CHRONICLES OF COURAGE
Stories of WARTIME AND INNOVATION

"The Spitfire"

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

"People should know just how evil war can be. It is all well and good talking about the glory, but a lot of people get killed."
—Ken Wilkinson, Battle of Britain Spitfire Pilot, Royal Air Force

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Video Preview

"The Spitfire" is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation.* At the start of World War II, the Battle of Britain erupted, and cities across England were Germany's targets. The Royal Air Force (RAF) relied on one of their most beloved planes—the Supermarine Spitfire—and the brand-new radar technology to defend their homeland against Hitler and his attacking military.

Time	**Video Content**
0:00–0:16	Series opening
0:17–1:22	Why the Battle of Britain matters
1:23–1:44	One of The Few
1:45–2:57	The nimble Supermarine Spitfire
2:58 –4:04	The British could sniff out German aircraft
4:05–5:28	How **Ra**dio **D**etection **a**nd **R**anging works
5:29–6:02	A victorious turning point
6:03–6:18	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 generations to explore. The technologies and solutions presented are contextualized by experts working to preserve historical aircraft technology.

- **Ken Wilkinson, Battle of Britain Spitfire Pilot, Royal Air Force.** Wilkinson volunteered for the Royal Air Force Reserves in late 1938 at the age of 20. When the war started, he joined the Royal Air Force as a sergeant pilot. Wilkinson finished the war as an officer pilot.
- **Cory Graff, Military Aviation Curator, Flying Heritage Collection.** Graff has more than 20 years' experience working in aviation museums, creating exhibits, conducting historical research, and educating visitors. Curators are content specialists that are focused on a specific subject relevant to a museum's collection.

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

Connect the Video to Science and Engineering Design

In the face of impending war in Europe, Supermarine, a British aircraft company, redesigned its famed racing seaplanes of the 1920s and 30s to create the Spitfire, a sleek, aerodynamic flyer that would become one of the most famous fighter airplanes of WWII. With its smooth curves and sleek lines, pilots were dazzled by the aesthetic beauty of the Spitfire, confirming their belief that "if a plane looks good, it flies good."

The Spitfire's design was so adaptable that it was the only WWII fighter to see production before, during, and after the war. The Spitfire was designed by R.J. Mitchell. The design had elliptical wings positioned below the fuselage with a single spar structure. A single spar structure is the primary structural element of the wing. It runs the length of the wing extending out from the fuselage and carries the load of the wing. The fuselage, wings, and tail unit were of monocoque construction, a design in which the load is supported by the external skin of the aircraft. Use an Internet search string such as "supermarine spitfire technical cutaway" to see details of the structure.

The Spitfire's wing has elliptical leading and trailing edges. This shape creates lift very efficiently. The wing became progressively thinner toward its tips so that the part of the wing closer to the fuselage wing would stall, or begin to lose lift, first. This shape allows for the thinnest possible wing with sufficient internal space for weapons and ammunition. However, they are more difficult to build and more expensive to manufacture. They also could be difficult to handle because at high speeds, using the ailerons might twist the thin wing tips, causing the aircraft to turn in the opposite direction than what the pilot intended.

The RAF's Spitfire faced off against Germany's Messerschmitt Bf 109. The two aircraft are about the same size and have very similar specifications. Yet, the Battle of Britain Spitfires were unable to follow the Luftwaffe's (Germany's Air Force) Bf 109s into a dive because they were not equipped with a fuel injection system. RAF Spitfire Pilot Officer H.R. Allen notes, "When we tried that tactic, our carburetors would flood under negative-g, and our engines would stall momentarily—as they frequently did—which lost us all-important seconds during the engagements."

Specifications

	Supermarine Spitfire MK 1	Bf 109E
Empty weight (lb)	4,541	4,400
Loaded weight (lb)	6,172	6,100
Length (ft)	30	29
Wing span (ft)	36	32
Maximum speed (mph)	354	359
Power-to-weight ratio (hp/lb)	.29	.25
Wing loading (lb/ft^2)	25.4	40.4
Rate of climb (ft/min)	2,995	3,300
Horsepower	1,310	1,085

Regardless of how advanced the Spitfire was, the Allied forces wouldn't have been successful in their defense of Britain without **Ra**dio **D**etecting **A**nd **R**anging, or radar. Radar was originally developed using the radio portion of the electromagnetic spectrum. These low-energy waves have an extremely long wavelength, resulting in indistinct images with little detail. Today, most radar uses microwaves and very high infrared portions of the electromagnetic spectrum.

