Autonomous Aircraft

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Appreciate the rich, global history of aviation/aerospace and the historical factors that necessitated rapid industry development and expansion. (EU1)

Aspire to the highest level of technical proficiency as it relates to flight operations and engineering processes. (EU4)

Develop an uncompromising safety mindset, understanding that growth and development in the aviation/aerospace industry must always be accompanied by responsive safety initiatives. (EU5)

ESSENTIAL QUESTIONS

1. What technologies have enabled the reduction of personnel needed to operate a complex commercial aircraft?
2. What evidence would it take to make you feel comfortable flying in an aircraft without a pilot?
3. How is autopilot technology similar to and different from fully autonomous flight?

LEARNING GOALS

Students Will Know

- Technology's role in reducing the number of pilots required to fly an aircraft
- Definition of autonomous aircraft
- Benefits of autonomous aircraft and challenges to making them mainstream

Students Will Be Able To

- *Summarize* how modern aircraft are enabled to fly through innovations in autonomy. (DOK-L2)
- *Explain* ways in which society will benefit from autonomous aircraft. (DOK-L2)
- *Create* a service utilizing an autonomous aircraft that would benefit society. DOK-L4)

ASSESSMENT EVIDENCE

Warm-up
Students will study a photo of five crewmembers on a flight deck. Solicit and summarize student ideas about each crewmember's role and duties.

Formative Assessment
Students will complete a video guide to learn about an autonomous aircraft in development and summarize the benefits of autonomy.

Summative Assessment
In small teams, students will create their own businesses utilizing an autonomous aircraft. Each team will make a five-minute presentation in an attempt to “sell” their aircraft to potential investors.

LESSON PREPARATION

MATERIALS/RESOURCES

- Autonomous Aircraft Presentation
- Autonomous Aircraft Student Activity 1
- Autonomous Aircraft Student Activity 2
- Autonomous Aircraft Teacher Notes
- Autonomous Aircraft Teaching Aid

LESSON SUMMARY

Lesson 1 – Supersonic Aircraft
Lesson 2 – Autonomous Aircraft
Lesson 3 – Electric Aircraft

This lesson begins by showing students a photo of an airline flight deck from the 1940s. Students will give their ideas on what each crewmember’s role and duties were. During a class presentation, students will learn that advances in technology reduced the workload previously placed on multiple crewmembers, to the point that we now have technology allowing for pilotless, or autonomous, aircraft.

Students will learn the concept behind autonomous aircraft, the difference between automatic and autonomous, different levels of autonomy, the benefits of autonomous aircraft and the challenges to making them mainstream. They also will explore, through video and Internet research, an autonomous aircraft in development.

Finally, students will work in small teams to develop their own businesses that provide a service of their choice through the use of an autonomous aircraft. Each team will make a five-minute presentation in an attempt to “sell” their aircraft to potential investors.

BACKGROUND

Pilots historically have operated aircraft. The Wright brothers flew their aircraft with a single aviator at the controls, but as aircraft became larger and more complex, the required flight crews grew to include three, four, or more crewmembers. Individual crewmembers served in the roles of pilot, co-pilot, radio operator, navigator, or flight engineer. In the latter half of the 20th century, as advances in technology caught up to the advances in aircraft design, the workload previously placed on multiple crewmembers was transferred to different aircraft systems like autopilots, radios, and navigation systems. By the end of the century, nearly all commercially operated aircraft were piloted by only two crewmembers. Today, the technology exists to operate an aircraft without a pilot on board.

Two different categories of autonomous aircraft are discussed in this lesson. As a review from Unit 1, semi-autonomous aircraft rely on a remote pilot to provide occasional input, problem-solving, and conflict resolution. By definition, a fully autonomous aircraft would not require any human intervention throughout a flight. In reality, a human likely will be involved in a fully autonomous aircraft if for no other reason than to tell the aircraft where to go initially. In the future, fully autonomous aircraft may be programmed to respond to inflight emergencies and avoid other air traffic.

For the purpose of this lesson, a fully autonomous aircraft is one that simply requires a human to program it, after which it is able to complete the entire flight on its own.

Autonomous aircraft provide several benefits over a piloted aircraft.

