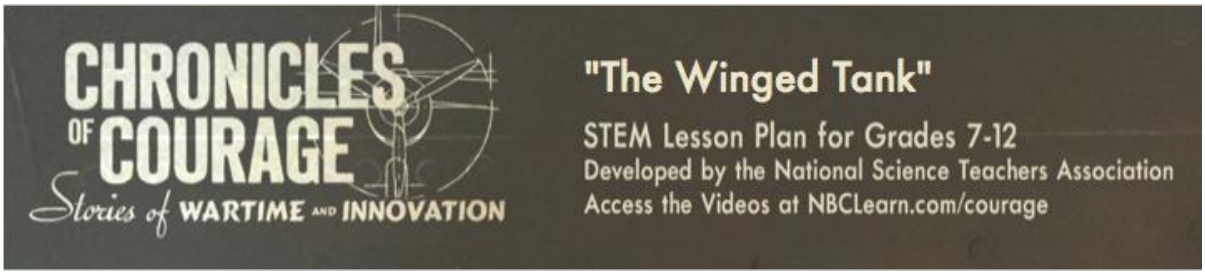

"The Il-2 was not just one of the best attack planes. It was the best attack plane in the world." — Nikolay Yefimovich Olovyannikov, Il-2 Pilot

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Video Preview

"The Winged Tank," is one of 20 short videos in the series *Chronicles of Courage: Stories of Wartime and Innovation.* In the late 1930s, engineers from the Soviet Union designed an airplane specifically for ground-attack missions (also known as close air support). The Ilyushin Il-2 Sturmovik was built to tactically support front line operations by attacking enemy tanks, trucks, and troops. The missions were dangerous and though the Il-2 was armored to be protected in its ground-attack role, many planes were lost in battle. Statistics calculated after the war found that the death rate for Il-2 pilots was 1 fatality in every 10 or 11 missions.

Time	Video Content
0:00–0:16	Series opening
0:17–1:03	Introduction to Soviet Air Forces pilot Nikolay Yefimovich Olovyannikov
1:04–1:50	Introduction to the Ilyushin Il-2 Sturmovik, ground-attack aircraft
1:51–2:14	The ground-attack mission is a dangerous business
2:15–3:51	Engineering a survivable effective ground-attack aircraft
3:52–4:25	Olovyannikov's astounding record
4:26–4:46	Summary
4:47–5:02	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.

- **Nikolay Yefimovich Olovyannikov, Soviet Air Forces ground-attack pilot.** Olovyannikov was born in 1922 into a peasant family in the village of Solomykino, Medvenskiy District, Kursk Region. He quit school in the ninth grade to enroll in a government funded Flying Club. He became a pilot at the Military Aviation College and was called up six days after World War II began. Olovyannikov flew 212 combat missions without getting shot down or even making an emergency landing.
- **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 Olovyannikov and other WWII veterans online at Flying Heritage Collection.

Connect the Video to Science and Engineering Design

The Battle of Kursk took place almost 300 miles southwest of Moscow during July and August of 1943. It is historically important as being one of the largest armored battles ever. Both the Russians and the Germans had ground-attack aircraft at the battle. Engineering wise, as shown in the data below, there are similarities in the armor plating of the two aircraft. Because these planes flew close to the ground, they faced a barrage of explosive shells fired at them by anti-aircraft guns on the ground. The aluminum alloys that planes of the day were typically made with were not protective enough. Instead, these ground-attack aircraft were made with heavy steel armor plating that protected the aircraft's pilot, cockpit, engines, and fuel tanks from ground fire. The armor that protects the airframe is formed to fit the airplane, and is made from heavier material to help deflect bullets and shrapnel. Also, with the aircraft flying low to the ground, it is critical that the pilot sits in a position in the aircraft that assures the best view for hitting targets. The potential of damage during ground-attack missions requires the aircraft to be relatively inexpensive to fly and able to be manufactured in large numbers. During World War II, almost 36,000 Soviet Ilyushin Il-2 Sturmoviks saw combat—the most of any WWII aircraft.

