# Aircraft Navigation

**Session Time:** One, 50-minute session

## DESIRED RESULTS

### ESSENTIAL UNDERSTANDINGS

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

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

### ESSENTIAL QUESTIONS

1. How has flight become more efficient with technological advancements in navigation?
2. How does enhanced flight navigation improve flight safety?

### LEARNING GOALS

**Students Will Know**

- The development of navigational techniques as it pertains to aviation
- The correlation between societal needs and the development of aviation navigation
- Basic map-reading skills for aeronautical charts

**Students Will Be Able To**

- *Investigate* and *identify* features of VFR aeronautical charts. (DOK-L3)
- *Hypothesize* what navigational technology might look like in the future. (DOK-L3)

## ASSESSMENT EVIDENCE

**Warm-up**
Students consider the evolution of navigation systems and possible future trends.

**Formative Assessment**
Students develop a navigation system for the future based on past and existing technologies.

**Summative Assessment**
Students complete a triple Venn diagram to compare past, present, and future navigation systems and technologies.

## LESSON PREPARATION

### MATERIALS/RESOURCES

- [Aircraft Navigation Presentation]
- [Aircraft Navigation Student Activity 1]
- [Aircraft Navigation Student Activity 2]

**VFR Chart Practice Activity (per student or small team)**

Acquire VFR sectional charts:

- Download them from the FAA: https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/vfr/
- Contact your local flight school; they might provide expired charts at no cost.
- Purchase sectional charts from an online pilot shop.

## LESSON SUMMARY

Lesson 1: Fly-by-Wire and "Glass" Cockpits

**Lesson 2: Aircraft Navigation**

Lesson 3: Composites and Structures

Students will be asked to discuss how they think navigation and its needs might have changed over the years and consider how aircraft navigation will change in the future.

Students will then explore navigation using VFR Sectional Aeronautical Charts. An activity will guide them as they learn how to read and interpret the chart. In the "explain" section of the lesson, teachers will guide students through the development of navigation technology, discussing how it has advanced to meet society's needs. Students will extend their learning by working in small groups and brainstorming ideas for a future navigation system. They will present their ideas to the class.

Finally, students will complete a triple Venn diagram to compare past, present, and future navigation systems and technologies.

## BACKGROUND

Throughout aviation history, innovations in aircraft navigation have changed how we fly. Aircraft navigation is critical for safety and allows pilots to fly efficiently from one location to another other. The rise in air travel and the increasing number of aircraft in the skies have created a need for more sophisticated navigation systems, in part to keep aircraft separated from one another in flight.

Visual navigation is the most basic means of navigation. The first pilots flew by simply looking out their windows for visual landmarks--a technique called pilotage that is still in use today. Early pilots sometimes used automobile maps as guides. Today pilots have access to specialized maps designed for aerial navigation. In this lesson, students will learn about navigation using sectional charts, a type of aeronautical chart used by pilots to fly by visual flight rules (VFR). These charts show topographical features and man-made objects that can be seen from the sky, such as lakes, major roads, railroad tracks, airports, mountains, towers, and other features. The charts also provide information about radio frequencies, the mileage scale, restricted areas, obstructions, controlled airspace, and other features affecting navigation and communication. More information will be presented on these charts in upcoming courses.

Flying visually works fine in good weather during the daytime but can be difficult or impossible in bad weather and at night. In 1919, the U.S. Army Air Service began to use bonfires for nighttime navigation because airmail operated around the clock. Soon after, the government built the transcontinental airway system that included a series of lighted airway beacons across the country. (Refer to Unit 3, Section A, Lesson 3 Airmail and the Transcontinental Airway System.) Next came lighted airport boundaries, spot-lit windsocks, and rotating beacons on towers. As aircraft became more widely used, the government developed regulations about landing fields, lighting, and other visual contact methods. By 1926, new technologies had developed to allow two-way communications between pilots and ground crews. The first use of aircraft guided by onboard instruments, necessary for operating in bad weather or night conditions when the pilot cannot see the ground below, occurred in 1929.

