CHRONICLES OF COURAGE
Stories of WARTIME AND INNOVATION

"Fw 190"

STEM Lesson Plan for Grades 7-12
Developed by the National Science Teachers Association
Access the Videos at NBCLearn.com/courage

"… there wasn't a manual or anything. And we were told, you see: 'Boys, take a plane and then go up and do what you want with it'."

—Feldwebel Erich Brunotte, Luftwaffe fighter pilot of the Bf 109 and the Fw 190

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Video Preview

"Fw 190," is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation.* The Focke-Wulf Fw 190 and the Bf 109 were the mainstay German fighter aircraft during World War II. Developed after its well-known counterpart the Bf 109, the Fw 190 was fitted with a radial, air-cooled engine because most production of liquid-cooled, inline engines had been allocated to other aircraft. Late in the war, the Fw 190 was updated with an inline engine requiring changes to the aircraft's design.

Time	Video Content
0:00–0:16	Series opening
0:17–1:00	Erich Brunotte and his airplane
1:01–1:37	Meet the Fw 190
1:38–3:00	Even the best can be made better
3:01–4:19	The importance of balance
4:20–5:16	Too few to change the outcome
5:17–5:32	Closing credits

Video Voices—The Experts Tell the Story

By interviewing people who have demonstrated courage in the face of extraordinary events, the *Chronicles of Courage* series keeps history alive for current and future generations to explore. The technologies and solutions presented are contextualized by experts working to preserve classic aircraft technology. Although some people featured in this video series fought on the side of the Nazis (an adversary to America and its Allies) hearing first-hand experiences from this unique perspective can be invaluable.

- **Erich Brunotte, Fighter pilot.** Brunotte began pilot training in 1941 after serving in France as a foot soldier. He was a German fighter pilot in the IV/JG 51 Molders and flew most models of the Bf 109 and the Fw 190 D during World War II.
- **Jason Muszala, Senior Manager of Restoration at Flying Heritage Collection.** The collection is located in Everett, Washington and is a premiere destination for aviation, military vehicles, and other conflict-era artifacts. Muszala restores and maintains the museum's aircraft to perfect flying condition—a role he takes seriously because he is one of the museum's pilots.

Find extensive interviews with Brunotte and other WWII veterans online at Flying Heritage Collection.

Connect the Video to Science and Engineering Design

As aircraft are flown and pilots and engineers analyze them, modifications and improvements are often made and implemented in a newer variant. During times of war, aircraft are judged against those of their opponents. There is no better example of this than with Germany's Fw 190. When the Luftwaffe needed to improve the Fw 190 A, its broad radial engine was replaced by an inline engine with a much narrower cross section—Fw 190 D. Doing so lengthened the nose of the airplane, changing the center of gravity of the aircraft, which affected its weight and balance. To correct this situation, engineers added weight to the rear of the aircraft by lengthening it and moving the pilot's oxygen supply rearward.

Specifications

	Fw 190 A	Fw 190 D-9 Dora
Empty Weight (lb)	7,060	7,694
Loaded Weight (lb)	9,735	10,688
Length (ft)	29	33
Wing Span (ft)	34	34
Maximum Speed (mph)	408	426
Power-to-weight ratio (hp/lb)	.21	.22
Wing loading (lb/ft^2)	49.4	47.7
Rate of climb (ft/min)	2,953	3,300

Center of gravity is commonly defined as the point over which an object would balance. It is also known as the center of mass. In an aircraft, the center of gravity is the point at which it would balance if suspended in air. There are two simple methods students might use to determine the center of gravity of a model aircraft. After standing a classroom ruler on edge in a clump of modeling clay, students can find the point at which a model airplane balances both longitudinally and laterally. Likewise, suspending the model airplane from a piece of string can help students locate the center of gravity. Center of lift is the point where the total lift generated by an aircraft's wings and control surfaces is balanced out. Center of lift is usually determined by wind tunnel data. A paper airplane's center of lift is controlled by bending the control surfaces up or down, adding fins, changing the angle of the wings, or changing the launch angle. The relative positions (location) of an aircraft's center of gravity and the center of lift determines its flight characteristics.

Related Concepts

- center of gravity
- center of mass
- center of lift
- balance control
- stability
- straight-and-level flight
- control surfaces
- center line
- lateral balance
- drag
- ailerons
- elevator
- rudder
- flap
- lever

Explore the Video

Use video to explore students' prior knowledge, ideas, questions, and misconceptions. View the video as a whole and revisit segments as needed. Have students write or use the bell ringers as discussion starters.

