Integrating Drones

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Aspire to the highest level of technical proficiency as it relates to flight operations and engineering processes. (EU5)

Develop an uncompromising safety mindset, understanding that growth and development in the aviation/aerospace industry must always be accompanied by responsible safety initiatives. (EU6)

ESSENTIAL QUESTIONS

1. What challenges/risks exist that limit the immediate integration of drones in the national airspace system?
2. What technologies exist to smooth the transition of drones into the national airspace system?
3. How can we ensure that drones do not pose a hazard to manned flight operations?

LEARNING GOALS

Students Will Know

- How sense-and-avoid technology can assist in integrating unmanned aircraft systems into the national airspace system
- How to develop/define a geofence area for UAS operations

Students Will Be Able To

- *Summarize* how innovation and technology help solve airspace integration limitations. (DOK-L2)
- *Describe* the challenges to integrating unmanned aircraft systems into the national airspace system. (DOK-L2)

ASSESSMENT EVIDENCE

Warm-up
Students will write about one purpose for which they would want to use a drone. Students will explain why a drone would be useful for this task compared with other methods and consider where their drone would fly to accomplish their mission.

Formative Assessment
Students will apply the concepts of sense-and-avoid and geofencing to an activity where they determine the operation of four drones. The drones will deliver food and beverages to spectators or record video/audio at a school football game.

Summative Assessment

Students will identify which of the drone operating rules might be eliminated due to sense-and-avoid and geofencing technologies. Students will show an understanding of the purpose of existing rules and be able to show why the rules may be adapted or removed based on technology.

LESSON PREPARATION

MATERIALS/RESOURCES

- Integrating Drones Presentation
- Integrating Drones Student Activity
- Integrating Drones Teacher Notes

Friday Night Drones Activity (per student)

- Access to “Google Earth”
- Graph paper
- Colored pencils

LESSON SUMMARY

Lesson 1 – Next Generation Air Transportation System
Lesson 2 – Integrating Drones

In the first session, students will begin by describing one task they want to use a drone to accomplish. Students should consider where their drones would fly in order to accomplish their missions. Through class discussion, students will realize that to complete their missions, they likely will be flying their drones in airspace also occupied by manned aircraft.

Students will think back to the beginning of the year, when they completed the “Introduction to Drones” unit, and understand that drone operating rules exist to separate unmanned and manned aircraft. In a class discussion, students will learn about the challenges to full integration of drones into the national airspace system (NAS) and about several key technologies that can separate manned and unmanned aircraft safely.

During an activity in the second and third sessions, students will apply the concepts of sense-and-avoid and geofencing technologies to the operation of four drones that will deliver food and beverages to spectators or record video/audio at a school football game.

As a summative assessment, students will identify which of the drone operating rules might be eliminated due to sense-and-avoid and geofencing technologies. Students will show an understanding of the purpose of existing rules and be able to show why the rules may be adapted or removed based on technology.

BACKGROUND

Traffic separation is as critical with unmanned aircraft as with manned aircraft. To ensure the safety of pilots and passengers aboard aircraft, it is imperative that safe and adequate traffic separation exists. Even with radar and other technology available, generally the responsibility for avoiding collisions lies with the pilots, who visually scan the sky for conflicting aircraft. Unmanned aircraft lack the pilot, so who will visually scan for traffic?

Safe integration of drones into the modernized NAS is essential to the future success of drones. The FAA forecasts over 7 million drones will be in operation by 2020.

Two main concepts are integral to the integration of drones into the NAS: sense-and-avoid and geofencing.

Sense-and-avoid is a similar concept to see-and-avoid, a tactic used by a pilot in a manned aircraft. Rather than seeing a conflicting aircraft, a drone will sense the presence of a conflicting aircraft or object and make appropriate maneuvers to avoid a collision.

Several sense-and-avoid technologies are in development, including the use of video and lasers. Even the use of Automatic Dependent Surveillance-Broadcast (ADS-B) is being considered.

Geofencing depends on the GPS technology found in drones and manned aircraft today. Simply put, a geofence is a geographic, invisible fence established to keep an unmanned aircraft on one side or the other, just like how a backyard fence either keeps the neighbor's dog out of the yard or keeps your dog in.

While a yard is simply two-dimensional, geofences can contain a third dimension and use altitude to ensure aircraft separation.

Geofences are created by determining a set of geographic coordinates (latitude and longitude) that define the area needed to either contain the drone or prevent the drone from entering.