An airmail pilot, Elrey Borge Jeppesen, realized that road maps did not provide enough information for pilots and started creating his own aeronautical maps by writing down details that he could refer back to in a loose-leaf notebook. He obtained information from farmers, surveyors, and roadmaps, and he included his own observations from personal experience. Other pilots expressed interest in using his charts and Jeppesen decided to print them. He compiled his charts into a manual, which he printed in his basement, and sold copies for $10 each. The Jeppesen company (now a part of Boeing) and aeronautical charts were born.

World War II sparked many advances in aviation navigation technology that carried into civilian aviation. After 1946, very-high frequency (VHF) and VHF omnidirectional range (VOR) airways became available to civilian pilots, who could now navigate by watching dials on their instrument panels rather than flying by sight or listening to radio signals. Adding distance-measuring equipment to navigation systems allowed pilots to confirm their positions in relation to how far they were from known checkpoints. A Doppler radar version made this technique more accurate over longer distances.

Another transition in navigation took place in 1967 when the Federal Aviation Administration (FAA) partnered with the National Aeronautics and Space Administration (NASA) to demonstrate the use of satellites to transmit data from aircraft to ground stations. From there, antennas were developed for aircraft to send and receive satellite messages.

As technology has advanced, some systems and instruments have become obsolete. The last federal airway light beacon ended in 1973 (although the state of Montana still operates a few). The 1980s saw new radio navigation aids equipped with solid-state construction. In the 1990s, the Free Flight Concept allowed pilots to choose the most efficient routes instead of following prescribed routes.

Today, navigation and aircraft surveillance in the United States is focused on Global Positioning System (GPS) technology and completing the Next Generation Air Transportation System (NextGen). NextGen will be able to track aircraft reliably and eventually replace the ground-based radar systems currently used. Other countries are developing similar systems. Some countries, such as Australia, already require Automatic Dependent Surveillance-Broadcast, or ADS-B, to monitor aircraft within certain airspace. The United States will require all aircraft flying in the busiest airspace to be equipped with ADS-B by 2020.

## MISCONCEPTIONS

The focus of this lesson is on aircraft navigation and how it has evolved based on the need to go further, faster, and more safely. Students need to understand that this type of technology is not static.

Some students may be unfamiliar with the way radar works, or the way satellites work in terms of sending and receiving signals, so ensure they understand these concepts as they are discussed in the lesson.

## DIFFERENTIATION

To support verbal reasoning in the class discussion during the **EXTEND** section of the lesson, organize the class into groups for Think-Pair-Share instead of a whole group discussion. This allows learners to think about the question, and discuss their thoughts with a partner before sharing with the larger group. Sharing encourages all students to participate and practice skills.

# LEARNING PLAN

## ENGAGE

**Teacher Material:** Aircraft Navigation Presentation

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

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

Students speculate about the evolution of navigation systems and possible future trends. Questions are provided on slide 4. Allow up to five minutes for the warm-up. Collect student work. [DOK 2; predict, DOK 1; state]

**Warm-Up**

Ask students to write how they think navigation has changed over the years with the introduction of cars, aircraft and other technology. They should also predict how navigation needs may continue to develop. Ask volunteers to shares their responses and allow for a brief class discussion.

**Questions**

Sample student responses:

How do you think navigation has changed over the years with the introduction of cars, aircraft, and other technology?

*Satellite navigation (GPS) has probably been the biggest game-changer. Higher-powered radios can also transmit much farther and in more remote locations.*

How might aircraft navigation needs continue to develop?

*They will have to accommodate more airplanes in the sky and safely integrate drones. People also may one day be in autonomous flying vehicles (like self-driving cars, but they are aircraft). If this occurs, then the navigation system may have to function without a human operating it.*

## EXPLORE

**Teacher Material:** Aircraft Navigation Presentation
**Student Material:** Aircraft Navigation Student Activity 1

**Slide 5**: Students will learn the basics of reading a VFR (visual flight rules) sectional chart, which is an aeronautical chart used by pilots to fly by visual reference. These charts help pilots navigate by referencing topographical features and man-made objects that can be seen from the sky, such as lakes, major roads, railroad tracks, airports, mountains, towers, and other features. Aeronautical information on a sectional chart includes radio frequencies, the mileage scale, airports, restricted areas, obstructions, areas of controlled airspace, other features affecting navigation and communication. The act of using topographical features, man-made objects, and checkpoints to navigate is called pilotage. More information will be presented on these charts in upcoming courses.

