Design an Airplane

Session Time: Seven, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The intended purpose and use of an aircraft drives aircraft design considerations and construction techniques, materials, and components. (EU1)

Innovations in aviation are driven by the desire to make aircraft safer, more capable, and more efficient. (EU3)

A deep understanding of how an aircraft operates enables a pilot to fly the aircraft to its maximum capabilities in both normal and abnormal situations. (EU5)

ESSENTIAL QUESTIONS

1. What considerations are used to determine if an aircraft has adequate equipment to achieve its intended purpose?
2. How does an aircraft's intended purpose impact its design?

LEARNING GOALS

Students Will Know

- What considerations need to be taken into account when designing an aircraft used for a specific purpose
- How the use of an aircraft impacts its design
- What systems, instruments, equipment, and other features are ideal for certain aircraft functions

Students Will Be Able To

- *Design* an aircraft with specific features that will be able to perform a specific role. (DOK-L4)

ASSESSMENT EVIDENCE

Warm-up
Students will answer Private Pilot Knowledge Test questions from previous lessons. These questions will jog students' memories and get them thinking about how the various aircraft components work together in particular designs to complete particular missions.

Formative Assessment
Students will work in pairs to create and present a poster that explains how a particular aircraft system and its components operate for different kinds of aircraft that perform specific missions. This assessment should take two sessions to complete: one to create the poster, and one to present their work to the class.

Summative Assessment

Students will divide into teams of 3 or 4. Each team will imagine it is launching a new aircraft company that will build a particular type of aircraft to serve a specific purpose or function. This assessment takes four sessions to complete and consists of two separate activities:

- First, teams answer a number of questions to help focus their thinking and write a one page "story" describing their proposed design.
- Then, teams first create a spreadsheet that explains how the major aircraft systems will be utilized and, as necessary, modified in their design. Teams then present their designs to the class and answer their classmates' questions.

LESSON PREPARATION

MATERIALS/RESOURCES

- Design an Airplane Presentation
- Design an Airplane Student Activity 1
- Design an Airplane Student Activity 2
- Design an Airplane Student Activity 3
- Design an Airplane Student Activity 1 Exemplar
- Design an Airplane Student Activity 3 Exemplar
- Design an Airplane Student Activity 3 Rubric
- Design an Airplane Teacher Notes 1
- Design an Airplane Teacher Notes 2
- Design an Airplane Teacher Notes 3

Formative Assessment

- Poster board
- Poster-making supplies (e.g., markers, colored pencils, construction paper, tape, glue)

Recommended Student Reading

- Pilot's Handbook of Aeronautical Knowledge
  Chapter Seven, Aircraft Systems, Chapter 7 https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/09_phak_ch7.pdf

LESSON SUMMARY

Lesson 1 - Design an Airplane

This lesson begins by engaging students' knowledge by quizzing them on what they have learned throughout the semester. The winner of the contest gets the first choice of aircraft system for the Formative Assessment (**Design an Airplane Student Activity 1**).

Next, students will review aircraft roles and missions (a topic they first studied in the first unit of the previous semester); by comparing and contrasting aircraft with similar roles and missions, students will consider how some aircraft are designed to achieve a very specific mission and how other aircraft are designed to be more versatile. Students will be encouraged to think about how the world today is changing and what kinds of aircraft that do not currently exist might be needed or desired in the future.

Students will then divide into pairs and begin the Formative Assessment. Each pair will focus on a single aircraft system; reviewing their notes from the course, they will consider how the system's components operate in general and how they may be modified to achieve a variety of specific missions. Students will then create a poster that explains these aspects of their chosen system and prepare a 5-minute briefing to explain their work to the class.