- Particularly today, airlines struggle to get enough qualified pilots to maintain flight schedules. Cost is always a driving factor in any aviation business, and using human pilots requires salaries, benefits, and training expenses. Reducing the number of pilots required to fly an aircraft, or eliminating them altogether, would relieve both demands.
- Advances in aircraft development and engineering have reduced the number of aircraft accidents to the point that the largest contributing factor to accidents is human error. Eliminating the human from the aircraft operation could reduce the accident rate even further.
- Additionally, some missions expose pilots to significant personal risk. Fighter pilots, weather research pilots, and even flight-test pilots are exposed to life-threatening risks. Autonomous aircraft performing those missions would result in less human exposure to risks.

The potential uses or missions for autonomous aircraft are limitless. Perhaps the most exciting is the evolving research in using autonomous aircraft for personal transportation. Our urban environments are clogged with surface-based transportation. It can take hours to travel short distances, all while emitting harmful pollutants into the atmosphere.

Uber is one company that is leading the charge for autonomous aircraft. Through their Uber Elevate project, the company wants to utilize small, electrically powered, autonomous aircraft to transport people throughout urban environments. For example, the commute from the Marina district in San Francisco to downtown San Jose currently takes one hour and 40 minutes by car or two hours and 12 minutes by train. Uber Elevate hopes to shorten that commute to 15 minutes. Recent studies show that residents in urban areas can spend over 200 hours a year commuting between home and work. That's a lot of time that could be more effectively used around the workplace or spent with the family at home. The impacts are even more impressive when you consider even more dense population centers around the world such as Mumbai, India, or São Paulo, Brazil.

To make this all happen, a couple of challenges must be overcome. First, autonomous aircraft will have to be safely integrated into the national airspace system, which means they will have to be able to "see and avoid" manned aircraft and other obstacles. This is just like a human pilot's ability to see another aircraft or obstacles in the sky and turn or climb to avoid them.

Second, passengers will have to become comfortable with readily boarding an aircraft that has no pilot on board. This may be the largest challenge facing the mainstream use of autonomous aircraft in passenger transportation.

MISCONCEPTIONS

Students may equate autonomous aircraft with unmanned aircraft. These definitions are independent. An autonomous aircraft likely will have people on board in the future.

LEARNING PLAN

ENGAGE

Teacher Material: Autonomous Aircraft Presentation

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

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

Warm-Up

Show students a photo of an airline flight deck from the 1940s. Ask them to study the photo and identify each crewmember with a brief written description of their role or duties.

Once students have written their answers, ask them to share their ideas with the class.

[DOK 2; *infer, predict,* DOK 1; *identify*]

Slides 5-9: Use the presentation to provide the answers about what each of the crewmembers on the flight deck actually did.

Navigator – The gentleman in the picture looks to be plotting the aircraft's course on a map. Perhaps he just determined a navigation fix by shooting stars and is noting that position on the map. In this era, navigators received different training and obtained different certification than that completed by pilots.

Captain – The pilot-in-command (PIC) of an aircraft is the person aboard the aircraft who is ultimately responsible for its operation and safety during flight. This would be the captain in a typical two- or three-pilot aircrew, or "pilot" if there is only one certificated and qualified pilot at the controls of an aircraft.

First Officer – The first officer is the second pilot (also referred to as the co-pilot) of an aircraft. The first officer is second-in-command of the aircraft to the captain. In the event of incapacitation of the captain or at the captain's discretion, the first officer will assume command of the aircraft.

Radio Operator – A radio operator refers to a person who is responsible for the operations of a radio and communications systems.

Flight Engineer – The flight engineer monitors and operates its complex aircraft systems. The position was sometimes referred to as the "air mechanic."

EXPLORE

Teacher Material: Autonomous Aircraft Presentation

Slide 10: Students just learned that up to five people were required to operate early passenger, cargo, and military aircraft. Ask students how many pilots they think are required to operate today's airliners.

Help students understand that in the latter half of the 20th century, advances in technology caught up to the advances in aircraft design, and the workload previously placed on multiple crewmembers was transferred to different aircraft systems such as autopilots, radios, and navigation systems.

Slide 11: Discuss among the class how the transition from a five-person flight crew to today's two-person crew took place.

The students may suggest many factors, and in fact the transition wasn't simply because of any one thing. However, the focus of this conversation should be technological advancements. The advances in radio technology, satellite-based navigation, solid-state computers, and advanced systems components allowed the duties performed by radio operators, flight engineers, and navigators to be consolidated and redistributed to the captain and first officer.

The following slides will highlight at least one technological advancement that contributed to that position no longer being necessary.

