Learning to Fly: Fundamentals of Control

Session Time: Four, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

A combination of theory and hands-on learning is necessary for students to become proficient remote pilots capable of planning and executing missions.

Effective teamwork is essential to ensure safe and successful UAS operations.

ESSENTIAL QUESTIONS

1. How should a drone be controlled to ensure a safe and successful operation?
2. How can students use the knowledge they have acquired so far to help other members of their team during group exercises?

LEARNING GOALS

Students Will Know

- The fundamentals of controlling an sUAS from takeoff until landing.
- How to use basic functions that are available on the classroom drone to augment manual control.
- How teams can function to complete safe and successful drone operations.

Students Will Be Able To

- *Apply concepts* learned throughout the semester to the practical act of flying the classroom drone. [DOK-L4]
- *Assess* their own progress at learning to control a drone, as well as the progress of their team members. [DOK-L3]
- *Make observations* about team members' strengths, and determine the roles that each member is most comfortable in. [DOK-L2]

ASSESSMENT EVIDENCE

Warm-up
Students will observe you give a flight demonstration of the classroom UAS and will learn the basics of virtual flight simulators using a flight simulator of your choice.

Formative Assessment
As a class, students will answer questions related to the classroom drone(s) and drone flight simulator.

Summative Assessment
Teams will take turns flying the classroom drone(s) and carry out a predetermined set of flight commands. After all teams have completed their flights, they will discuss teacher observations and accompanying questions.

LESSON PREPARATION

MATERIALS/RESOURCES

- Learning to Fly: Fundamentals of Control Presentation
- Learning to Fly: Fundamentals of Control Student Activity 1
- Learning to Fly: Fundamentals of Control Student Activity 2
- Learning to Fly: Fundamentals of Control Student Activity 3
- Learning to Fly: Fundamentals of Control Student Activity 4
- Learning to Fly: Fundamentals of Control Teacher Notes 1
- Learning to Fly: Fundamentals of Control Teacher Notes 2
- Learning to Fly: Fundamentals of Control Teacher Notes 3
- Learning to Fly: Fundamentals of Control Teacher Notes 4
- Learning to Fly: Fundamentals of Control Teaching Aid

Learning to Fly: Fundamentals of Control: Student Activity Days 1–4

- Classroom drone(s)
- Several fully-charged batteries per drone
- Drone flight simulator(s) on a computer or mobile device
- Class rules regarding safety
- Obstacles and targets (e.g., safety cones, landing pads, photographic targets)
- First aid kit (recommended)
- Tool kit (recommended)
    - See **Learning to Fly: Fundamentals of Control Teaching Aid** for suggested tools.

Flight Simulation Activity

- Computer(s) or mobile device(s) with drone flight simulation software
- Physical or electronic control station

Teaching Tips

Prior to beginning this lesson, review the **Learning to Fly: Fundamentals of Control Teaching Aid**. This will provide you with helpful suggestions, information, and general guidance depending on the classroom resources and circumstances: e.g., the make and model of the classroom drone(s), drone flight simulators, and locations available for drone flights.

Make use of this **Learning to Fly: Fundamentals of Control Teaching Aid** throughout the lesson.

LESSON SUMMARY

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

The lesson will begin with a warm-up in which students form groups and briefly review what they have learned about operating drones. Students will then observe you demonstrate a complete flight of the classroom drone. Students will also learn the basics about drone flight simulators and use a flight simulator of your choice. Students will then take a brief, orally administered formative assessment in which they answer questions about the classroom drone and the flight simulator.

On Day 2, students will work in teams, taking turns briefly flying the classroom drone(s). If there are not enough drones available, teams that are not flying will use drone flight simulators to practice.

On Day 3, teams will continue their flight practice, carrying out more challenging types of flights. Students will also continue to use drone flight simulators as needed.

On the last day (Day 4), teams will demonstrate their drone flying skills by completing a practical test activity. Teams will be assessed on their skill conducting their assigned operation and their ability to work as a team to accomplish their objective. If time allows, each group should discuss the strengths of its members in the context of roles within the team.

