CHRONICLES OF COURAGE
Stories of WARTIME AND INNOVATION

"The V-2 Rocket: Hitler's Vengeance Weapon"

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

" Science does not have a moral dimension. It is like a knife. If you give it to a surgeon or a murderer, each will use it differently."
— Wernher von Braun, pioneer in the development of rockets including Nazi Germany's V-2 and NASA's Saturn V

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Video Preview

"The V-2 Rocket: Hitler's Vengeance Weapon" is one of 20 short videos in the *Chronicles of Courage: Stories of Wartime and Innovation* series*.* After years of fighting during World War II, German scientists develop a new, terrifying weapon—the V-2 rocket. It is the world's first long-range guided missile. Fired from far away locations, the rockets could travel up to 200 miles and were aimed at towns in Belgium and the United Kingdom. Thousands of civilians died as a result of V-2 rocket explosions. Although effective, the rockets were inaccurate, cumbersome to launch in combat conditions, and could not be built in sufficient numbers to impact the war's outcome.

Time	Video Content
0:00–0:16	Series opening
0:17–1:16	The V-2 rocket: Vengeance weapon
1:17–2:03	An inaccurate guided missile
2:04–3:19	Secrecy and slave labor
3:20 –4:31	The V-2 guidance system
4:32–5:36	A successful terror weapon?
5:37–5:52	Summary

5:53–6:07 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.

- **Franz Stolle, German artillery specialist.** Stolle was 15 when war broke out in Europe. He served in the German infantry and artillery. Late in the war, Stolle was a member of a V-2 unit that fired rockets from deep inside Belgium's Ardennes Forest.
- **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 Stolle and other WWII veterans online at Flying Heritage Collection.

Connect the Video to Science and Engineering Design

During July of 1943 the British Royal Air Force launched a series of attacks on Germany's second largest city, Hamburg. Over the course of nine days, 40,000 Germans were killed. Germany's leaders demanded revenge attacks on England's population. A great deal of emphasis and expenditure of capital and resources were committed to develop the V-2 rocket to deliver that vengeance. Wind tunnels that could withstand supersonic speeds were used to design the rocket.

A typical V-2 flight would achieve an altitude of almost 80,000 feet one minute after the rocket was launched. For a given target, a rocket's launch azimuth (vector to a given location) was identified, allowing the rocket to travel toward its intended target. While today's rockets use a global positioning system (GPS), this first ballistic missile's guidance system was quite rudimentary. The rocket would simply be pointed in the direction of the intended target. With a range of up to 200 miles, however, being pointed even a few degrees to the left or right could result in a significant miss of the intended target.

The liquid-propelled rocket was guided by moving portions of its four tail fins and four heat-resistant vanes located in the exit jet stream of the engine. These components were directed by two gyroscopes, and the engine would shut off when the rocket reached a predetermined velocity. A V-2 Rocket is on display at Flying Heritage Collection in Everett, Washington.

Once its motor was cut off, the rocket continued to soar upward to an altitude of around 55 miles, at which point it began its unguided descent to its target. V-2 rockets had a range of up to 200 miles, and delivered just over a ton of explosives. However, the V-2s were so inaccurate during World War II, as indicated in the video, that after initial failures the rockets were aimed mostly at large targets such as London and Antwerp. From September 1944 to late March 1945 more than 1,400 V-2 rockets were fired at London, causing 2,754 fatalities.

Although the V-2 project was as expensive as the Allied atomic bomb program, overall it delivered fewer explosives than a single large bomber aircraft raid on Germany.

Related Concepts

- guidance system
- ballistic missile
- liquid propellant
- thrust
- accuracy
- balance of forces
- aerodynamics
- thermodynamics
- gas dynamics
- rocket propulsion
- nose cone
- control surfaces
- body tube
- fins
- stability
- fin shape
- nose cone shape
- body tube length
- lift
- drag
- weight

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
0:17–1:16	Weapon of terror or magic bullet?	Students might identify physical and psychological effects on people who are attacked by terror or vengeance weapons.
1:17–2:03	A guided missile?	**".... the first long-range guided missile in the world."** Have students discuss this statement from the video segment. Have them identify an acceptable degree of accuracy for a guided missile. Students might also discuss if accuracy was a design constraint in the development of the V-2.
2:04–3:19	The costs of slave labor	Pose this question to the class: What practical consequences did the (morally dubious) decision to use slave labor have on the effectiveness of the V-2 program?
3:20 –4:31	A guidance system that brought the V-2 down somewhere…	Students might identify the variables in play when the V-2 is launched at a target 200 miles away. Also, remind students that the area of the city of London is 1.12 mi^2. How would students determine the chance of a V-2 hitting its target in London if fired from 200 miles away?
4:32–5:36	What can war bring?	Point out to students that over nine nights in July 1943, nearly 800 Allied bomber aircraft repeatedly attacked Hamburg, Germany, and killed approximately 40,000 people. In retaliation, from September 1944 to March 1945, the Germans fired 1,358 V-2 rockets at London alone where at least 2,754 people were killed. Students might consider the conditions and challenges of living in either Hamburg or London during this time.