Additional Aeronautical Background

- The rate of positive altitude change over time is known as rate of climb.
- Wing loading reflects the weight of the aircraft divided by the area of its wing. An aircraft with higher wing loading is less maneuverable and has a higher takeoff and landing speed.
- Dividing the aircraft's engine power output by the weight of the aircraft gives its power-to-weight ratio. This ratio indicates how efficient an aircraft is at producing lift, with a higher ratio producing more lift. It also can be used to predict aircraft performance.
- Maximum speed influences the rate at which an aircraft dives.

All of this information has to be taken into account when tactics are employed by the pilot of a particular aircraft.

Related Concepts

- wing planforms—rectangular, elliptical, taper, pointed, sweepback
- aspect ratio
- taper ratio
- wing chord
- lift/drag ratio
- induced drag
- angle of attack
- stall
- aileron effectiveness
- stall warning
- wash
- single spar construction
- fuel injection
- carburetor

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
0:17–1:22	Introduction to the Battle of Britain	Before students view the video, have them take one minute to write down what they know about the Battle of Britain and how early World War II aircraft made use of aeronautical engineering ideas.
1:23–1:44	Introduction to Ken Wilkinson	Students might discuss the data a pilot would need to intercept attacking enemy aircraft.
1:45–2:57	Introduction to the Supermarine Spitfire	The Spitfire was very maneuverable. Science would support that the Spitfire's elliptical wing retained turn energy better than other wing planforms. Have students write down and share the questions they would ask an expert to confirm this to be true.
2:58 –4:04	Radio detection and ranging	Germany did not yet possess radar technology. Students might explain how radar was an advantage for the Royal Air Force. Although not discussed in the video, the Spitfire had a combat range of 395 miles due to fuel limitations, which allowed for takeoff and landing and only 15 minutes to confront the enemy. Students might explain how radar helped to overcome this limitation.
4:05–5:28	How radar works	Have students make a drawing that illustrates how radar works. They should include labels, callouts, and an explanatory caption. Encourage them to ask a question about radar that was not answered in the video.
5:29–6:02	Summary	Have students write a one-sentence summary that details the importance of the Chain Home early warning radar stations to England's war effort.

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.

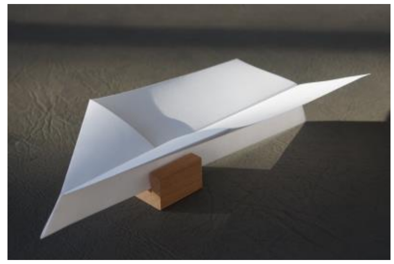
1. Explore readiness to learn from the video with the following prompts:
   - *Aircraft engineering constraints that must be overcome in order to attack an island country include….*
   - *Having a sleek body improves an aircraft's….*
   - *Being equipped with a high horsepower engine impacts a fighter aircraft by….*
   - *Radar is useful when your country is under siege by an enemy air force because….*
   - *Other uses of radar include….*
2. Show the video and allow students to discuss their observations and questions. The Spitfire is light and nimble with specially designed wings that make it very maneuverable. It was a sleek, aerodynamic aircraft that would become one of the most famous fighter planes of WWII. Elicit observations about the aircraft presented and how its technology and innovations helped it to be successful in its mission.
3. Explore understanding with the following prompts:
   - *Design features that would allow a fighter plane to turn quickly include….*
   - *Variations shown in these diagrams of wing planforms include….*
   - *Aeronautical characteristics of an elliptical wing planform include…*
   - *Aeronautical features that make the Spitfire a "fighter pilot's plane" include….*
   - *The Chain Home stations formed an early warning system that….*
   - *Design features of the Spitfire not discussed in the video that I observed include….*
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 ensure a successful completion of its mission. If needed, show the video segment on (1:45–2:57) as a way to spark ideas or direct student thinking along the following lines.