BACKGROUND

There is a first time for everything, and piloting a sUAS is no exception. Although studying, preparing, and learning rules and regulations are important, hands-on training is the crucial final step to becoming a confident and skilled remote pilot.

Historically, aviation is more than a profession—in this field, humans have pushed the boundaries of what is possible, using engineering and technology to explore the world from the air. The history of manned and unmanned flight is full of people who took tentative first steps, often testing new and unproven technologies for which the outcomes were uncertain. From Orville and Wilbur Wright, who completed the first successful flight on December 17, 1903, to Chuck Yeager, who was the first to break the sound barrier on October 14, 1947, pilots have continually learned by doing. These advances in aviation were always group efforts, with many working together to achieve a desired goal.

As the commercial drone industry continues to grow, an increasing number of students are embracing this new technology and using it for applications that were inconceivable a decade ago. With applications in agriculture, construction, mapping, and weather forecasting, new remote pilots—often with the help of teams—are charting a course forward for unmanned aviation.

MISCONCEPTIONS

Because many drones have advanced automated capabilities (e.g., obstacle avoidance, waypoint GPS navigation, and Return to Home), some students may have the misconception that remote pilots can fly missions with just a basic understanding of a UAS controller or simply by entering flight commands. While advanced drones do have many automated capabilities, it is important that remote pilots do not rely on these. A remote pilot should be able to manually fly a drone, not only for emergencies, but also because hands-on manual flying lays the groundwork for more advanced UAS knowledge and programming.

DIFFERENTIATION

To provide additional support to students during the entire lesson, encourage students to keep any notes and handouts from Lesson 9.A.2 at hand (where they became experts) so that they can reference their notes if they have questions during the activity.

LEARNING PLAN

ENGAGE

Teacher Material: Learning to Fly: Fundamentals of Control Presentation

Session 1

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

Teaching Tips

Explain to students that this lesson is entirely activity-based and serves to give hands-on training with the classroom sUAS. This lesson also builds on the work that students completed in the previous lesson (9.A.2: Expert Mode) and will continue into the next and final lesson (9.B.1: UAS Team Operations).

Ask students to recall the topics they became experts on in Lesson 9.A.2, as some students will continue to work as experts for their groups within this lesson.Ask students if they have any experience flying drones, and if any have earned their Part 107. As students form teams during the Warm-Up, distribute experienced and certificated students equally, so that they can help instruct students who are new to flying drones. Note that it is not necessary for students to have their Part 107 certification to conduct this lesson.

Slides 4–5: Conduct the **Warm-Up.**

Warm-Up

Forming Drone Flight Teams

Explain to students that this lesson will give them a chance to work as drone flight crew teams; teams will take turns getting hands-on flight training flying the classroom drone(s) and using a drone flight simulator. In preparing students to fly, this lesson serves as a transition into the final lesson of the semester (9.B.1), during which students will use a drone to complete an extended group project. Explain that students should remain in the same teams for this lesson and the next one.

Slide 4: This lesson is entirely activity-based, first through observation of a complete drone flight and use of a drone flight simulator, and then through hands-on experience. This lesson also builds on the work students completed in the previous lesson (9.A.2: Expert Mode). Ask students to recall the topics they researched as teams to become experts in Lesson 9.A.2; they will continue to work as experts for their new drone flight crews in this lesson. Remind students the previous teams were as follows:

- Aircraft & Ground Systems
- Aircraft Control
- Aircraft Setup & Maintenance
- Flight Operations & Safety

Direct the class to form drone flight crew teams of 4–6 students, and explain that they will remain in these teams for all 4 sessions of this lesson and for the next, final lesson of the semester. Then explain that the new teams should include at least one student from each of the four teams in Lesson 9.A.2. This will ensure that each of the new teams has a subject matter expert from each of the four previous teams. If possible, students with Part 107 certification should be distributed equally among the teams.

Slide 5: Play the following DJI video to introduce students to how drone flight simulators work and how they can be helpful for flight training.

