CHRONICLES OF COURAGE
Stories of WARTIME AND INNOVATION

"The First Fighter Jet"

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

" We had only single-seaters. They stood on the wing [and] we were sitting in the cockpit. They showed us everything…, then they said to us, 'this is your speed for take off, and that's your landing speed… now take off!' And that's how we learned to fly it."
--Fran Stigler, Luftwaffe Ace on learning the fly the Me 262

Table of Contents

Click the section title to jump to it. Click any blue or purple head to return:

Video Preview

"The First Fighter Jet" is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation*. Introduced in April of 1944, the German Messerschmitt Me 262 was the world's first jet-powered fighter aircraft. Nicknamed the Schwalbe (Swallow), its twin turbojets were the first ever to be mass produced. The result of innovative research and engineering prowess, the Me 262 could fly faster than its piston engine rivals and was heavily armed. Around 1,400 were built, an insignificant number when compared with the total production runs of almost 34,000 for the Messerschmitt Bf 109 and more than 20,000 for Great Britain's Supermarine Spitfire. Too few Me 262s arrived too late to change the outcome of World War II.

Time	Video Content
0:00–0:16	Series opening
0:17–0:50	Can innovative technology win the war?
0:51–1:25	A plane that flies without a propeller?
1:26–2:41	Introduction to the Me 262.
2:42–3:00	Turbojet engines provide the thrust.

3:01 –3:39	The relationship of thrust and speed.
3:40–5:17	The Me 262's high speed requires new tactics.
5:18–5:36	Summary
5:37–5:50	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.

- **Lieutenant Jorg Czypionka, Luftwaffe Night Fighter pilot.** In 1940, 19-year-old Czypionka enlisted with the Luftwaffe (German Air Force) and received his initial pilot training in Austria. After completion of advanced training he spent the next three years as a primary and basic flight instructor. The summer of 1944 saw him flying Bf 109s at night, protecting Berlin against nocturnal bombing raids during World War II. His group had little success against the British Royal Air Force's Mosquito bombers because of their high speed. This changed when the Me 262 jet became available.
- **Jason Muszala, Senior Manager of Restoration at the Flying Heritage Collection.** The collection is a premiere destination for aviation, military vehicles, and other conflict-era artifacts, located in Everett, Washington. 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 Czypionka and other WWII veterans online at Flying Heritage Collection.

Connect the Video to Science and Engineering Design

Germany, the United Kingdom, and the United States all had jet aircraft that were operational during WWII. But Germany was able to produce about 300 more jets than the other two countries combined. Jet engines work on the principle stated in Newton's Third Law of Motion: for every action there is an equal and opposite reaction. You might mimic this for students using an inflated balloon attached to a straw threaded onto a taut string.

A fan at the front of the engine sucks in air, which is compressed by a compressor behind the fan. Fuel is combined with the compressed air and ignited. The burning gases expand and pass through the turbine and are ejected out the nozzle at the back of the engine. The compressor and turbine are attached to the same shaft. When the hot gases turn the turbine they also turn the compressor. As the hot gasses shoot out of the engine's nozzle, the engine and the aircraft attached to it are thrust forward.

Because the Me 262's twin Jumo turbojets were placed below its wings, there was room in the forward fuselage to place the nose wheel of its tricycle landing gear. This is the first innovation that Czypionka extolls in the video. Aircraft equipped with tricycle landing gear, like the Me 262, are easier to land, take off, and taxi. Tricycle landing gear eliminates ground loops (where if one of the main gear wheels touches down first, the landing aircraft quickly veers in that direction) to which tail draggers—planes with two wheels at the front and one in the tail—are prone. It also allows for much better visibility over the nose of the aircraft.

To overcome weight and thrust issues with the twin Jumo turbojets, engineers adopted a swept-wing design, instead of the common straight wing. Although the swept wing was implemented to balance the aircraft on its nosewheel, it also made the Me 262 faster. As a comparison, the swept-wing, jet-powered Me 262's top speed was more than 120 mph faster than the straight-winged, jet-powered American Bell P-59. The swept wing worked very well at high speeds but made the aircraft more difficult to fly at slow speeds.

To compare the jet-engine-powered Me 262 with its main piston-engine-powered Allied adversary, compare the specifications that follow.

Specifications

	Me 262 (Germany)	P-51H Mustang (USA)
Empty Weight (lb)	8,366	7,040
Loaded Weight (lb)	14,272	11,500
Length (ft)	35	33
Wing Span (ft)	41	37
Maximum Speed (mph)	559	490
Power-to-weight ratio (hp/lb)	.28	.18
Wing loading (lb/ft^2)	35.7	39
Rate of climb (ft/min)	3,900	3,200
Range (mi)	652	855

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 its weight 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

- lift
- drag
- thrust
- weight
- maneuverability
- fan
- compressor
- blades
- shaft
- expand
- nozzle
- turbine
- swept wing
- center of gravity
- nosewheel
- tailwheel

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
0:17–0:50	A tide-turning innovation?	Students who have watched other videos in the series might take one minute to write down observations about other WWII planes that made them successful in their missions. Or they might simply note design features of commercial jets or private planes they have observed. Before more advanced students view the video, have them take one minute to write down what they know about typical configuration and design features of WWII aircraft and why the first jet fighter might stand out.
0:51–1:25	Flight without a propeller	Students might also make sketches that connect the features of the first fighter jet engines to current rockets they have observed lifting off into space. Or, have groups of students identify the innovations or design features presented in this segment and suggest how each is inherent in a turbojet-powered aircraft with tricycle landing gear.
1:26–2:41	Introduction to the Me 262	Pairs of students might take turns explaining the new information presented in this section to each other. Their focus should include: heavy armament, high rate of climb, and high top speed.
3:01 –3:39	Thrust and speed	Have students focus on the drag portion of the narration. On the basis of what they have seen in the video prior to this segment, students could present and support their ideas about the Me 262 design features that reduce drag.
3:40–5:17	High speed requires new tactics	Have students identify the benefits and drawbacks of the Me 262's tactics using science terms relating to motion.
5:18–5:36	Summary	Have students write a one-sentence summary detailing why the science and engineering behind the Me 262 was revolutionary.