Specifications of two ground-attack aircraft

	Russian Ilyushin Il-2	German Henschel Hs 129
Empty Weight (lb)	9,612	8,860
Loaded Weight (lb)	13,580	11,574
Length (ft)	38	32
Wing Span (ft)	48	47
Maximum Speed (mph)	257	253
Power-to-weight ratio (hp/lb)	.13	.16
Wing loading (lb/ft^2)	31.3	28.4
Rate of climb (ft/min)	2,050	1,595

Range(mi)	450	428
Number of engines	1	2
Total Horsepower	1,720	1,400
Armor plating (lb)	1540	2,380
Armor thickness (inch)	.24 - .47	.24 - .47

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 a particular aircraft.

Related Concepts and Terms

- alloy
- malleability
- aluminum
- steel
- iron
- carbon
- durability
- speed
- damage tolerance
- heavy armor
- close air support
- dive bomber
- firepower vs loadout
- cost per flying hour
- monocoque structure

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
0:17–1:03	Introduction to Nikolay Yefimovich Olovyannikov	Before students view the video, have them take a short time to write down what they know about tank warfare and how science and math could be used to defeat an armored vehicle.
1:04–1:50	Introduction to the Ilyushin Il-2 Sturmovik	*Sturmovik* is the Russian word for ground attack. Form students into groups and give each member a sticky note. Show the video. Each student generates a question relating to ground-attack missions from the material presented. The question is posed to group members, in turn, until consensus agrees an appropriate answer has been given.

1:51–2:14	Dangers of the ground-attack mission	Have students participate in an open discussion about the merits of the design strategy offered by Cory Graff.
2:15–3:51	Engineering a survivable ground-attack aircraft	Students might identify design features of other vehicles (e.g., cars, busses, spacecraft) that allow them to be survivable. Students might make and support a claim that the weight of the Il-2's armor makes it more or less successful than a smaller, lighter plane may have been. (Reducing the weight reduces its bomb load, speed, and overall maneuverability.) Although the final video doesn't dwell on it, students might brainstorm about the nickname "Winged Tank" to consider how a tank might or might not actually fly.
3:52–4:25	Olovyannikov survives	Students might create a bulleted list of physical characteristics or mental aspects that may have contributed to Olovyannikov's good fortune.

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:
   - *Features of the optimal ground-attack aircraft might include….*
   - *It would be important to have these optimal features because…*
   - *Dangers that a ground-attack aircraft must survive include….*
   - *In order to be effective, a ground-attack aircraft's armor plating must….*
   - *Tactics useful to the ground-attack mission might include....*
2. Show the video and allow students to discuss their observations and questions. The video presents the efforts made to design an aircraft specifically for ground-attack missions and highlights the strengths and weaknesses of the Il-2's design. Elicit observations about the aircraft and how its technology and innovations aided in the success of its mission.
3. Explore understanding with the following prompts:
   - *Critical components of a ground-attack aircraft that must be protected by armor include….*
   - *The benefits and drawbacks of aluminum and steel as ground-attack aircraft armor include….*

- *Construction techniques that allow the ground-attack aircraft armor to be kept as light as possible include….*
- *Flying a heavy aircraft is like driving a moving truck in that….*
- *Benefits and drawbacks of a heavy aircraft 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 assure a successful completion of its mission. If needed, show the video segment on the Ilyushin Il-2 Sturmovik's armor (2:15–3:51) as a way to spark ideas or direct student thinking along the following lines.

- Students might explore the optimal thickness of the armor used in a design by varying the thickness of the paper used to construct an airplane. Students would set certain criteria for flight and modify their designs until they can use the strongest armor (paper weight) and maintain the desired flight characteristics. They might also use different coverings on a Styrofoam or balsa-wood model, such as foil, duct tape, or different weights of paper.
- Students might compare and contrast the design of the Il-2 and the Fw 190 to support an argument about which features of the Il-2 (besides armor) made it more effective than a broad bull-nose plane, such as the Fw 190.
- Students could discuss design options and tactics to make recommendations to reduce the mortality rate among ground-attack pilots.
- The Il-2's armor protected critical components of the aircraft. The aircraft's pilot would probably think that he or she was more important than any part of the plane. Students might participate in the classic egg drop experiment with a twist. Their challenge is to create an armored aircraft cockpit that is survivable (by the egg) when slid down a taught string at a given angle. The cockpit could be attached to a straw and the angle of the string could be increased until only a single egg (pilot) survives.
- Students might use sculpting clay and additives to model alloys and their properties and make generalizations about aluminum and steel.