- "DJI - Introducing DJI Flight Simulator" (Length 2:45) https://video.link/w/UZ59

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/watch?v=Zb_XKPgr0oo

EXPLORE

Teacher Materials: Learning to Fly: Fundamentals of Control Presentation, Learning to Fly: Fundamentals of Control Teacher Notes 1, Learning to Fly: Fundamentals of Control Teaching Aid, **classroom drone(s), several fully charged batteries per drone, drone flight simulator(s) on a computer or mobile device**
Student Material: Learning to Fly: Fundamentals of Control Student Activity 1

Slide 6: Ask students to accompany you to the location where the drone flight demonstration is to take place.

Teaching Tips

- If possible, conduct the sUAS demonstration flight in the EXPLORE section of this session at the same location in which students will be flying for the next three sessions.
- If the drone flight simulator is computer-based and cannot be used on location where the drone is to be flown, give a brief demonstration of the simulator before escorting the class to where the drone is to be flown.
- Have students take their materials with them and, if necessary, assign students to help you carry any sUAS equipment to the flight demonstration location.

Use the **Learning to Fly: Fundamentals of Control Teaching Aid** and **Learning to Fly: Fundamentals of Control Teacher Notes 1** to conduct this part of the lesson and the flight demonstration with students. Students should follow along in **Learning to Fly: Fundamentals of Control Student Activity 1**. When finished, have students answer the questions in the Formative Assessment aloud as a class.

Slide 7: Conduct the **Formative Assessment**.

Formative Assessment

This assessment is to be conducted and answered orally. These questions appear in Learning to Fly: Fundamentals of Control Student Activity 1. General answers and other instructor tips can be found in Learning to Fly: Fundamentals of Control Teacher Notes 1.

In addition to the general questions provided, ask students any additional questions that are relevant to the demonstration.

[DOK-L2; *make observations*, DOK-L3; *assess*]

EXPLAIN

Teacher Materials: Learning to Fly: Fundamentals of Control Presentation, Learning to Fly: Fundamentals of Control Teacher Notes 2, Learning to Fly: Fundamentals of Control Teaching Aid, **classroom drone(s), several fully charged batteries per drone, drone flight simulator(s) on a computer or mobile device**
Student Materials: Learning to Fly: Fundamentals of Control Student Activity 2, **2–3 pieces of paper per student, 1 pen or pencil per student**

Session 2

Slide 8: Use the Learning to Fly: Fundamentals of Control Teaching Aid and Learning to Fly: Fundamentals of Control Teacher Notes 2 to conduct this part of the lesson. Students should follow along in **Learning to Fly: Fundamentals of Control Student Activity 2.**

Inform students that each team will conduct hands-on flight training today. Instruct students to take turns performing brief sUAS flights or using the drone flight simulator. Teams should assign each member a role prior to each flight. Team roles will be as follows:

- A pilot in command (PIC) responsible for safe flight operation
- At least one visual observer (VO) to observe the surrounding area
- A manipulator of controls to fly the sUAS
- Team members to conduct preflight and postflight inspections

Slide 9: If the classroom drone flight simulator is available, teams should use it to practice while other teams are flying the drone.

Session 3

Teacher Materials: Learning to Fly: Fundamentals of Control Presentation, Learning to Fly: Fundamentals of Control Teacher Notes 3, Learning to Fly: Fundamentals of Control Teaching Aid, **classroom drone(s), several fully charged batteries per drone, drone flight simulator(s) on a computer or mobile device**
Student Materials: Learning to Fly: Fundamentals of Control Student Activity 3, **2–3 pieces of paper per student, 1 pen or pencil per student**

Slide 10: Use the Learning to Fly: Fundamentals of Control Teaching Aid and Learning to Fly: Fundamentals of Control Teacher Notes 3 to conduct this part of the lesson. Students should follow along in **Learning to Fly: Fundamentals of Control Student Activity 3.**

Tell students that they will continue hands-on flight training. Today, all members of each team will take turns performing more advanced sUAS flights. Instruct students to take turns performing brief sUAS flights or using the drone flight simulator. Teams should assign each member a role prior to each flight. Team roles will be as follows:

- A pilot in command (PIC) responsible for safe flight operation
- At least one visual observer (VO) to observe the surrounding area
- A manipulator of controls to fly the UAS
- Team members to conduct preflight and postflight inspections

Slide 11: If the classroom drone flight simulator is available, teams should use it to practice while other teams are flying the drone.