Geofences could be designed and imposed by an individual drone pilot or could be imposed by other agencies – for example, the FAA could issue a temporary flight restriction.

MISCONCEPTIONS

Students may believe drones and manned aircraft will operate in different airspace segments, but drones eventually will need to operate along with manned aircraft in all segments of the NAS.

DIFFERENTIATION

In the **ENGAGE** section of the lesson plan, circulate around the classroom and assist students who might have trouble coming up with ideas for the warm-up. Ask questions that provoke their own ideas for possible answers.

For learners with low working memory, create graphic organizers for information in the **ENGAGE** section. Ask students to record and review their notes in graphic organizers to be able to recall this information more easily.

LEARNING PLAN

ENGAGE

Teacher Material: Integrating Drones Presentation

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

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

Warm-Up

Ask students to write a paragraph about one purpose they would want to use a drone for. They might include things like taking overhead video of their friends at the park, playing geocaching games, or finding a lost dog.

In their paragraphs, students should explain why a drone would be useful for this task compared with other methods. They also should consider where their drones would fly to accomplish their missions. How high would they need to go? Would they be over neighborhoods? Near an airport?

As time allows, have students share their answers, and help them realize that at some point they likely will be flying their drones in airspace where manned aircraft also fly.

[DOK 2; *describe, explain*]

EXPLORE

Teacher Material: Integrating Drones Presentation

Slide 5: Ask students to think back to the beginning of the year, when they first learned about drones in the first unit. Split the students into small teams and ask them to recall as many of the FAA's rules for flying drones as they can.

Slide 6: Review important guidelines that students should follow at all times when flying drones.

Slides 7-8: In a class discussion, ask students what they think is the primary reason these rules exist.

Questions

What is the primary reason these rules exist?

Traffic separation is as critical with unmanned aircraft as it is with manned aircraft. To ensure the safety of pilots and passengers aboard aircraft, it is imperative that safe and adequate traffic separation exists. Even with radar and other technology available, generally the responsibility for avoiding a collision lies with the pilots who visually scan the sky for conflicting aircraft. But in the case of a drone, a pilot isn't on board to see and then avoid another aircraft or an obstacle.

Drone rules exist today to try to keep drones physically separated from manned aircraft.

EXPLAIN

Teacher Material: Integrating Drones Presentation

Slide 9: In the next part of the lesson, students will learn about technologies and innovations needed to integrate drones and traditional aircraft into the same airspace.

Begin by explaining the primary challenges facing full integration of drones into the NAS.

- Traffic separation/collision avoidance
- Air traffic management
- Issues related to operating drones out of the operator's direct line of sight.

Traffic separation is as critical with unmanned aircraft as it is with manned aircraft. To ensure safety of pilots and passengers aboard aircraft, it's imperative to ensure safe and adequate traffic separation exists. Even with radar and other technology available, generally the responsibility for avoiding a collision lies with the pilot(s), who relies on visually scanning the sky for conflicting aircraft. An unmanned aircraft lacks the pilot, so who can visually scan for traffic?

Flight plans for a UAS are likely to be significantly different than for those of manned airplanes and may require current systems used in air traffic management to be updated or replaced. In general, a manned flight is conducted with the purpose of going from Airport A to Airport B. There may be some operations with a little more complexity, but generally airport-to-airport travel is the case. With UAS, it's very likely that the aircraft will be flying irregularly compared with that of manned aircraft. Manned aircraft typically travel via named airways or navigation fixes/aids.

Unmanned aircraft might utilize geographic coordinates instead of names. Additionally, UAS could do other abnormal maneuvers like reversing course multiple times or orbiting over a specific point for hours. Missions for UAS are ever-expanding, and it's very likely the NAS will need to be modified to accommodate them.

When a UAS expands to "beyond visual line of sight" (BVLOS), additional issues need to be considered. One significant area of concern is the time it will take an unmanned aircraft to respond to an air-traffic-control instruction. The instruction likely would be relayed to the operator via radio or satellite. The operator then would have to instruct the vehicle to make a change, again perhaps via radio or satellite. Like we learned in the last lessons, these transmissions all will take a certain amount of time and could result in significant delay from a controller issuing an instruction until the unit actually responds.

Slide 10: Safe integration of drones into the modernized NAS is essential to the future success of drones. The FAA forecasts over 7 million drones will be in operation by 2020.