After a brief class discussion, students will divide into teams of 3 or 4 and begin work on their Summative Assessment. Each team will imagine it is launching a new aircraft company that will build a particular type of aircraft to serve a specific purpose or function. This purpose will drive the aircraft's overall mission, along with its intended use and targeted user (e.g., commercial pilot, cargo, surveillance, defense, transportation, recreation, military). Students will write a brief paper that tells the "story" of their aircraft and its mission. They will then develop a spreadsheet that explains how each system within their aircraft will be utilized or modified to suit the mission. Finally, teams will develop and deliver a presentation (approximately 1020 minutes, depending on the number of teams and the time available) that explains their design to the class. Following their presentation, teams will answer questions about their design from other students in the class.

BACKGROUND

The world today is constantly changing, and in turn so are aircraft designs, as manufacturers try to meet the demands of commercial, military, and recreational users. In time-sensitive environments, aircraft that can move extremely quickly are of utmost importance. When protection and military advantage are paramount, the ability to maneuver and strike quickly in harsh environments is critical. For the general commuting public, airlines are looking for ways to cut costs and gain efficiencies while pleasing their customers by delivering an enjoyable flying experience.

Every aircraft component and system should be considered when developing a new aircraft to meet a client's needs. In this lesson, it's up to students to bring together all they have learned and deliver a thoughtful, well-organized presentation of a new aircraft design that meets a particular demand.

MISCONCEPTIONS

Students may think that most new aircraft simply take existing aircraft and modify them slightly in order to meet a new demand. In fact, the level of redesign depends mainly upon the level of innovation required. Businesses typically have only a set amount to invest in research and development (R&D), so when only minor modifications are needed, existing blueprints and machining can typically be utilized in order to save both cost and time. When aircraft must achieve a truly innovative goal, however, engineers typically have to start from scratch and build from the ground up.

DIFFERENTIATION

To encourage motivation in the **ENGAGE** section of the lesson plan, place students into pairs (these can be the pairs they work in for the Formative Assessment in the **EXPLAIN** section of the lesson plan). The pairings can help increase participation and confidence among students who are struggling.

To promote student choice and creativity in the **EXPLAIN** section of the lesson plan, allow students to create something other than a poster. Depending on the resources available, students might create a slide presentation or webpage to illustrate the features of their selected system. Just remember that students should be able to use this Formative Assessment as a resource/reference for the Summative Assessment, so any digital presentations should be easily accessible.

LEARNING PLAN

ENGAGE

Teacher Material: Design an Airplane Presentation

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

Slides 4-58: Conduct the **Warm-Up Contest**.

Warm-Up Contest

Students will individually answer Private Pilot Knowledge Test questions from the lessons on aircraft systems in units 7 and 8 of this semester. These questions will jog students' memories and get them thinking about how the various aircraft components work together in particular designs to complete particular missions. There are 26 total questions (slides 6-57), but to conserve time consider selecting only half for the warm-up. Alternatively, consider dividing the class into two groups. The group that correctly answers the most questions wins.

For each question, students will raise their hands as quickly as possible. Whoever raises their hand first gets to answer first. If correct, the teacher will record a point. If incorrect, the student will lose a point. The student with the most points at the end wins. The winner gets their first choice of aircraft system to research for the formative assessment.

[DOK-L2; *describe*]

EXPLORE

Teacher Material: Design an Airplane Presentation

Slide 59: Provide students with a brief lesson overview.

- Review: This lesson will begin with a review of aircraft roles and missions; students will consider how some aircraft are designed to achieve a very specific mission, while others are designed to be more versatile and accomplish a range of goals. Encourage students to begin to think about the world today: how it is changing, and whether there is (or will be) a need for an aircraft that does not currently exist.
- Activity 1 (Formative Assessment): Following this review, students will divide into pairs. Each pair will focus on one of the main systems that students have studied throughout the semester, considering how the system and its components operate in general and how they would have to be modified to complete a particular mission or achieve a particular goal. Students will create a poster and prepare a brief presentation that answers these questions for the class.
- For the Summative Assessment, students will divide into small groups. Each group will imagine it is launching a new aircraft company that will build a particular type of aircraft to serve a specific purpose or function. This purpose will drive the aircraft's overall mission, along with its intended use and targeted user (e.g., commercial pilot, cargo, surveillance, defense, transportation, recreation, military, etc.).
    - Activity 2: Groups will begin by writing a one-page description that tells the story of their aircraft and its mission.
    - Activity 3: Each group will then develop a spreadsheet that explains how each individual system within its aircraft will be utilized or modified to suit the mission. Groups will then develop a presentation (approximately 10 to 20 minutes, depending on the number of groups and the time available) that utilizes additional media (posters, videos, slide presentations, computer renderings, 3-D printing, drawings, handouts, etc.) in order to make a compelling presentation. Each group will conclude its presentation by answering questions from other students in the class. All materials and the overall presentation will be considered together when calculating the final grade.

