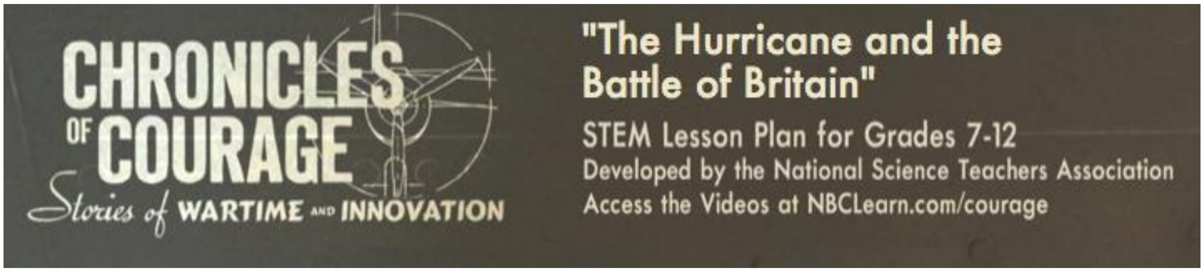

"When you are on fire you don't hang about—I was out of the aircraft like a champagne cork."
— Tony Pickering, Battle of Britain Hurricane Pilot, Royal Air Force

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Video Preview

"The Hurricane and the Battle of Britain," is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation.* After France fell in 1940, Hitler turned his attention to invading Great Britain, the only Western European country standing against him. Prior to the attempted invasion, Germany's Air Force—also called the Luftwaffe—tried to establish air superiority over Great Britain. The fate of Britain rested in the hands of Royal Air Force (RAF) pilots flying Hawker Hurricanes and Supermarine Spitfires. During July, August, and September of 1940, the RAF and Luftwaffe tangled in the skies above Britain. RAF pilots destroyed almost 3,000 German aircraft. Although the Spitfire has a more iconic reputation, the Hurricane scored almost 60% of those victories. Failing to gain air superiority, Hitler did not invade Great Britain.

Time	Video Content
0:00–0:16	Series opening
0:17–0:57	Can Germany take all of Europe?
0:58–1:42	Only air superiority can stop the invasion
1:43–2:49	The renowned Hawker Hurricane
2:50 –3:53	A drawback of traditional construction

3:54–4:20	Fueling the barbecue
4:21–4:53	Hurricane victory
4:54–5:22	Summary
5:23–5:37	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 classic aircraft technology.

- **Tom Neil, RAF Hawker Hurricane pilot.** Wing Commander Thomas Francis "Ginger" Neil was born in 1920. As a child he was interested in airplanes and won a prize for a drawing of one he made. While working in a bank after secondary school, Neil trained as a pilot with the RAF Volunteer Reserve. He was called to active duty at the outset of WWII and is credited with 14 kills. He retired from the RAF in 1964.
- **Cory Graff, Military Aviation Curator, Flying Heritage Collection.** Graff has over 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 Neil and other WWII veterans online at Flying Heritage Collection.

Connect the Video to Science and Engineering Design

During the 1930s, the Royal Air Force (RAF) sought to modernize its fighter aircraft. They transitioned from the Hawker Fury, Hawker Demon, and Bristol Bulldog—all fabric biplanes—to a composite design monoplane called the Hawker Hurricane. Developed from the Hawker Fury, the Hurricane's biplane heritage led to its thicker wing design and fabric covered tail.

The Hurricane's airframe is a combination of interwar design and forward thinking development. It has a metal covered wing, fabric covered tail, and retractable landing gear. The fabric tail allowed easy repairs to the fuselage and helped the Hurricane withstand cannon shell hits, which could pass through the aircraft without exploding. However, the fabric was treated with a highly flammable sealing agent. During the Battle of Britain, the Hurricane earned a bad reputation for its cockpit fires. Its two main fuel tanks, located in the wing center section, were not self sealing or protected by armor. It was reported that when the fuel tanks were set ablaze the temperature in the cockpit could climb to over 5,000˚F in about ten seconds.

Related Concepts

- combustion
- chemical reaction
- ignition temperature
- flash temperature
- thermal energy
- complete combustion
- Incomplete combustion
- tautening medium
- flammability
- solubility
- chemical change
- continued contraction
- physical change

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
0:17–0:57	Prelude to the Battle of Britain	Before students view the video, have them identify variables that would determine the outcome of a battle fought solely between aircraft.
0:58–1:42	A battle for air superiority	Have students examine the numbers: The Battle of Britain began on July 10 and ended October 31, 1940. During that time, 1,244 RAF aircrew were killed and 1,023 aircraft were lost. On the other side, 2,500 Luftwaffe aircrew were killed and 1,887 airplanes were lost. What conclusions can be reached from this data?
1:43–2:49	Introduction to the Hawker Hurricane	Divide the class into groups. Challenge them to create annotated illustrations to further explain Cory Graff's comment, "The Hurricane is the RAF's first monoplane—a plane with one pair of wings—which makes it more steady and aerodynamic in flight." Remind students that prior to the advent of the Hawker Hurricane, RAF fighter planes were all biplanes.
2:50 –3:53	Traditional construction techniques with a major drawback	Students might, from an engineering point of view, explore why a chemical compound would be used to seal an aircraft's surface knowing that it may make it extremely susceptible to fire.
3:54–4:20	Vulnerability of the Hurricane's fuel tanks	Students might create a timeline that identifies the sequence of events resulting in flames traveling from the engine or fuel tanks to the aircraft-dope-covered fabric tail of the aircraft. Student might speculate about the location of flames that would pose the greatest threat to the pilot.
4:21–4:53	Victorious Hurricanes	The Hawker Hurricane had eight machine guns located in its thick wing. Mathematically and scientifically, why was it critical that an attacking aircraft get "very, very close" to its prey?