UAS are being used for a multitude of reasons, including search and rescue, surveillance, photography, agricultural purposes, security, scientific research, fire-fighting, and warfare. They can survey toxic or dangerous environments, scout remote locations to ensure businesses are complying with laws and regulations, perform crowd control, find missing people in remote locations, and more. Often times, UAS can perform these tasks at a much lower cost than manned aircraft. These are important missions with much benefit to society. It is worth considering how to overcome the challenges of integrating UAS into the NAS.

Slide 11: The next several slides will go into detail on key technologies that will keep manned and unmanned aircraft safely separated. The technologies fall into two main concepts: sense-and-avoid and geofencing.

Slide 12: In manned aircraft, even with the advanced technology now available, see-and-avoid is the relied upon method to avoid mid-air collisions and traffic conflicts. See-and-avoid is a simple concept that relies on pilots to visually scan the horizon for traffic. Pilots spend a majority of their time with their vision focused outside their airplanes, identifying any potential traffic that could become an issue.

Why does see-and-avoid not work for a UAS?

First, the nature of a drone means there isn't a pilot on board to see any conflicting traffic. Secondly, drones, especially small ones, can be difficult for pilots of other aircraft to see, thus making the see-and-avoid method somewhat unreliable.

Because see-and-avoid is unreliable when applied to drones, sense-and-avoid technologies are being developed.

Slide 13: Sense-and-avoid is a similar concept to see-and-avoid. Because there is no pilot to see a conflicting aircraft, a drone will sense the presence of a conflicting aircraft/object and make appropriate maneuvers to avoid a collision.

There are several different concepts under development and evaluation. A few are listed on this slide.

The first example is a system based on multiple video cameras rapidly processing images to identify objects. These objects are analyzed by an onboard computer, and in the case of a likely collision or conflict, control inputs are made to maneuver around the object. In this method, the images are processed in real time, several times per second. Advances in computer processors and technology provide small and lightweight processors to complete these tasks without increasing the weight of an aircraft significantly.

The next example is a small UAS that uses laser sensors to identify objects in its path. Similar to the video-processing system, the aircraft uses onboard computer processors to analyze the data obtained from the lasers and alter the aircraft's course as needed to avoid any obstacles.

On a larger scale, the FAA is implementing its NextGen air traffic management technology, as discussed earlier in this unit. A portion of this technology is of critical importance to the integration of UAS into the national airspace system. Automatic Dependant Surveillance-Broadcast (ADS-B) is a cornerstone technology within the NextGen initiative. ADS-B is a ground- and satellite-based system that receives position high-fidelity GPS data from aircraft and distributes that data to air traffic control facilities and other aircraft. Drones will be able to participate in this system by supplying their position data into the system. Drones also will be able to use data supplied from other ADS-B-equipped aircraft to anticipate any potential traffic issues and adjust flight paths as necessary to avoid collisions.

It's important to note these are just a handful of technologies, some still in development. Drones could rely on one of these, several of these, or even something that doesn't exist yet.

Slide 14: Drones will be equipped with cameras and will use algorithms to detect potential objects of collision. Show students an example of how video technology is being used on a UAS today.

- "Drone Autonomously Avoiding Obstacles at 30 MPH" (Length 2:29)
  http://video.link/w/dQMd

Slide 15: Some drones are being equipped with laser-emitting devices. Onboard computer processors analyze the data obtained from onboard lasers and alter the drone's course to navigate around objects. Show students an example of how lasers are being used on a UAS today.

- Autonomous robotic plane flies indoors at MIT (Length 2:47)
  http://video.link/w/eQMd

Slide 16: In the previous lesson, students learned how ADS-B is a key component to modernizing the air traffic control system.

Students should recall that ADS-B is a system in which electronic equipment on board an aircraft automatically broadcasts the precise location of the aircraft via a digital data link. The data allows other nearby aircraft and air traffic control to see what a broadcasting aircraft is doing, transmitting identity, altitude, velocity, and other relevant data without the need for radar.

Drones using ADS-B will be able to communicate their coordinates and altitude automatically with facilities on the ground and other aircraft, and use that information to keep out of the way of manned aircraft.

Slide 17: Introduce and explain geofencing technology.

Explain that geofencing, like ADS-B, relies on a drone's GPS technology. However, instead of communicating with other aircraft, it simply creates a "fence" around the airspace in which the drone is allowed to operate.

A geofence is a geographic, invisible fence established to keep an unmanned aircraft on one side or the other, just like a backyard fence either keeps the neighbor's dog out of your yard or keeps your dog in.

While a yard is simply two-dimensional, geofences can contain a third dimension and use altitude to ensure aircraft separation.