**Slide 6**: VFR stands for "visual flight rules." VFR Sectional Aeronautical Charts, often referred to as simply, "sectionals" or "VFR sectionals," help pilots navigate by reference to features of the landscape below, including natural objects such as lakes and man-made objects such as towers, railroad tracks, and airports. These features are indicated on the charts.

**Slide 7**: Ask students to identify features that they see using the sectional chart on the slide. They may indicate they see water, an airport, elevated terrain, etc.

**Slide 8**: Provide students with samples of VFR sectional charts and Aircraft Navigation Student Activity 1. Students can work with partners or individually. The following are ways to acquire sectional charts for your students:

- Download them from the FAA: https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/vfr/

- Contact your local flight school; they might provide expired charts at no cost.
- Purchase sectional charts from an online pilot shop.

The “*FAA Aeronautical Chart User’s Guide*” will help decode chart symbology: https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/aero_guide/

## EXPLAIN

**Teacher Material: Aircraft Navigation Presentation**

**Slide 9**: Ask students to recall other ways pilots navigated that were mentioned in previous lessons (i.e. beacons and arrows).

**Slide 10**: Early airmail pilots had the difficult task of flying long distances, both day and night, with very few navigational aids. During nighttime hours, they used bonfires and later lighted airways to find their way. During the day, they looked out the window for familiar landmarks. Many of these pilots used road maps to help them find their way, but these did not provide enough detail to help pilots navigate efficiently in unfamiliar territory. One airmail pilot, Elrey Borge Jeppesen, decided to solve this problem by making detailed notes in a loose-leaf notebook that he could refer to on his flights. He collected as many details as he could find, gathering and recording information from farmers and surveyors, as well as his own observations. Other pilots learned of his work and asked to purchase his charts. Jeppesen and his wife compiled the charts into manuals, which they printed in their basement and sold for $10 each. Eventually, Jeppesen stopped flying and focused just on his aeronautical chart business. Today, the Jeppesen company is a subsidiary of the Boeing Company.

**Slide 11**: Visual navigation has been used since the earliest days of aviation, and is still relevant today. Known as pilotage, this form of navigation allows pilots to look at the landscape below and navigate based on what they see, including topographical features like lakes and man-made features like railroad tracks. Pilots using pilotage to navigate must be able to see the ground, making it most effective in good weather, at low altitudes, and when flying at slow to medium speeds. Pilots flying by pilotage must be operating under visual flight rules (VFR). The maps pilots use for this type of navigation are called VFR Aeronautical Sectional Charts.

**Slide 12**: As discussed in Unit 3, there was a need to transport mail more efficiently, so airmail pilots began flying at night as well as during the day. To make this possible, new tools were developed for nighttime navigation. In 1919, the U. S. Army Air Service began to use bonfires to help pilots find their way in the dark. Soon after, the government built the transcontinental airway system that included a series of lighted airway beacons across the country. Next came lighted airport boundaries, spot-lit windsocks, and rotating beacons on towers. Each of these developments helped improve safety and efficiency.

**Slide 13**: As aircraft became more widely used, regulations were developed to help keep pilots and passengers safe. These regulations were designed to standardize operations and help prevent mid-air collisions and improve navigation. By 1926, two-way radio communication was allowed pilots to talk to ground crews. The first use of aircraft guided by onboard instruments, necessary for operating in bad weather or night conditions when the pilot cannot see the ground below, occurred in 1929.