Teaching Tips

Consider encouraging students to get together outside of class to begin brainstorming ideas for both the Formative and Summative Assessments. The amount of time available in class may not by itself be sufficient for students to fully flesh out their ideas and complete the media for their presentations. You may even wish to assign such planning tasks as homework in order to keep students on track throughout this lengthy lesson.

Slide 60: To get students' creative juices flowing, view the following video, which offers a glimpse of 10 aircraft already being developed to meet various future demands. As students watch, they should identify the specific need and consumer base (e.g., military, space exploration, commercial aviation) for each new aircraft.

- "Top 10 Future Aircraft" (Length 4:37)
  https://video.link/w/fMhl

Slide 61: Remind students that aircraft are designed with particular roles and missions in mind; two aircraft that have different roles or missions may have very different designs. Aircraft may also be designed to complement each other as they work together to achieve mission success.

As they have learned throughout this course (particularly during the first semester, unit 1, section C, lesson 1), students can deduce the relationship between an aircraft's design and function by examining the aircraft's features. The following slides will review these relationships in the context of the U.S. military.

Slide 62: The U.S. military flies many different types of missions around the globe. In some cases, aircraft depend on synergy (the benefits that result from two or more agents working together to achieve something that cannot be achieved alone) to accomplish the mission.

Let's take a look at how different missions require different aircraft designs.

Slide 63: This slide shows a KC-135. Ask students:

- What do you think the mission of this aircraft is?
- How does the design reflect the mission?

Slide 64: The KC-135 is a refueling aircraft for the U.S. Air Force. Its primary mission is to extend the range and "on-station" time of other aircraft by allowing these other aircraft to refuel during flight. Mid-flight refueling allows smaller aircraft to travel greater distances and devote more time to achieving their missions.

Invite students to notice design features that reflect the KC-135's mission. For example, there are no windows in the fuselage because the airplane is primarily designed to carry fuel, not people. The aircraft is also equipped with a special refueling boom to deliver fuel to the smaller aircraft it serves. Some KC-135s can refuel two aircraft simultaneously.

Also notice that it has tapered, swept-back wings to reduce drag and allow it to fly at higher speeds. In fact, it can fly at 530 mph at 30,000 feet. The four large engines also contribute to its speed and its ability to carry heavy loads of fuel. The KC-135 can carry up to 83,000 pounds of cargo and take off at gross weight of up to 322,500 pounds.

Slide 65: This slide shows an E-3 AWACS. Ask students:

- What do you think the mission of this aircraft is?
- How does the design reflect the mission?

Slide 66: This aircraft serves missions related to C2ISR: Command & Control, Intelligence, Surveillance, and Reconnaissance. In short, it is the "eyes in the sky," containing many personnel and sophisticated equipment for conducting surveil operations.

More than most aircraft, the AWACS (Airborne Warning and Control System) has some very visible and unique features —most notably the large dome on the back, which provides radar coverage, typically to manage airborne traffic.

The aircraft itself is based on a modified Boeing passenger aircraft. It must be able to travel long distances and remain airborne for long periods of time, so range and endurance are important. Long, slender wings help increase fuel efficiency.

Slide 67: This slide shows an MQ-1 Predator. Ask students:

- What do you think the mission of this aircraft is?
- How does the design reflect the mission?

