually, they are able to rotate to any heading and angle on three axes freely.

Movable mounts are more limited than gimballed mounts, but they allow the camera operator more freedom to make adjustments than fixed mounts.

Fixed mounts are restrictive and not intended to move during a flight. These mounts can be useful for mounting devices such as antennas, cargo devices, or lighting.

Slide 20: Surveying in its simplest form is done by taking still images of Earth's surface in a predetermined manner. This can be done using a flight path or pattern generated by mapping software and uploaded to the onboard memory. However, as seen in the warm-up video, advanced types of surveying can be done in a cave or tunnel using other camera methods. Surveying can even be done using underwater drones.

The purpose of surveying to gather images and stitch them together for data or research purposes. Components used for this typically include a camera or image sensor, a fixed or movable mount for the sensor, and perhaps a mechanism to trigger photos.

Ask students the following question before moving on:

Questions

In what types of missions or applications would surveying payloads be useful?
Answers will vary but could include agriculture, mining, and land mapping.

Slide 21: FPV reconnaissance is when a camera on board the UAV is used to search for or look at something or someone. FPV recon typically uses a camera, gimbal mount, and video transmitter on the UAV paired with a video receiver at the ground control station.

Ask students the following question before moving on:

Questions

In what types of missions or applications would FPV reconnaissance payloads be useful?
Answers will vary but could include structural inspection, search and rescue, and professional video production.

Slide 22: FPV pilot cameras are forward-only cameras that provide live video from the perspective of the UAS. While this type of camera typically is not commercially useful by itself, it enhances safety during missions. They usually use an on screen display (OSD) with an overlay of flight telemetry, much like a military aircraft's heads up display (HUD) would show. This information is superimposed onto the video feed.

Slide 23: Ground support equipment includes any components on the ground used to support the UAS during the mission, including video receiver electronics/antennae, a monitor for viewing, and a power source.

Slide 24: Conduct the **Formative Assessment**.

Formative Assessment

This slide contains questions to check retention of information given in Session 1.

Ask students the following questions as a class, and discuss their answers:

- What are the basic purposes of a flight controller?
  A flight controller converts sensor inputs to motor outputs and monitors and maintains stability.
- Does a multicopter need a flight controller? Why or why not?
  Yes; It would not be possible to safely or reasonably manage motor RPM or control without one.
- What type of payloads might you need for surveying?
  Camera/imaging sensor, camera mount, photo trigger mechanism (hardware/software)
- What type of payloads might you need for FPV reconnaissance?
  Camera, gimbal (gimballed mount), video transmitter on the drone, and receiver on the ground
- What four primary sensors does a flight controller commonly use?
  inertial measurement unit (IMU), power management unit (PMU), range sensor, and optical flow sensor

[DOK-L2; *summarize*]

Session 2

Slide 25: The first session discussed the basics of drone components. This slide gives a refresher on the content covered.

- **Flight controllers** convert sensor inputs to motor outputs to monitor and maintain stability.
  - Multicopters must use a flight controller.
- **Surveying payloads** use camera/imaging sensors, camera mounts, and photo trigger mechanisms.
- **FPV payloads** use cameras, gimbals, video transmitters on the drone, and receivers on the ground.

- **Flight controller sensors** include inertial measurement units (IMU), power management units (PMU), range sensors, and optical flow sensors.

Slides 26-27: Depending on the type of UAS and the sensors used, a variety of flight modes are available. However, there are four flight modes that are common to nearly all controller systems: stabilize, automatic modes, Return to Home, and Land Now.

- **Stabilize (Attitude/"Atti Mode")**

This self-levels the roll and pitch axis, while allowing the pilot to manually control the UAV. The drone will not attempt to hold a position in space; rather, it will use the IMU and flight controller to maintain a constant attitude. Wind will cause the drone to drift.

- **Automatic Modes ("Auto-Fly")**

These can come in several different forms, and might include using a payload camera to track a subject automatically ("Follow Me Mode") or flying continuously on a specific heading without needing pilot input (Heading Mode). It can be augmented with GPS for additional functionality.

- **Return to Home (RTH)**

This mode can be triggered manually by the pilot or automatically under certain conditions, such as a situation involving low battery or a loss of signal or as part of an autopilot route. In RTH, the drone will climb to a preset altitude (if the drone supports the feature) and maintain that altitude as it flies to the point from which it took off. Then, the drone will land and shut off the motors or hover (if the drone supports this feature).

- **Land Now**

This command will tell the drone to immediately descend in place and land. Some drones support obstacle sensing while landing, which will dynamically guide the drone around obstacles such as trees and allow it to find a level area on the ground to land.