Slide 12: Early aircraft radios were large and significantly complicated to use, requiring specialized training and experience and a crewmember dedicated solely to their operation (radio operator). Operators often had to fine tune frequencies and make several adjustments to send or receive a clear message. Today's radios require a pilot to simply enter a frequency, either with a dial or, in newer units, a keypad and then press a button to transmit. The workload required to operate an aircraft radio today is a small fraction of what it was 75 years ago. In aircraft today, radio communications are performed by the captain or first officer.

Slide 13: Human navigators became obsolete when advanced computer navigation systems were developed. Even before satellite-based systems like GPS, there were other forms of navigation more accurate than humans determining an aircraft's position via the stars or simple pilotage and dead-reckoning.

Ground-based radio navigation aids placed around the country (like VORs students learned about in the first semester) provided guidance to aircraft in the air while onboard inertial reference systems sensed an aircraft's movement and calculated precise, up-to-the-minute location data.

Some military aircraft still utilize navigators. The navigation skills discussed earlier are still trained and tested, as the more sophisticated electronic means of navigation may be unreliable in a combat situation.

Slide 14: In early large aircraft, systems were incredibly complicated. Also, aircraft configurations with three, four, or more engines were not uncommon, whereas today the majority of large aircraft are twin-engine airplanes. All of these factors meant that significant time was spent by humans monitoring gauges and maintaining systems within their design specifications.

As technology advanced, individual systems became more autonomous, only alerting crewmembers when their attention is required. This level of autonomy in the aircraft systems allowed the monitoring workload performed by flight engineers to be assumed by the captain and first officer.

Almost all transport category aircraft in the United States have eliminated the requirement for a flight engineer.

EXPLAIN

Teacher Material: Autonomous Aircraft Presentation

Slide 15: Have students respond to the following two questions by writing at least one paragraph for each:

- How many pilots will airliners require in the future?
- Would you fly on an airplane without a pilot?
- What evidence would it take to make you feel comfortable flying in an aircraft without a pilot?

After the students complete their writing assignment, ask them to share their answers. Students are likely to draw the conclusion that because advances in technology have reduced the common aircrew size from five to two, it's reasonable to assume that as technology continues to evolve, airplanes eventually will not require pilots.

Slide 16: Ask students their thoughts on the differences between automatic and autonomous. Students may use an example of a car in their answers. Generally, the difference between automatic (or automated) and autonomous is the degree of human intervention. An automated car does not have the level of intelligence or independence that an autonomous car has. So "driverless" and "autonomous" are nearer to synonyms, as are "self-driving" and "automated." A truly autonomous car would decide on destination and route, as well as provide control within the lanes. An automated car would follow orders about destination and route, and might only adopt some lane-keeping or car-following guidance.

This is also true for automatic versus automated aircraft.

Slide 17: Provide students another example that describes automatic versus autonomous.

Automatic – Consider a common clothes-washing machine. Depending on the machine, a user may set the water temperature and type of items being washed, and press go. The washing machine will fill with water, start the wash cycle, drain, do a rinse cycle and then a spin cycle to partially dry the clothes. This is an automatic process, known as "automation." While a great time-saving invention, the washing machine is not intelligent. It does a fine job of completing the clothes-washing process as programmed, but what if something goes wrong? If the machine loses power, does it start over? What if a stain doesn't come out of the shirt? It doesn't apply stain treatment and start over.

Autonomous – What would it take to get that washing machine to step into the realm of autonomy? The machine could check the clothes hamper, ensure there are enough dirty clothes to make a load of laundry, combine the dirty clothes with soap and fabric softener, start the wash, rinse, spin, and then dry the clothes. After the clothes are dry, the machine could fold or hang them and put them in the closet or drawers. This machine would be considered autonomous: intelligent, self-aware, and capable of making its own decisions.

Slide 18: A semi-autonomous aircraft requires some input from a pilot or remote operator. Many unmanned aircraft systems (UAS) are semi-autonomous.

Are today's airliners semi-autonomous? A *New York Times* article states that pilots of Boeing 777 aircraft spend as little as seven minutes with their hands on the controls, flying the airplane. The rest of the time is spent monitoring while the advanced autopilot systems fly the aircraft along pre-programmed routes.

Slide 19: Fully autonomous aircraft will operate independently and without the assistance of an operator. A fully autonomous aircraft would have built-in fault detection and management and continuously monitor systems, and could take corrective actions when irregularities were discovered. Admittedly, "fully autonomous" is an unrealistic name, simply because for the foreseeable future a human always will be involved, if for no other reason than to input a destination.