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:
- *Constructing an aircraft of fabric materials might be a problem because….*
- *Designing an aircraft that incorporates traditional construction techniques poses challenges such as….*
- *Design features that make a fighter plane able to withstand a great deal of damage include….*
- *When an aircraft traveling at a high rate of speed catches on fire, the flames….*
- *Events that would cause the tail of a flying aircraft to catch fire include…*

2. Show the video and allow students to discuss their observations and questions. The video presents an aircraft that while constructed with very traditional techniques, is still a durable, fast, and reliable fighter aircraft. Although it fought alongside the technologically more advanced Spitfire during the Battle of Britain, it accounted for three kills for every two enemy planes destroyed by the Spitfire. Also, because of its traditional construction, it could be built much more quickly than the Spitfire and require less skilled labor to assemble it. Survivability and system resilience are both strong attributes of the Hurricane. Elicit observations about the Hurricane and how, despite its lack of technological advancements, was still successful in its mission.

3. Explore understanding with the following prompts:
- *Conditions that make use of nitrocellulose 'risky' include….*
- *The tail section of the Hurricane might catch fire when….*
- *In the Hurricane construction, technical and moral trade-offs between function and safety include….*
- *Some of the trade-offs associated with the Spitfire's production compared with Hurricane's production include….*
- *The shift from biplane to monoplane construction….*
- *Design features that made the Hurricane such an effective weapon include….*

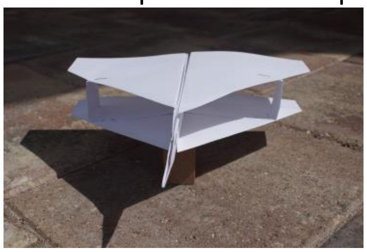
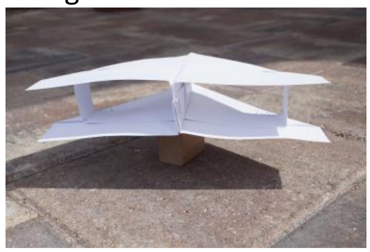
4. Help students identify a challenge, which might be based on questions they have. Teams should focus on questions that can be answered by research or an investigation. Possible activities that students might explore are offered in *Identify the Challenge*.

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, and what obstacles or challenges it faced. If needed, show the video segment on why the Hurricane had a bad reputation for catching on fire (3:54–4:20) as a way to spark ideas or direct student thinking along the following lines.

- The video proclaims: *The Hurricane is the RAF's first monoplane, a plane with one pair of wings, which makes it more steady and aerodynamic in flight.* Have students compare the flight characteristics of biplane and monoplane paper airplanes that are constructed from the same amount of paper.

  An example of a possible design for a biplane that uses 1.5 sheets of paper that students could compare to a monoplane might look like this:


- The location of the Hurricane's fuel tanks hugely increased the threat of fire to its pilots. An aircraft's fuel tanks might be compared with a liquid filled bladder. Students might explore ways to limit the amount of liquid that escapes from a bladder after it is punctured.
- Students might design a chemical compound that when coated on a linen fabric makes it water proof without making it flammable.

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
- 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
- sticky notes
- string or fishing line
- glue
- measuring tape
- ruler
- protractor
- calculator
- cell phone camera
- 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.

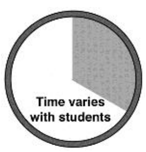
Present/Compare/Revise

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

Wood was a major component of the structure of the fuselage, specifically the formers and stringers that were fastened to the Hurricane's steel and duralumin frame. Wood burns at 300˚F, as does the flammable aircraft dope used to seal the linen fabric that covers much of the tail's surface. The maximum temperature of the fluid in the cooling systems of the Hurricane's Rolls Royce Merlin engine was 275˚F. The metal parts of the engine generated a great deal of heat that had to be dealt with so that the aircraft could operate safely. The exhaust gases exiting the engine approached 3,000˚F.

Encourage students to imagine the modern commercial airliner. The fuel in its combustion chamber burns at over 3,600˚F. Metals that make up some parts of the jet engine actually melt at just over 2,000˚F. Students might compare and contrast how engineers dealt with heat issues during World War II and in modern, jet powered aircraft.



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.*

- Hawker Hurricane - Defender of the Realm
- Burning Hurricanes
- Avoiding that shrinking feeling
- Hurricane Season

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 write an article for a science magazine that explains why, when a crisis such as global war is imminent, it is prudent to develop aircraft designs that are based on tried and true engineering and manufacturing processes.
- On the basis of what students have seen and read, they should make a claim about using a chemical or design practice that involves recognized risks or danger and support it with evidence.
- Students might write an argument as to which of the two RAF fighter aircraft actually kept the Luftwaffe from gaining air superiority over Great Britain. Encourage them to address the issue from a design perspective, ensuring that they provide evidence for the claims they make.

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.

- *SOAPS*
  - **S**peaker: What did the expert voices say in the source materials?
  - **O**ccasion: In what context will the source materials be integrated?
  - **A**udience: How will the information gleaned from the source materials meet the needs of the writer's audience?
  - **P**urpose: What is the purpose of the source materials? What does the writer want the audience to think or do after reading the completed assignment?
  - **S**ubject: Do the writing efforts address the topic? Is the writing as specific as it needs to be? Do the internal parts of the writing support the overall message?
- *Short Summaries.* Students underline the most important information in each paragraph. In the margins to the left of each paragraph students might demonstrate their understanding by writing a short summary of the paragraph. The margins to the right of each paragraph could be used to write questions that are raised by the information presented in the paragraph.

Summary Activity

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

Have students quickly and verbally share the ramifications of one thing they learned from the video or their investigation. They might toss a ball from one to another or simply solicit volunteers.

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.