Slide 68: The Predator is an unmanned aircraft used for reconnaissance and to destroy targets. It is propeller driven and uses a combustion engine, which limits altitude and speed. However, the single engine also contributes to fuel efficiency for extended range. Students should note that it does not have a traditional cockpit because it is piloted remotely through a satellite link. Students should also note the weapons mounted under the wings. The aircraft's relatively small size makes it harder to see and detect.

Slide 69: The previous slides all showed examples of military aircraft with a specific role and mission. On a piece of paper, have students list as many other types of aircraft users and aircraft/missions as they can. Remind students that not every aircraft is precisely engineered for one specialized role or mission; many aircraft are designed to be versatile and adaptable to achieve a variety of missions for different users.

Teaching Tips

For the sake of organization, consider having students first name different user groups; as students name each user group, make it a row or column header in a table, as suggested below. Then, challenge students to identify two or three aircraft for each category; students can also identify each aircraft as specialized (labeled "s," below) or versatile (labeled "v," below). This should help to broaden students' understanding of the variety of specialized and versatile aircraft, and should encourage even greater creativity in their projects/presentations.

Possible Answers (sorted by user groups):

User	Mission	Examples of Aircraft		
Airlines	Move people and cargo	Boeing fleet (v)	Airbus fleet (v)	Regional RJ (v)
Military	Transport people and equipment, surveillance, fight	C-130 (very v)	B-2 (s)	KC-10 refueler (s)
Recreation	Personal travel, fun	Seaplanes (v)	Hot air balloon (s)	Gliders (s)
Space Agency	Exploration, science, military applications	Rockets (s)	Shuttles (s)	Satellites (v)
Cargo/Delivery	Move cargo	Boeing/Airbus (v)	Drone (s)	Smaller aircraft like Cessna Caravans (v)
Law Enforcement	Surveillance, Apprehension	Helicopters (v)	Small GA aircraft (Cessna 172) (v)	Drones (v)
Agriculture	Herding, spraying, Monitoring	Helicopters (v)	Drones (v)	Spraying aircraft (s)
Humanitarian Relief	Moving people and goods, often to places with damaged or non-existent infrastructure	Helicopters (v)	STOL (short takeoff and landing) airplanes (V)	Cessna Caravan

Other user groups might include pipeline surveillance, firefighting, news gathering, medical transport, etc.

EXPLAIN

Teacher Materials: Design an Airplane Presentation, Design an Airplane Teacher Notes 1, Design an Airplane Student Activity 1 Exemplar
Student Material: Design an Airplane Student Activity 1

Slide 70: Students will complete the **Formative Assessment**. This will likely require two sessions, one to create the poster and another for class presentations. If time is a concern, consider breaking students into groups of three or four for this activity to reduce the number of presentations and allow greater division of labor.

Formative Assessment

Distribute **Design an Airplane Student Activity 1**. Working in pairs, students will choose a particular aircraft system to analyze and present to the class. In addition to any remaining time in Session 1, this activity will likely take two full sessions to complete:

- Students will research an aircraft system and create a poster that explains how their chosen system and its components typically operate for different kinds of aircraft and how this system may be modified to allow aircraft to perform specific missions for different user groups.

- Each pair will present its poster to the class, giving a briefing (approximately 5 minutes) that explains the components of the system and the rationale for making particular choices (i.e., How does the chosen system help an aircraft to perform a particular mission?).

For additional guidance on completing this activity, see **Design an Airplane Teacher Notes 1**.

[DOK-L4; *analyze,* DOK-L2; *summarize*]

EXTEND

Teacher Material: Design an Airplane Presentation

Slide 71: Take time to discuss with students the following questions, based on the presentations from the previous activity:

- What did you learn that surprised you, either from your own system or someone else's?
- Which system seemed to be the most applicable across the various missions that aircraft perform?
- Which system had to be modified the most across the various missions that aircraft perform?
- Which mission or user group was the most challenging to apply your system to?

