# Fly-By-Wire and "Glass" Cockpits

**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. In what ways has technology improved flight safety?
2. What determines when an innovation in aircraft design or the arrangement of flight tools is needed?

### LEARNING GOALS

**Students Will Know**

- How human factors affect the design of flight tools
- Improvements to safety and efficiency due to technology advancements in avionics and flight controls.

**Students Will Be Able To**

*Explain* how the "glass cockpit" and fly-by-wire helped pilots fly the airplane better and safer. (DOK-L2)

## ASSESSMENT EVIDENCE

**Warm-up**
Students will be given several "apps" to arrange on a simulated cell-phone screen on paper. They will write a short explanation of why they chose their apps and arrangement.

**Formative Assessment**
Students consider which instruments are most essential for all flights and provide support for their reasoning.

**Summative Assessment**
Students imagine they are an exhibit designer in a museum of flight, 100 years from now and design an exhibit on some of the improvements to flight safety and efficiency that were developed in the late 20th century.

## LESSON PREPARATION

## MATERIALS/RESOURCES

- Fly-by-Wire and Glass Cockpits Presentation
- Fly-by-Wire and Glass Cockpits Student Activity 1
- Fly-by-Wire and Glass Cockpits Student Activity 2

## LESSON SUMMARY

### LESSON SUMMARY

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

Lesson 2: Aircraft Navigation

Lesson 3: Composites and Structures

In this lesson, students will learn about glass cockpits, as well as the transition to fly-by-wire technology. Glass cockpit technology transitioned many different aircraft instruments and dials to be placed on a computer screen, allowing pilots to have a more central location for finding crucial flight information and to have flexibility in the flight instruments and dials in view of the pilot. Fly-by-wire technology made flight physically easier and safer once computers were added to aircraft.

To teach students about these transformative technologies, there is an engagement activity where students will select from a variety of cell phone or computer apps to place on their fictitious screens. They will discuss why they chose the apps they did and why they located apps in different places on their screens. For many students, frequency of use and convenience will be their reasons. This is similar to the development of glass cockpits, which allows for the same type of flexibility.

A presentation will lead students into discussion about glass cockpits and how its development has changed how pilots fly, connecting students' prior knowledge about their own use of cell phone/computer apps with glass cockpit technology. Students will be divided into groups and asked to become experts on the instruments in the "six pack" of standard aviation instruments found in an aircraft's cockpit. They will use suggested Internet links or conduct research on their own to complete this task. Each group will share information about their instrument with the rest of the group. Students will take notes on all of the instruments. Then, as a group, they will discuss the importance of each instrument, along with where the instruments should be placed based on importance and frequency of use.

Next, students will take notes on fly-by-wire technology and discuss how this advancement made flight safer and more efficient. This can be completed as a class discussion or in small groups.

Finally, students imagine they are an exhibit designer in a museum of flight, 100 years from now and design an exhibit on some of the improvements to flight safety and efficiency that were developed in the late 20th century.

## BACKGROUND

Aviation's story continues to develop along with technological advancements, global needs, and increased awareness of human impact on our planet. While there seem to be new ideas and improvements every day, several points in aviation history came with certain advancements that marked distinct shifts in how we fly and navigate through the sky—aircraft design changes including fly-by-wire technology and glass cockpits, utilization of composites in aircraft, stealth, and other specialized technology, and major shifts in aircraft navigation. The following unit takes a look at these advancements and their impact on aviation and society.

Earlier aircraft were controlled via heavy, complex mechanical linkages. This made flight a physically exhausting and often unsafe undertaking. However, in 1972 NASA research pilot Gary Krier became the first pilot to fly a fly-by-wire, or FBW, aircraft. Fly-by-wire technology—originally developed to help maneuver the Apollo lunar module—takes a pilot's actions in the cockpit and turns them into electrical signals, which computers then use to move the aircraft control surfaces and thereby fly the aircraft. The pilot no longer moves actuators connected to cables, for example. Instead, an electronic signal from movement of the yoke or stick tells the computer to command an actuator adjustment. These same computers also monitor a pilot's actions, making sure his or her commands are within acceptable limits. Flight has become safer with the oversight of this computer technology. In the 1980s, commercial aviation adopted fly-by-wire technology—still used today—and it changed the landscape of flight.