Time	Video Content	Bell Ringers
0:17–1:00	Introduction to Erich Brunotte	"The Americans mostly flew during the day…" refers to the aerial bombing campaigns against German military targets and resources. American bombers flew during the day. British bombers flew at night. Use what you know about science to evaluate the challenges encountered by the two different campaigns.
1:01–1:37	Introduction to the Fw 190	During the clip, attention is given to the Fw 190's bullish, radial engine. Examine the images of the aircraft and make observations about the innovations the aircraft incorporates to make its bullish engine more aerodynamic. Keep in mind that a radial engine is cooled by the flow of air around it.
1:38–3:00	Why the Fw 190 is constantly updated	Focus on Erich Brunotte's comments on why the Fw 190 was like a truck. From an engineering point of view, why would wide landing gear be a good design?
3:01–4:19	Center of gravity and flight	Make and support a claim as to why it is or is not important for an aircraft to be balanced both longitudinally and laterally.
4:20–5:16	Too few, too late	Explain the role that balance has on the speed of an aircraft.

		Construct an analogy between the Allies and harmful bacteria or invasive plants about how strength in numbers contributed to the Allies' success.

Language Support
To aid those with limited English proficiency or others who need help focusing on the video, make available the transcript for the video. Click the TRANSCRIPT tab on the side of the video window, then copy and paste into a document for student reference.

Explore and Challenge

After prompting to uncover what students already know, use video for a common background experience and follow with a minds-on or hands-on collaboration.

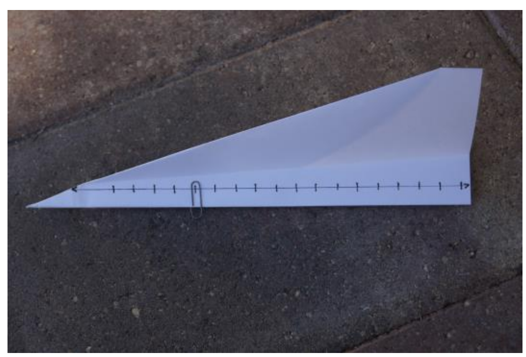
1. Explore readiness to learn from the video with the following prompts:
    - *Conditions that make daylight aerial bombing more effective include….*
    - *A fighter aircraft could be considered successful when…*
    - *Technological advances during war require the other side to….*
    - *The distance between the main landing gear wheels is important because….*
    - *Changing the length of one part of an airframe might….*
2. Show the video and allow students to discuss their observations and questions. The video describes how the Fw 190 was initially designed with a radial engine to increase reliability, reduce overall production time, and promote ease of service. Installation of a more powerful V-12 engine required that the fuselage in front of the tail had to be lengthened in order to regain an appropriate center of gravity. Elicit observations on the aircraft presented in the table above to show about how their technology and innovations helped them to be successful in their mission.
3. Explore understanding with the following prompts:
    - *An aircraft is good at diving if….*
    - *An airplane that is fitted with an engine that adds longitudinal length to the airframe requires….*
    - *The engineering process promotes product updates because….*
    - *Aircraft weight and balance are important variables because….*
    - *Having an aircraft's center of gravity too far forward would impact its control surfaces by….*
4. Help students identify a challenge, which might be based on the questions they have. Teams should focus on questions that can be answered by research or an investigation. Possible activities that students might explore are offered in *Identify the Challenge*.

Identify the Challenge

Stimulate small-group discussion with the prompt: *This video makes me think about….* Encourage students to think about what aspects of the aircraft/technology shown in the video helped assure a successful completion of its mission. If needed, show the video segment depicting the addition of the new, longer engine (3:01 –4:19) as a way to spark ideas or direct student thinking along the following lines.

- Students might adjust the folds of the airplane so that the position of the center of gravity is changed. They should note changes in glide characteristics and the efficiency of control surfaces and then redesign to overcome negative characteristics.
- Using a launch system such as a pulley and weight or a rubber band, students might explore how moving the center of gravity forward or backward changes take off distance.
- Students could depict and explain a system to determine the center of gravity of an actual aircraft.
- Students might mathematically determine the center of gravity of regularly and irregularly shaped objects. See Georgia State University's Hyperphysics site for support.
- Students could compare and contrast the center of mass of males and females with simple standing and lifting actions. Students can support their claims with mathematical evidence.