**Slide 14**: Very high frequency (VHF) omnidirectional range (VOR) airways allowed pilots to navigate by watching an instrument on their instrument panel rather than listening to a radio signal or looking out the window. These ground-based navigation aids made it easier than ever to navigate from point to point in bad weather or darkness. The advancement of radar during World War II had a significant impact on aviation. Radar is “seeing” with radio waves and was used to navigate at night and through fog, locate enemy ships and aircraft, and to track storms. The addition of distance measuring equipment made it possible for a pilot to pinpoint his or her location. The later development Doppler radar technology made measuring more accurate over longer distances. Doppler radar bounces microwaves off an object and times the return signal to provide information on the target object’s distance, direction, and velocity.

**Slide 15**: The Global Positioning System (GPS ) is a radio-navigation system that sends signals between satellites and ground stations to determine position. GPS is operated by the Department of Defense. GPS allows for greater accuracy and better navigational coverage across the country.

**Slide 16**: Automatic Dependent Surveillance-Broadcast (ADS-B) is a newly developed technology that utilizes GPS.  ADS-B provides much more accurate information on location of aircraft, even in remote areas. It also and makes it easier for aircraft to share location information, helping to prevent midair collisions. In some countries, including Australia, ADS-B is already mandatory. By 2020, all aircraft flying in busy U.S. airspace will have to have this technology.

**Slide 17**: This slide summarizes the content of this lesson in order to help students consider what technologies might be developed in the future. Over time, advances in navigation have been developed to improve efficiency, accuracy, and safety. Will these continue to be the goals of future advancements? How might those goals be achieved?  Ask students to consider this and what would further improve aviation safety in the U.S. airspace, including the integration of unmanned aircraft systems (drones).

## EXTEND

**Teacher Material:** Aircraft Navigation Presentation

**Slide 18**: Conduct the **Formative Assessment.**

Allow groups to share their work with the class. Take no more than 10 minutes for this assessment. [DOK 4; create; DOK 2; show]

**Formative Assessment**

In groups of 2 to 3, have students develop a navigation system for the future based on past and existing technologies. Student work should include 4-5 sentences.

Students should consider:

- Societal needs: What navigation needs do you think there will be in the future? It might help to think about the new types of aircraft in the air, such as unmanned aircraft systems (UASs), as well as increasing air traffic..
- Emerging technologies: How might the newer technologies that we use today be applied to aviation?
- Where are we going? What advancements in navigation might be needed to help us get there?

## EVALUATE

**Teacher Material:** Aircraft Navigation Presentation
**Student Material:** Aircraft Navigation Student Activity 2

**Slide 18**: Conduct **Summative Assessment**.

Ten minutes before the end of class, give each student a copy of Aircraft Navigation Student Activity 2. Have students read the directions carefully and work individually. Allow them to use their notes. Collect student work at the end of class and grade using the Scoring Rubric. [DOK 4; synthesize, DOK 3; differentiate]

**Summative Assessment Scoring Rubric**

Follows assignment instructions
Student work shows evidence of one or more of the following:

- An understanding of the development of flight navigation
- An ability to draw comparisons between past, present, and future aviation navigation systems
- An understanding of aeronautical charts

Student work shows overall 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 | Consistently demonstrates criteria |
| 7-8 | Usually demonstrates criteria |
| 5-6 | Sometimes demonstrates criteria |
| 0-4 | Rarely to never demonstrates criteria |

**Summative Assessment**

Students complete a triple Venn diagram to compare past, present, and future navigation systems and technologies.

## GOING FURTHER

For students seeking more information on learning to fly under visual flight rules:

https://www.aopa.org/news-and-media/all-news/2008/april/flight-training-magazine/basic-vfr

## 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

## COMMON CORE STATE STANDARDS

- **HSN.Q.A.2 -** Define appropriate quantities for the purpose of descriptive modeling.
- **HSA-REI.B.3** - Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **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.
- **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 as well as 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.

STANDARDS FOR MATHEMATICAL PRACTICE

- **MATH.PRACTICE.MP4** - Model with mathematics
- **MATH.CONTENT.HSN.Q.A.1** - Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas.
- **MATH.CONTENT.HSN.Q.A.3** - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

## REFERENCES

https://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/amt_airframe_handbook/media/ama_ Ch11.pdf
http://www.centennialofflight.net/essay/Government_Role/navigation/POL13.htm
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