Slides 20-21: To make this all happen, there are a couple of challenges that must be overcome. First, autonomous aircraft will have to be safely integrated into the national airspace system (NAS), which means they will have to be able to "see and avoid" manned aircraft and other obstacles, just like a human pilot can see another aircraft or obstacle in the sky and turn or climb to avoid them. In the previous section, students learned how "sense and avoid" technologies are being built into UAS in order to safely integrate them into the NAS.

Second, passengers will have to become comfortable with readily boarding an aircraft without a pilot on board. This may be the largest challenge facing the mainstream use of autonomous aircraft in passenger transportation.

Slides 22-23: Review several key benefits of autonomous aircraft with students:

Staffing – Relying on autonomous aircraft to conduct missions that would otherwise be executed by crewed aircraft could help relieve the current worldwide pilot shortage.

Costs – Autonomous aircraft have the potential to reduce costs by reducing the need for highly skilled operators.

Weight and payload – Autonomous aircraft could enable more efficient operations by reducing the need for crewmembers on board, which increases the aircraft's total weight and decreases the space available for extra cargo and passengers.

Safety – Because human error remains the leading cause of aircraft accidents, flight may become safer with automated aircraft. Automated aircraft also can take on the dangerous missions currently executed by crewed aircraft, as in fighting forest fires.

This will complete the first session of the lesson.

EXTEND

Teacher Materials: Autonomous Aircraft Presentation, Autonomous Aircraft Teacher Notes
Student Material: Autonomous Aircraft Student Activity 1

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

Formative Assessment

Show students a video that introduces them to the use of electric vertical takeoff and landing vehicles (eVTOLS).

- "Uber Elevate" (Length - 4:01)
  http://video.link/w/uu8f

Have students answer the questions on **Autonomous Aircraft Student Activity 1** after the video is complete. Time may be given to students to supplement their answers using Internet research. Finally, review student responses as a group.

Answers for the video guide can be found at **Autonomous Aircraft Teacher Notes**.

[DOK 3; *draw conclusions*; *investigate*]

EVALUATE

Teacher Materials: Autonomous Aircraft Presentation, Autonomous Aircraft Teaching Aid
Student Material: Autonomous Aircraft Student Activity 2

Slide 25: Conduct the **Summative Assessment**. This assessment will take the remainder of the second session and the complete third session.

Summative Assessment

In small teams, students will create their own business concepts using an eVTOL aircraft. The goal of this task is for students to apply the potential benefits of autonomous aircraft to a service these aircraft could perform in the future.

Split students into small teams and provide each with **Autonomous Aircraft Student Activity 2**. Each team is responsible for building a five-minute presentation that will impress potential investors (their classmates) so they will want to invest in their start-up company.

Encourage the teams to be creative in how they create and deliver their presentations (video, song, PowerPoint, etc.).

Each team must address the following in their presentations:

- Name their business.
- Describe the business and explain clearly how it will utilize eVTOL aircraft.
- Define the service(s) provided and how it is unique and different.
- Describe why the use of eVTOL for the service provided is beneficial over a traditional aircraft or other existing technology.
- Describe their target market and who will utilize their service.
- Describe ways in which society will benefit from this service.

As an example, students may describe a business that delivers blood between hospitals. The delivery would be fast (no ground traffic), inexpensive (no need to hire drivers or pilots), and could happen in any weather and at any time of the day (reduces human risk and improves safety).

Students will deliver their five-minute presentations in "Autonomous Alley." After all presentations are complete, students will rank their favorite three businesses, and the teacher will determine the winners.

Have a broader discussion with students about which services presented seem most realistic to be developed in the future and why. Ask students what innovations would need to be developed to make the service possible.

Use the grading rubric in **Autonomous Aircraft Teaching Aid**.

[DOK 4; *create*; *design*]

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 a 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
  - Crosscutting Concepts
    - Systems and System Models

COMMON CORE STATE STANDARDS

- **HSG.MG.A.1** – Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
- **RL.9-10.2** – Determine a theme or central idea of a text and analyze in detail its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.
- **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).
- **RST.9-10.2** – Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **RST.9-10.4** – Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
- **RST.9-10.7** – Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **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.9-10.6** – Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.**7 – Conduct short and more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- **WHST.9-10.8** – Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** – Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

https://www.nytimes.com/2015/04/07/science/planes-without-pilots.html?mcubz=1
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