"Glass cockpits" were introduced in the 1980s, altering how pilots fly. Before glass cockpits, individual dials and indicators were placed in the cockpit, forcing the pilot to study each readout and look at many different locations in the cockpit. Indicators were limited to space within the cockpit. With the introduction of glass cockpits, digital readouts of several indicators could be placed on one screen. This screen also allows the user to select the indicator arrangement based on frequency and importance of use. This increases both pilot efficiency and pilot safety. Other visual contact methods also emerged. By 1926, new technologies to allow two-way communications between pilots and ground crews began to develop. The year 1929 saw the first use of aircraft guided by onboard instruments.

World War II sparked many advances in aviation navigation technology that carried into civilian aviation. Very high frequency (VHF) and VHF omnidirectional radio (VOR) airways started to be utilized more after 1946. Pilots could navigate by watching dials on their instrument panels rather than flying by sight or listening to radio signals. The addition of 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 for 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 was closed 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. And now, future navigation and aircraft surveillance in the United States is focusing on adopting 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 in use today. 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.

Many of the developments discussed in this unit, as well as in many other sections of this course, have taken place due in large part to human factors. Human factors are the ways people react physically and psychologically to environments or situations. Human factors have a large part to play in the development of aviation technologies. While innovations are exciting and advance science and engineering, how humans interact with technology is crucial and often guides technological development. It is important to keep this in mind as we look at where developments started, where they might be headed, and why.

## MISCONCEPTIONS

There may be misunderstandings about how aircraft were flown before fly-by-wire technology and how aircraft indicators function. Glass cockpits are only digital representations of actual flight indicators (which are still a part of the aircraft), and students may think a glass cockpit replaces the need for indicators. In reality, the glass cockpit replaces the dials that display readouts from the indicators.

## DIFFERENTIATION

To promote reflective thinking and guided inquiry in the **EXTEND** section of the lesson plan, circulate around the classroom and assist students who might have trouble coming up with ideas identifying the two most necessary instruments. Ask questions that provoke their own ideas for possible answers.

## ENGAGE

**Teacher Material:** Fly-by-Wire and Glass Cockpits Presentation
**Student Material:** Fly-by-Wire and Glass Cockpits Student Activity 1

**Slides 1-3:** Introduce the topic and learning objectives for today's lesson.

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

Provide students with the **Fly-by-Wire and Glass Cockpits Student Activity 1.**

After students have chosen and arranged their apps, place them in groups of three to five. Give each group three minutes to discuss their choices and arrangements, and decide whether there is such a thing as a "best" choice and arrangement of apps.

After groups have discussed, ask them to share their thoughts. Guide them to understand that there is no single "best" choice or arrangement for apps; the "best" setup depends on the context and use. Point out that one benefit to smartphones is that they provide the flexibility for each user to arrange his or her own interface in the most effective way for them. [DOK 3; assess, develop a logical argument]

**Warm-Up**

Students will be given several "apps" to arrange on a simulated cell-phone screen on paper. They will then write a short explanation of why they chose the apps and arrangement they did.

## EXPLORE

**Teacher Material:** Fly-by-Wire and Glass Cockpits Presentation

**Slides 5-9:** These slides provide information about cockpit instrumentation and the development of glass cockpits. The information derived from the "six pack" (i.e., airspeed, altitude, airplane attitude) is translated onto a glass cockpit display. However, the information included on a glass cockpit display does not have to be limited to data from the six pack (i.e., fuel quantity, oil temperature, engine parameters). This section of the lesson explains how glass cockpits work and ties into the earlier engagement activity. Students will be asked to relate how their own needs and interests—in relation to their cell phones, tablets, or computers—compare with glass cockpits.

Before glass cockpits, individual dials and indicators were placed in the cockpit, forcing the pilot to study each readout and look at many different locations in the cockpit. Indicators were limited to space within the cockpit. With the introduction of glass cockpits, digital readouts of several indicators could be placed on one screen. This screen also allows the user to select the indicator arrangement based on frequency and importance of use. This increases both pilot efficiency and pilot safety. Other visual contact methods also emerged.

**Slide 10:** Conduct the **Formative Assessment.**

Students will decide which two of the "six pack" instruments are the most essential for all flights and defend their reasoning. [DOK 3; cite evidence, compare]

Sample reasoning:

*The altimeter and airspeed indicator are required for both visual and instrument flight because they provide the most critical information required for safe flight.*

*Pilots need to know their altitude to avoid obstacles and comply with ATC instructions. The airspeed is critical to ensure a safe flying speed is maintained, assisting in avoiding a stall.*

*The other four of the typical instruments are not required for flight by visual reference, but only required when flying in clouds or low visibility. Pilots flying visually use sight and feel in place of the other instruments. A pilot can obtain the same information that the artificial horizon and the turn-and-slip indicator present by looking out the window at the horizon and by feeling the forces of flight in his or her seat. The magnetic compass and outside visual references found on charts can replace the need for a more accurate directional gyro that is required for instrument-based flying. The last instrument typically found is the vertical speed indicator, or VSI. This instrument is not actually legally required at all, but it will greatly enhance the pilot's ability to fly accurately in an instrument environment.*

*In a visual flying environment, the pilot spends the majority of time flying by visual references, significantly reducing the reliance placed on flight instruments.*

**Formative Assessment**

Working in small groups, have students consider which two of the "six pack" instruments are most essential for all flights. Students should write one to two paragraphs defending their choices, providing support for their reasoning.