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:
   - *Differences between piston and turbojet engines include….*
   - *Aircraft equipped with tricycle landing gear are…*
   - *A jet aircraft is easier to fly than a propeller aircraft because….*
   - *Having swept wings allows an aircraft to….*
   - *A turbojet generates thrust by….*
2. Show the video and allow students to discuss their observations and questions. The Me 262 was a product of much research and engineering prowess and could fly at speeds of well over 500 mph. Elicit observations about the aircraft presented in the video and how technology and innovations helped it to successfully complete its missions.
3. Explore understanding with the following prompts:
   - *Flight characteristics of a jet aircraft when compared with a propeller-driven aircraft include….*
   - *From a mathematics or engineering point of view, the location of the Me 262's heavy machine guns allows….*
   - *Design features that make a turbojet fighter plane successful include….*
   - *Although the Me 262 was very successful against Allied bomber and fighter aircraft, it was unable to change the outcome of WWII because….*
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 on the relationship between thrust and the Me 262's high maximum speed (3:01–3:39) as a way to spark ideas or direct student thinking along the following lines:

- Students might design and build a paper airplane that can be launched by thrust generated by a means other than throwing.

  An example of a possible design that explores an alternative thrust source such as a twisted rubber band might look like this:

- Jorg Czypionka tells us that the Me 262's tricycle landing gear allowed the plane to stay absolutely straight on its takeoff run. Students might compare airplanes with tricycle and tail dragger landing gear to examine differences in angle of attack and length of takeoff run.
- Engineers gave the Me 262 swept wings to balance the aircraft on its nosewheel. Its wings had an 18.5˚ leading edge sweep that properly positioned the center of lift with respect to the center of mass. Students might examine the flight characteristics of paper airplanes with identical mass but varying degrees of sweep in their wings.

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
- glue
- measuring tape
- ruler
- protractor
- rubber bands

- balloons
- drinking straws
- model propellers
- toy wheels
- sticky notes
- foam core board
- 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.

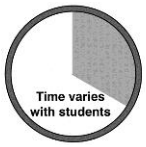
Guide the class as a whole to develop two or three criteria for their investigation at the outset. You or your students might also identify two or three constraints. One major constraint in any design investigation is time. Give students a clear understanding of how much time they will have to devise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

The majority of World War II aircraft were tail draggers. The first four Me 262 prototypes were also tail draggers. The operational models, such as those flown by Czypionka, were equipped with tricycle landing gear. A majority of modern aircraft, especially jet aircraft, are equipped with tricycle landing gear. Have students conduct research and report on why modern aircraft are designed to take advantage of tricycle landing gear.



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.

- Group history
- Messerschmitt Me 262
- Messerschmitt Me 262 -Schwalbe
- Jumo 004 compared to a 1960s jet engine
- Why you must fly a tail dragger
- Tricycle landing gear

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:

- Any engineering design process must take constraints into account. The original design for the Me 262 was submitted in June of 1939. Students might generate a timeline of required redesign efforts and constraints that delayed production of combat-ready Me 262s until April of 1944.
- Much of the delay in producing combat-ready Me 262s was related to problems putting its Jumo turbojets into production. As a result of the scarcity of the rare earth metals that would have allowed the engines to have a long operating life (200 hours or more), the Germans had to use inferior materials, resulting in

around one-tenth of that. Beginning in the 1990s, a project got underway to create replica Me 262s, to return the Schwalbe to the air. The first replica aircraft flew in late 2002. An inevitable concession that had to be made was replacement of the original, unreliable Jumo turbojets with improved jet engines from the 1960s. Students might write to compare and contrast these engines by explaining the data presented in Jumo 004 compared to a 1960s jet engine.

- Students might analyze the table shown earlier in this document. They can compare this information and explain why the Me 262 was such a threat.
- Students might make a claim backed by evidence about their preferred landing gear configuration.

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 will be more helpful if students read the text more than once.

- *Make Predictions.* As students read the source materials, guide them to identify the main idea of each paragraph, chunk, or section. They then use the margins to record a prediction for what will come in the next paragraph, chunk, or section. When rereading each source, students might place a check beside predictions that are correct.
- *Plot a Movie Trailer.* As students read, they could think of a potential video trailer that could be used to promote the reading to other students. To adequately complete this task, students must have a firm grasp of the main idea and supporting details. They must also address the problem identified in the video and text, and how that problem was overcome so that the mission could be accomplished. Historical perspective should play a role in student trailers. Have students list items that have to appear in their trailers as they read.

Summary Activity

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

With each word worth 10 cents, have students write a $2 summary of the learning from the lesson. Students should include at least six technical, engineering, or science terms from the lesson.

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.