5:37–5:52	Summary	At least 2,754 people were killed in V-2 attacks on London. Rocket attacks on Antwerp left 1,736 dead. More than 10,000 slave laborers died producing V-2 rockets. As a weapons system, the V-2 program caused more deaths during its production than in its deployment. Students might discuss the reasoning that scientists and engineers might have used to justify the V-2 program.

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:
   - *In the 1940s, a 30-foot crater in the ground might be caused by….*
   - *The parts of a rocket include…*
   - *In the atmosphere during flight, a rocket is steered by….*
   - *A guided missile is different than an unguided missile in that….*
   - *Without the use of radio, a missile could be guided by….*
   - *Aspects of a weapon that could induce terror in a civilian population include….*
2. Show the video and allow students to discuss their observations and questions. The video relates that near the end of World War II, the technologically advanced V-2 was used as a weapon of terror. With a range of around 200 miles, V-2 rockets targeted London and Antwerp. V-2s were inaccurate, cumbersome to launch in combat conditions, and could not be built in sufficient numbers to change the course of the war.
3. Explore understanding with the following prompts:
   - *Design features that make the V-2 a magic bullet include….*
   - *Science concepts behind a supersonic ballistic missile that makes it a good way to get 2,200 pounds of explosives to a target include….*
   - *A supersonic rocket approaches its target in silence because….*
   - *V-2 rockets were guided to their target by….*
   - *The main determining factor in the accuracy of a V-2 rocket was….*
   - *A terror weapon, such as the V-2 can be deemed successful if….*
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 (3:20 –4:31) as a way to spark ideas or direct student thinking along the following lines:

- Students might build paper rockets that can be launched by propelling them with their breath through drinking straws. Their designs should explore overall rocket length; nose-cone shape; and the number, positioning, and shape of fins that guide the rocket in a straight path.
- After launching, a V-2 rocket burned its liquid fuel for a predetermined amount of time to control the overall flight distance of the rocket toward its target. Students might examine the rocket shape, fuel payload, and exhaust gas nozzle shape needed to send a balloon rocket suspended on a horizontal string to a given target (stopping point).
- The flight path of a V-2 rocket followed a parabolic curve. Using small spherical projectiles, students might explore whether accuracy is increased when launching projectiles at low or high launch angles.

  An example of a possible design that allows students to explore the flight characteristics of rockets might look like this:

Ask groups to choose their challenge and rephrase it in a way that can be explored through elaborations on simple balloon-powered rocket designs or through research or other investigative methods. If students choose to investigate with simple rockets and need more support, they might use one of these resources.

- Model Rocketry
- How to Make a Soda-Straw Rocket

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 learned previously. 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
- drinking straws
- scissors
- tape, clear and masking
- glue
- sticky notes
- measuring tape
- ruler
- protractor
- balloons
- fishing line
- propellers
- rubber bands
- small toy balls
- marbles
- calculator
- cell phone camera

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.

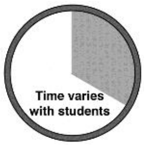
Guide the class as a whole to develop two or three criteria for their investigation at the outset. You or your students might also identify two or three constraints. One major constraint in any design investigation is time. Give students a clear understanding of how much time they will have to devise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

Students might examine how today's precision-guided munitions compare with the best efforts of the V-2 rocket. Sadly, today's students have lived most of their lives during the war on terror. In light of their observations about how this war has been conducted they might compare the terror weapons of today with those used to terrorize civilian populations during World War II.



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.

- V2: The Nazi rocket that launched the space age
- Beginner's Guide to Rockets
- Wernher von Braun's V-2 Rocket
- A-4/V-2 Makeup
- V-2
- Dora and the V-2 or Mittlebau Overview
- Nordhausen Survivor Michel Depierre

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 about the success of the V-2 in the role for which it was engineered.
- On the basis of what students have seen and read, they should identify the tactics used to produce the V-2 rocket and evaluate their effectiveness.
- Students might select design aspects of the V-2 rocket and explain how each feature contributed to the first Americans in space.
- Students might write a fictional story that depicts the true terror of Hitler's V-2 vengeance weapon.

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.

- *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.
- *Close Reading and Art*. (Use Dora and the V-2 or Mittlebau Overview.) Students read the text closely and mark up the text as instructed. Their focus should be to generate six storyboard panels of illustrations that represent the main points of the texts. They might do this on a piece of paper that is folded into thirds (using front and back). Under each drawing, students write evidence from the text to support each image.

Summary Activity

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

Give each student a piece of unlined paper. Have them fold it in half twice to make eight equal sized areas (front and back). Post a time limit during which they fill as many of their blanks with a word or phrase that explains what was learned during the lesson. When time expires, students trade with a partner. Each partner then takes a turn explaining the knowledge that is evidenced by the paper in their possession.

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.