## EXPLAIN

**Teacher Material:** Fly-by-Wire and Glass Cockpits Presentation
**Student Material:** Fly-by-Wire and Glass Cockpits Student Activity 2

**Slides 11-14:** Many of the developments discussed in this unit, as well as in many other sections of this course, have taken place due in large part to human factors. Human factors are the ways people react physically and psychologically to environments or situations. Human factors have a large part to play in the development of aviation technologies. While innovations are exciting and advance science and engineering, how humans interact with technology is crucial and often guides technological development. It is important to keep this in mind as we look at where developments started, where they might be headed, and why.

The slides will lead the teacher to setting-up the **Fly-by-Wire and Glass Cockpits Student Activity 2** where students will be given a list of the "six pack" instruments found in a standard cockpit.

**Teaching Tips**

During the discussion on slide 13, break students into small groups to answer the questions prior to a large group discussion.

## EXTEND

**Teacher Material: Fly-by-Wire and Glass Cockpits Presentation**

**Slides 15-17:** Fly-by-wire technology—originally developed to help maneuver the Apollo lunar module—takes a pilot's actions in the cockpit and turns them into electrical signals, which computers then use to move the aircraft control surfaces and thereby fly the aircraft. The pilot no longer moves actuators connected to cables, for example. Instead, an electronic signal from movement of the yoke or stick tells the computer to command an actuator adjustment. These same computers also monitor a pilot's actions, making sure his or her commands are within acceptable limits. Flight has become safer with the oversight of this computer technology. In the 1980s, commercial aviation adopted fly-by-wire technology—still used today—and it changed the landscape of flight.

**Teaching Tips**

To wrap up the discussion on slide 17, show students the video "Airbus Fly By Wire" (Length 2:40) http://video.link/w/dNMd

## EVALUATE

**Teacher Material:** Fly-by-Wire and Glass Cockpits Presentation

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

Students should imagine that they are an exhibit designer in a museum of flight, 100 years from now. They are designing an exhibit on some of the improvements to flight safety and efficiency that were developed in the late 20th century. They are focusing on two technologies: fly-by-wire and glass cockpits. They should write in an engaging way that would be understandable and appealing to someone at a museum. [DOK 2; summarize, construct]

**Summative Assessment Scoring Rubric:**

- No more than two paragraphs for each technology. (1 point per technology)
- Answer explains how each technology changed flight. (1 point per technology)
- Answer explains how each technology improved safety. (1 point per technology)
- Answer provides evidence to support each explanation. (1 point per technology)
- Text is clearly written and understandable to the general public. (1 point per technology)

| 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 should write no more than two paragraphs about each fly-by-wire and glass cockpits (no more than four paragraphs total) for the exhibit display. Their paragraphs should explain how the technology changed flight and improved aviation safety.

## GOING FURTHER

Possible writing prompts

- Do you think a talented pilot or a fully digital fly-by-wire control system would do a better job at flying an aircraft? Explain your thoughts, providing examples to support your position.
- Create a science fiction short story where a fully digital fly-by-wire control system exists for aircraft.
- What future technology advancements can you think of that one day may exist to build on fly-by-wire technology? Think about flight categories such as safety, fuel efficiency, navigation, and expanding opportunities for more people to pilot aircraft, among other possibilities.

## STANDARDS ALIGNMENT

### NGSS STANDARDS

- **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

### 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.
- **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.

## REFERENCES


https://www.nasa.gov/vision/earth/improvingflight/fly_by_wire.html

https://www.youtube.com/watch?v=N4PuNOeUDYE

https://www.nasa.gov/centers/langley/news/factsheets/Glasscockpit.html

https://airandspace.si.edu/exhibitions/america-by-air/online/jetage/jetage17.cfm

https://www.ntsb.gov/safety/safety-studies/Documents/SS1001.pdf

https://www.thebalance.com/aircraft-flight-instruments-the-basic-six-pack-282852

https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/advanced_avionics_handbook/media/aah_ch02.pdf