  An example of a possible design allowing observation of the impact that changing the center of gravity has on flight characteristics might look like this:



Ask groups to choose their challenge and rephrase it in a way that it can be explored through elaborations on a classic paper airplane or through research or other investigative methods. If students choose to investigate with paper airplanes and need more support, they might use one of these resources.

- Paper airplanes
- 10 of the best paper plane designs
- Secret paper aeroplanes
- Paper airplane aerodynamics
- Launchable drinking straw planes

Investigate, Compare, and Revise

Remind students that their engineering design challenges connect to real-world problems and usually have multiple solutions. Each team should be able to explain and justify the challenge they will investigate using concepts and math previously learned. Approve each investigation based on student skill level and the practicality of each team completing an independent investigation. Help teams to revise their plans as needed.

Assemble Equipment and Materials

Many materials can be found in a classroom to help students investigate challenges such as those suggested in *Identify the Challenge*. Suggestions include:

- square and rectangular sheets of paper of various thicknesses
- paperclips
- scissors
- tape, clear and masking
- sticky notes
- string or fishing line
- glue
- measuring tape
- ruler
- protractor
- calculator
- cell phone camera
- rubber bands
- pulleys
- electric plane launcher (optional)

Manipulate Materials to Trigger Ideas: Allow students a brief time to examine and manipulate available materials. Doing so aids students in refining the direction of their investigation or prompts new ideas that should be recorded for future investigation. Because conversation is critical in the science classroom, allow students to discuss available materials and change their minds as their investigations evolve. The class, as a whole, can decide to exclude certain materials if desired. Placing limitations on the investigations can also be agreed to as a class.

Consider having students record their initial observations and thoughts in their science notebooks. Encourage them to write down questions, ideas, and terms that come to mind and make simple sketches. This will lead to ideas for exploration.

Safety Considerations: Foster and support a safe science classroom. While investigating, students should follow all classroom safety routines. Review safe use of tools and measurement devices as needed. Augment your own safety procedures with NSTA's Safety Portal.

Investigate

Determine the appropriate level of guidance you need to offer based on students' knowledge, creativity, ability levels, and available materials. Provide the rubric found at the end of this lesson plan to students prior to the activity and review how it will be used to assess their investigations.

Guide the class as a whole to develop two or three criteria for their investigation at the outset. You or your students might also identify two or three constraints. One major constraint in any design investigation is time. Give students a clear understanding of how much time they will have to devise their plan, conduct their tests, and redesign.

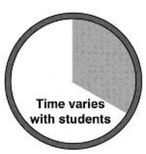
Present/Compare/Revise

After teams demonstrate and communicate evidence-based information to the class about their findings and reflect on the findings of other groups, allow teams to make use of what they have learned during a brief redesign process. Encourage students to identify limitations of their investigative design and testing process. Students should also consider if there were variables that they did not identify earlier that had an impact on their results. It is also beneficial to discuss any unexpected results. Students should quickly make needed revisions to better meet the original criteria, or you might make suggestions to increase the difficulty of the challenge.

Pushing the Envelope

Engineers and aeronautical designers were intensely motivated by the ongoing impact of World War II. The Fw 190 had its radial engine replaced by an inline V-12 engine that was lighter and produced more horsepower. At around the same time, Germans were investigating or fighting in jet and rocket powered aircraft.

Have students conduct research and report on how modern aircraft are designed and built out of materials that allow them to be both lighter and faster.



Build Science Literacy THROUGH READING AND WRITING

Integrate English language arts standards for college and career readiness to help students become proficient in accessing complex informational text.

INTEGRATE INFORMATIONAL TEXT WITH VIDEO

Use the video to set the context for reading and writing. Then, provide students access to scientific or historical texts such as these. *NOTE: At times, fighter pilots use colorful language when describing the terrible events that took place in war. Review the first two texts for appropriateness in your teaching situation.*

- The Fw 190
- Focke-Wulf Fw 190 (Note that although Wikipedia references are often frowned upon as resources, this reference includes a documented section.)
- Hans Dortenmann Top Scorer in the Fw 190 D (Note that this reference lays the basis for an art connection.)
- Weight and Balance

You can also find interviews with many WWII veterans online at Flying Heritage Collection. Encourage students to use search words to find the key ideas they are looking for or specific veterans who talk about those ideas. If students would benefit from a hard copy of the transcript or portions of it, triple-click on the transcript to copy-and-paste.