Slide 18: Geofences are created by determining a set of geographic coordinates (using latitude and longitude) and altitudes that define the area (zone) you would like to use to either contain the drone or prevent the drone from flying into.

In other words, geofencing can be used to 'fence off' a sensitive or restricted area (such as an airport or a prison). It also can be used to "fence in" a drone on a particular mission – for example, when mapping an agricultural field.

Students will experience how this is done in the student activity.

Slide 19: Show students a video from a drone manufacturer about how geofencing is incorporated into its products. This will conclude the first session of this lesson.

- DJI - Introducing the GEO System (Length 3:35)
  http://video.link/w/rQMd

Teaching Tips

Some of the content in the provided videos may be technically complicated. It is recommended that teachers watch them beforehand so as to be prepared for student questions.

EXTEND

Teacher Materials: Integrating Drones Presentation, Integrating Drones Teacher Notes
Student Material: Integrating Drones Student Activity

Slide 20: Conduct the Formative Assessment.

This activity and class presentations will cover the next two sessions of the class. Provide students with copies of **Integrating Drones Student Activity**. Emphasize that this is a hypothetical future scenario and that there are currently rules banning the flight of drones over people due to safety concerns.

Prepare students to share their solutions with the class at the conclusion of this activity.

Formative Assessment

In the activity called "Friday Night Drones," students will imagine they live in the near future when technological advances have made rules banning the flight of drones over people unnecessary. They will apply the sense-and-avoid and geofencing concepts to the operation of four drones. The drones will deliver food and beverages to spectators or record video/audio at a school football game.

Students will complete the following steps:

- Draw a map on graph paper of their high school football field and spectator area.
- Draw areas of operation for each drone.
- Indicate what technologies each drone will use to operate safely and avoid collisions.

Allow for a brief discussion where volunteers share their maps.

[DOK 3; *construct*, DOK 2; *organize, show*]

Teaching Tips

As an optional approach, consider having students complete this assignment in pairs or small groups.

Be sure to remind students at the beginning and end of this activity that this is purely hypothetical. Not only would it be a bad idea to try this in real life, it's illegal. The activity should lead students to conclude that the rule of not being able to fly drones near people or stadiums could be adapted as technology for drones is developed.

EVALUATE

Teacher Material: Integrating Drones Presentation

Slides 21-22: Conduct the **Summative Assessment**.

Summative Assessment

In the last 15-20 minutes of class, have students refer to the list of operating rules for drones on slide 22 and identify which of the rules might be eliminated due to sense-and-avoid (video, laser, ADS-B) and geofencing technologies. Students should explain their reasoning in several paragraphs.

Students should show an understanding of the purpose of existing rules and be able to show why the rules may be adapted or removed based on the technologies they have learned about in this lesson.

[DOK 3; *analyze*]

Summative Assessment Scoring Rubric

- Demonstrates understanding of purpose for existing rules
- Explains ways existing rules could be adapted in the future
- Describes technologies that may be available in the future
- Explains reason for adapting existing rule
- Student writing shows in-depth thinking, including analysis or synthesis of lesson objectives
- Student writing includes an organized explanation with correct grammar and spelling

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

GOING FURTHER

Using Google Earth, create a group of 3D polygons to “map” your proposed geofences around your sports facility. Use Google Search for assistance in creating 3D shapes within Google Earth.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-ETS1-1** – Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
    - 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
    - Systems and System Models
    - Influence of Science, Engineering, and Technology on Society and the Natural World

- **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
    - Constructing Explanations and Designing Solutions
  - Disciplinary Core Ideas
    - ETS1.C: Optimizing the Design Solution
  - Crosscutting Concepts
    - None
- **HS-ETS1-3** – Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
  - Science and Engineering Practices
    - Constructing Explanations and Designing Solutions
  - Disciplinary Core Ideas
    - ETS1.B: Developing Possible Solutions
  - Crosscutting Concepts
    - Influence of Science, Engineering, and Technology on Society and the Natural World
- **HS-ETS1-4** – Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
  - Science and Engineering Practices
    - Using Mathematics and Computational Thinking
  - Disciplinary Core Ideas
    - ETS1.B: Developing Possible Solutions and Actions
  - Crosscutting Concepts
    - Systems and System Models

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.

- **RL.9-10.4** – Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the cumulative impact of specific word choices on meaning and tone (e.g., how the language evokes a sense of time and place; how it sets a formal or informal tone).
- **SL.9-10.1.C** – Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
- **WHST.9-10.2** – Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
- **WHST.9-10.4** – Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **WHST.9-10.9** – Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

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