EXTEND

Teacher Materials: Learning to Fly: Fundamentals of Control Presentation, Learning to Fly: Fundamentals of Control Teacher Notes 4, Learning to Fly: Fundamentals of Control Teaching Aid, **classroom drone(s), several fully charged batteries per drone, drone flight simulator(s) on a computer or mobile device, obstacles and targets (e.g., safety cones, landing pads, photographic targets)**
Student Materials: Learning to Fly: Fundamentals of Control Student Activity 4, **2–3 pieces of paper per student, 1 pen or pencil per student**

Session 4

Slide 12: Use the Learning to Fly: Fundamentals of Control Teaching Aid and Learning to Fly: Fundamentals of Control Teacher Notes 4 to conduct this part of the lesson. Students should follow along in **Learning to Fly: Fundamentals of Control Student Activity 4.**

Inform students that each team will fly the classroom drone and carry out a set of assigned flight commands. The goals of this exercise are for each student within the team to take on a particular role and for all students to work together as a team. Additionally, students should continue to practice on drone flight simulators.

Teams should assign each member a role prior to each flight. Team roles will be as follows:

- A pilot in command (PIC) responsible for safe flight operation
- At least one visual observer (VO) to observe the surrounding area
- A manipulator of controls to fly the UAS
- Team members to conduct preflight and postflight inspections

Slide 13: If the classroom drone flight simulator is available, teams should use it to practice while other teams are flying the drone.

EVALUATE

Teacher Materials: Learning to Fly: Fundamentals of Control Presentation, Learning to Fly: Fundamentals of Control Teacher Notes 4, Learning to Fly: Fundamentals of Control Teaching Aid
Student Material: Learning to Fly: Fundamentals of Control Student Activity 4

Slide 14: Conduct the **Summative Assessment**.

Summative Assessment

This assessment is to be conducted and answered orally. These four questions appear at the end of **Learning to Fly: Fundamentals of Control Student Activity 4**. General answers can be found in **Learning to Fly: Fundamentals of Control Teacher Notes 4**.

In addition to the four general questions provided, ask students any additional questions that you deem relevant to the exercise.

[DOK-L4; *apply concepts*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Postings show evidence of one or more of the following:
    - Knowledge of the classroom sUAS and its control functions
    - Successfully executes tasks related to sUAS operations
    - Demonstrates understanding of individual roles within their team
    - Demonstrates knowledge of safety procedures
- 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	Shows excellent group participation and organization when following the given procedure; responds to all 4 questions thoroughly, referencing their team's assigned goal
7–8	Shows sufficient group participation and organization when following the given procedure; responds to all 4 questions, referencing their team's assigned goal, with some gaps in understanding

5–6 Shows lack of organization when following the given procedure; responds to most questions, many gaps in understanding
0–4 Shows little or no organization or participation; does not follow the procedure correctly; question responses show little or no understanding

GOING FURTHER

Slide 15: Inform students that the next lesson will be the start of an ambitious project: the team will work together to plan and fly an agreed-upon sUAS operation. Teams should take notes on the agreed-upon strengths of the different members. Teams will need these notes in the next lesson.

Have teams discuss the strengths and skills of each team member. Teams should consider questions such as the following. These questions also appear in **Learning to Fly: Fundamentals of Control Student Activity 4**.

- Who might make the best team leader, or PIC, for a mission?
- Who is the best at physically manipulating a drone's controls?
- Who has the most thorough understanding of flight restrictions and sectional charts?
- Who is knowledgeable about computers and apps, including updates to the drone's software or firmware?
- Who is particularly skilled at being a visual observer?
- Is there anyone on the team who is a skilled photographer or who has experience shooting or editing video?
- Which team member is comfortable talking to people who might interfere with the mission?

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.11-12.3** - Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
- **RST.11-12.7** - Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

- **RST.11-12.9** - Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

REFERENCES

None