WRITE You might give students a writing assignment that allows them to integrate the text(s) and video as they write about an aspect of all the information they will examine. Students should cite specific support for their analysis of the science and use precise details and illustrations in their explanations and descriptions. Examples of writing prompts that integrate the video content with the text resources cited above include the following:

- Students might make and support a claim that a design innovation present in the Fw 190 made it a more successful aircraft.
- On the basis of what students have seen and read, they might write and illustrate a pamphlet that explains why aircraft weight and balance should be important to a pilot.
- Students might compare and contrast the data in the table above and information from their readings to explain which was the better aircraft.

READ Any good piece of writing must be carefully planned. Its internal segments must work together to produce meaning. According to Tim Shanahan, former Director of Reading for Chicago Public Schools, students must do "an intensive analysis of a text in order to come to terms with what it says, how it says it, and what it means."

Encourage close reading using strategies such as the following to help students identify the information they will use to develop a selected topic. For background on close reading, see the ASCD resource Closing in on Close Reading. As with any Close Reading Strategy, these strategies will be more helpful if students read the text more than once.

- *Start with an Image*. (Hans Dortenmann Top Scorer in the Fw 190 D) Students start with the still image in the reading itself. As students read the text closely, they text code sentences with the letter *V* wherever the text elucidates on the projected visual image. Students might discuss how the visual image helped them to focus as they read.
- *HIPPO Document Analysis* After reading text students are accountable for:
  - **H**istorical Context – How does what was happening when the text was written help you to better understand the document?
  - **I**ntended Audience – Learn the person or group the author attempted to influence or inform. How does this effort change the manner in which the message is presented?
  - **P**oint of View – How does the race, gender and socioeconomic class of the author impact the perspective of the writing?
  - **P**urpose – Why was the text created and what was its intended use?
  - **O**utside Information – What specific historical information not included in the document can be connected to it? How does this information aid in comprehension of the document?

Summary Activity

Increase retention of information with a brief, focused wrap-up.

Exit Pass: Before students leave class, have them answer in writing or reflect in some way about the video and its content with prompts such as the following:

- A point that is very clear to me now is….
- One thing that squares with what I already know is….
- An idea that is still going around in my head is….

NATIONAL STANDARDS CONNECTIONS

Next Generation Science Standards

Visit the online references to review the supportive Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts for these connected Performance Expectations.

MS-PS2 Motion and Stability: Forces and Interactions

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

MS-PS3 Energy

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-5. Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

MS-ETS1 Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Common Core State Standards for ELA & Literacy in Science and Technical Subjects

Visit the online references to find out more about how to support science literacy during science instruction.

College and Career Readiness Anchor Standards for Reading

1. Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.
6. Assess how point of view or purpose shapes the content and style of a text.
7. Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.
8. Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.

College and Career Readiness Anchor Standards for Writing

1. Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence.
2. Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
7. Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
8. Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

ASSESSMENT RUBRIC FOR INQUIRY INVESTIGATION			
Criteria	**1 point**	**2 points**	**3 points**
Initial problem	Problem had only one solution, was off topic, or was not researchable or testable.	Problem was researchable or testable but too broad or not answerable by the chosen investigation.	Problem was clearly stated, was researchable or testable, and was directly related to the investigation.
Investigation design	The design did not support a response to the initial question or provide a solution to the problem.	While the design supported the initial problem, the procedure used to collect data (e.g., number of trials, or control of variables) was insufficient.	Variables were clearly identified and controlled as needed with steps and trials that resulted in data that could be used to answer the question or solve the problem.
Variables (if applicable)	Either the dependent or independent variable was not identified.	While the dependent and independent variables were identified, no controls were present.	Variables were identified and controlled in a way that resulting data could be analyzed and compared.
Safety procedures	Basic laboratory safety procedures were followed, but practices specific to the activity were not identified.	Basic laboratory safety procedures were followed but only some safety practices needed for this investigation were followed.	Appropriate safety procedures and equipment were used and safe practices adhered to.
Data and analysis (based on iterations)	Observations were not made or recorded, and data are unreasonable in nature, or do not reflect what actually took place during the investigation.	Observations were made but lack detail, or data appear invalid or were not recorded appropriately.	Detailed observations were made and data are plausible and recorded appropriately.
Claim	No claim was made or the claim had no relationship to the evidence used to support it.	Claim was related to evidence from investigation.	Claim was backed by investigative or research evidence.
Findings comparison	Comparison of findings was limited to a description of the initial problem.	Comparison of findings was not supported by the data collected.	Comparison of findings included both group data and data collected by another resource.
Reflection	Student reflection was limited to a description of the procedure used.	Student reflections were related to the initial problem.	Student reflections described at least one impact on thinking.