- Students might build paper airplanes from identical pieces of paper that will allow them to examine the flight characteristics of different wing planforms. Alternatively, they might modify the foam plate glider model.

  Examples of possible designs that explore flight characteristics of different wing planforms might look like these:

- Scientifically, the elliptical wing planform should provide lift more efficiently than any other shape. Have students do research on the shape of bird wings to see if this is also true in nature.
- As plane performance improved on both sides during WWII, the number of jobs aircraft were asked to perform increased. The Spitfire proved its versatility as a new range of designations was introduced. Those Spitfires designed for high-altitude work were given the preface “HF,” those for low-altitude “LF”, and those for normal duties “F.” The HFs and LFs were given variations of the Merlin engine specifically designed for their tasks. The HFs were distinguishable by their extra long wing tips, whereas the LFs had clipped wings. Students might compare the flight characteristics using identical paper airplanes that have their wingspan progressively shortened. Students might then use this data to make claims supported by evidence from Internet research on how the wing design enabled the success of the different Spitfires, or more generally other kinds of planes.
- Students might use technology and materials available to them to demonstrate how radar can track moving objects and send data that can be interpreted as numbers and sizes. They might include research about the Chain Home early warning radar stations and how their design and relative positions supported the task for which they were built.

Ask groups to choose their challenge and rephrase it in a way that 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
- Styrofoam glider

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
- string or fishing line
- sticky notes
- glue
- measuring tape
- ruler
- protractor
- calculator
- cell phone camera
- computers
- internet
- electric plane launcher (optional)
- plastic foam plate

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.

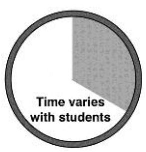
Guide the class as a whole to develop two or three criteria for their investigation at the outset. You or your students might also identify two or three constraints. One major constraint in any design investigation is time. Give students a clear understanding of how much time they will have to devise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

In the video, Cory Graff says, “They could actually sniff out these German airplanes that were coming….” He was referring to the Chain Home network of coastal radar stations used by Great Britain during WWII. It was the first early warning radar system in the world. Students might do research to explore the rapid development of both military and civilian radar applications after the war.



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.*

- Battle of Britain pilot
- Supermarine Spitfire
- Wing Geometry Definitions
- 6 Wing Designs
- Wing Planform
- The Chain Home radar system

You can also find interviews with many RAF pilots and other 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 write an article for a history magazine that explains how the Chain Home early warning radar system kept Great Britain safe during the Battle of Britain.
- Students might create a sales brochure or presentation about the design features that made the Spitfire such a good fighter plane, to convince military leadership of its value.
- At the end of the Battle of Britain, Hitler decided to call off the invasion of Britain. Students might explore how science and engineering innovations contributed to his decision.
- Students could write letters home (as if they were the pilots in the RAF) sharing their experiences with the technology.

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.

- *Reading Questions*. Give students the following questions.
  - **1.** What is the meaning of "The Few" in reference to the Battle of Britain?
  - **2.** What engineering aspects influenced the outcome of the Battle of Britain?
  - **3.** What design considerations did aircraft designer R.J. Mitchell focus on when creating the Spitfire?
  - **4.** How can math be used to explain a wing's planform?
  - **5.** How does the shape of a wing impact its flight characteristics?
  - **6.** What components and techniques were involved in the Chain Home early warning system?

  As they read, students write the question numbers above portions of the text that will help them to answer specific questions.
- *Word Choice*. As students read, have them circle words that make claims. Then have them draw a line from the word to the nearest margin and explain how the word helps or hurts understanding, evokes emotions, produces an effect, or has more than one meaning.

Summary Activity

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

Have each student write a single possible test question related to their learning. Their questions should *not* be of a yes/no nature and should be written to provoke both thought and discussion. Students might write their questions on index cards that can be distributed to the class.

Alternatively, students might create a visual representation that captures their learning from the lesson. This can be a drawing, collage or three-dimensional piece if materials are available (transmediation).

NATIONAL STANDARDS CONNECTIONS

Next Generation Science Standards

Visit the URLs 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.