EVALUATE

Teacher Materials: Design an Airplane Presentation, Design an Airplane Teacher Notes 2, Design an Airplane Teacher Notes 3, Design an Airplane Student Activity 3 Exemplar, Design an Airplane Student Activity 3 Rubric
Student Materials: Design an Airplane Student Activity 2, Design an Airplane Student Activity 3

Slide 72: Students will begin preparing for the final activity, in which they imagine they are launching a new aircraft company that will build a particular type of aircraft to serve a specific purpose or function.

Divide students into teams of 3 or 4 members (or allow students to choose their own teams), and distribute **Design an Airplane Student Activity 2**. This activity consists of two parts:

- Teams will answer the planning questions to help them focus their ideas on a particular kind of aircraft with a specific mission.
- Teams will write a one-page "story" describing the new aircraft they plan to design.

For additional guidance as well as sample responses, see **Design an Airplane Teacher Notes 2**.

Slide 73: It is time for students to draw upon their systems knowledge and bring together all they have learned during this course, and reviewed during this lesson, to design their new aircraft. Students must consider what they have learned regarding aircraft systems, components, and other variables in order to determine what equipment, materials, and design features their aircraft will need. Remind students that some equipment they had planned to include may need to be discarded to save time, cost, and weight. Other equipment may be absolutely critical to safety or to the overall success of the mission; the design may need to change in order to accommodate this necessary equipment or incorporate a backup or contingency plan. Students should also consider cost as a critical element in their design: i.e., is one design more feasible, efficient, and cost-effective than another?

Remind students to use the posters they created in the first few sessions of this lesson as resources; these posters are handy “cheat sheets” for the systems they will be designing.

Slide 74: Students will complete the **Summative Assessment**.

Summative Assessment

Distribute **Design an Airplane Student Activity 3**. Working in teams of three or four, students will design an aircraft to complete a particular mission. This activity will take three full sessions to complete:

- Using the notes they have gathered throughout the course, teams will create a spreadsheet that identifies each pertinent system within their aircraft and explains how that system will be utilized or modified to suit the aircraft’s mission.
- Teams will develop a presentation (approximately 1020 minutes) that utilizes additional media to explain why a particular design would enable a new aircraft to complete its mission
- Teams will present their work to the class and answer their classmates’ questions.

Students will be assessed on all three parts, as well as on the one-page stories they drafted during the previous activity. Use the rubric detailed in **Design an Airplane Student Activity 3 Rubric** to assess students’ work, and be sure to share this rubric with students before they begin working on this activity.

For additional guidance on completing this activity, see **Design an Airplane Teacher Notes 3**. For an example of a completed spreadsheet, see **Design an Airplane Student Activity 3 Exemplar**.

[DOK-L4; *design,* DOK-L3; *investigate*]

GOING FURTHER

Slide 75: Conclude the lesson by having students express their ideas and opinions about the design process one last time. There are no wrong answers to the following questions; the goal is to generate excitement for the world of aviation and the possibilities that the future holds!

- What is one thing that you learned when developing your design and presentation?
- Was it easy or difficult to work as a team and incorporate everyone’s ideas into a single design?
- Of the presentations you saw, which aircraft and mission did you find the most compelling or persuasive?
- Of the presentations you saw, which aircraft do you think is most likely to be developed in the future?

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
        - ETS1.B: Developing Possible Solutions
        - ETS1.C: Optimizing the Design Solution
    - Crosscutting Concepts
        - Systems and System Models
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs 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
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
        - ETS1.B: Developing Possible Solutions
        - ETS1.C: Optimizing the Design Solution
    - Crosscutting Concepts
        - Systems and System Models

COMMON CORE STATE STANDARDS

- **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.9-10.8** - 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.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/09_phak_ch7.pdf
https://www.af.mil/About-Us/Fact-Sheets/Display/Article/1529736/kc-135-stratotanker/
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