Slides 28-29: Some drones support additional modes. These modes may require additional components, such as GPS modules, optical flow sensors, cameras, or manufacturer-specific accessories.

- **GPS (Position Mode/"P-Mode")**

This mode is like stabilize mode, except the drone will also use GPS communication to maintain an "XYZ" point in physical space. This allows the drone to autocorrect when it drifts due to air movement. GPS mode is useful when hovering and keeping a steady camera picture or when navigating small areas where precision flying is necessary.

- **Grid Mode**

This mode uses a programmed grid pattern, which works with the autopilot and GPS modules to fly along a set course. Grid mode is useful for surveying or patrolling.

- **Smart Modes**

Smart modes use a combination of available sensors on a drone to generate advanced flight paths in real time. Orbit mode, for example, automatically circles a subject indefinitely. Other modes are cinematically focused, including artistic zoom and flight effects, panoramic photo generation, or automatic follow with obstacle avoidance.

EXTEND

Teacher Material: The Right Drone for the Job Presentation

Slide 30: This lesson has looked at components and sensors used in UAS systems. The variations among systems are numerous, and deciding on a UAS may seem daunting given the number of possibilities. It is important for remote pilots to begin by evaluating the type of mission for which a drone will be used.

Once a pilot understands the mission, the pilot should consider several key questions, including the following:

- What payload will be required for the mission?
- What airframe would be most appropriate? (e.g., multicopter vs. airplane, number of rotors)
- What are the requirements of the flight controller based on the mission? (e.g., what flight modes will be required, and what types of sensors will be required?)

Slide 31: Use the provided mission scenario on this slide for the class to discuss and determine what type of drone and payload should be selected to accomplish the mission. Remind students to incorporate the provided equipment and the budget of $4,000 into their analysis of the right drone for the job. Students will perform similar analyses on the upcoming Summative Assessment.

- You are a consultant intern for a drone survey company. A customer wants a 1-mile by 6-mile plot of land surveyed for water erosion. You have the following equipment available and a budget of $4,000:
    - ***Drones****: Fixed wing ($1,700), Multicopter ($500)*
    - ***Cameras****: Thermal ($1,500), Optical ($230), FPV Pilot View ($20), Thermal + Optical with a Gimballed Mount ($3,500)*
    - ***Mounts****: Gimballed ($250), Fixed ($50)*
- After the class discussion, you can present the following options to students as the best choices for this mission:
    - ***Drone: Fixed wing ($1,700):*** *Although the fixed-wing drone is more expensive, using a multicopter would be nearly impossible for a job this size.*
    - ***Camera: Optical ($230) + FPV Pilot Camera ($20):*** *A thermal camera would incur a large, unnecessary expense. An FPV pilot camera is very reasonable at $20, and the added safety it brings outweighs the expense.*
    - ***Mount: Fixed ($50):*** *Only downward facing is needed for this type of survey.*
- ***Total Spent: $2,000 (out of a $4,000 budget)***

EVALUATE

Teacher Materials: The Right Drone for the Job Presentation, The Right Drone for the Job Teacher Notes
Student Material: The Right Drone for the Job Student Activity

Slide 32: Conduct the **Summative Assessment**.

Summative Assessment

Provide students with **The Right Drone for the Job Student Activity**.

Students will assume the role of a consultant for a small UAS firm. Students will advise senior management on the best type of drone for a given mission scope and recommend equipment needed for the job from the inventory available. Guidance for responses is provided in **The Right Drone for the Job Teacher Notes**.

[DOK L-2; *relate,* DOK-L3; *draw conclusions*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Postings show evidence of one or more of the following:
    - Knowledge of different UAS payload and flight monitoring components
    - How UAS components are involved in flight management
    - What equipment is best suited for different types of applications
- 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 Provides accurate information to senior management about the best drone and equipment to use with complete justifications for the use of each piece of equipment. Answers all 5 questions correctly.
7–8 Provides mostly correct information to senior management about the best drone and equipment to use with brief justifications for the use of each piece of equipment. Answers 4 questions correctly.
5–6 Provides some correct information to senior management about the best drone and equipment to use with few justifications for the use of each piece of equipment. Answers 3 questions correctly.
0–4 Provides incomplete or inaccurate information to senior management little or no justifications for the use of each piece of equipment. Answers at most 2 questions correctly.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-Dimensional Learning

- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
    - Science and Engineering Practices
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - None

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

- Underground Mining Drone: Stope Photogrammetric Mapping, YouTube: https://youtu.be/e8UVLwRfRdg
- The Droner's Manual (pp. 38-44, 53-63, 90-93)