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
- aluminum foil
- duct tape
- cheesecloth
- paperclips
- scissors
- tape, clear and masking
- string or fishing line
- sticky notes
- glue
- measuring tape
- ruler
- protractor
- card board
- paper cups
- eggs
- drinking straws
- rubber bands
- sculpting clay
- sand
- packing materials
- calculator
- cell phone camera
- plastic foam plates
- electric plane launcher (optional)

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

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

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

Investigate

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

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

Cost is often another constraint. If you choose to make the investigation more complex, assign a cost or point value for each material used or quantity used. Costs could also be added for consultation with you or simply compared across designs.

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 steel armor in the Il-2's construction is highly durable and extremely versatile. It is also malleable, and can be shaped to the contours of the aircraft's skin. The fuselage sections form a load-bearing monocoque armor plating structure that does not require an internal framework. Structurally, monocoque (French for single shell) design is one where the skin takes on part or all of the structural load. A full monocoque design relies on the skin of the plane to hold the structure together. In a semi-monocoque design, the skin is reinforced by the underlying structure in part of the plane. Both designs require much less internal framework.

This unique design helps to reduce the Il-2's overall weight. Elicit from students the features of the Il-2 that suited their use for the mission presented in *The Winged Tank*. Have students conduct research and report on how modern aircraft are designed to take advantage of modern armor that is both stronger and lighter.

The current emphasis on multirole combat aircraft has reduced the need for designated ground-attack aircraft. Students might find out more about how the few that remain, such as the A-10 Warthog and the Su-25 Frogfoot, make use of new technologies and materials that make them more survivable. Some references students might use include:

- Top 10 attack aircraft
- Military today
- Fighter/attack aircraft

Although the Il-2 was armored, it couldn't be 100% armored. Give students the following quote from Olovyannikov as a prompt to find out more about how windows in airplanes have been constructed then and now. *"The plane was armored and so was the cockpit. But the sliding windows were not armored. They were made of Plexiglas. It was perhaps 10 millimeters thick. A shell exploded and pierced through this sheet of Plexiglas, losing its lethal power as it did so. Its fragment hit my headset here and fell into my lap. I picked it up and it was still hot."*

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:

- Il-2
- Hs 29
- Ju 87G
- Best WWII ground-attack aircraft

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 the design considerations given when creating a ground-attack aircraft. Students should cite specific support for their analysis of the science and use precise details and illustrations in their explanations and descriptions of design features. Examples of writing prompts that integrate the video content with the text resources cited above include the following:

- Students might compare and contrast two of the featured aircraft and identify the design features that made them successful ground-attack aircraft.
- Students might focus on a single aircraft and identify the ways in which the understanding of science helped to make it a successful aircraft.
- After reading all of the texts students might create a pamphlet that extols and explains the benefits of a fictitious ground-attack aircraft.
- Students might use the nickname Winged Tank as a basis for creating arguments about similar anomalies, such as flying car, kite-carrying human, and winged battleship.

- Students might create a fantasy football type activity, where they can combine the best features from any of the WWII ground-attack aircraft into a new fantasy WWII ground-attack aircraft. Students must explain why that feature was chosen and the benefit it provides.

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.

1. *Box quotations.* Have students identify sentences that might support their writing. The margins where the text is located can be used to justify why the quotation was selected and explain its significance.
2. *Main idea and supporting details*. During the initial reading of the text passage, students attempt to identify its main idea(s). After underlining or highlighting the main idea(s) the text is read again. During a second, even more close reading, students identify five sentences that support the main idea.

Summary Activity

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

Remind students that main ideas are the most important concepts they should remember. Then, have students work in pairs to create a fictional tweet about the main ideas of the lesson. The tweet must be 140 characters or less, so students should choose their words carefully. Ask for volunteers to share their tweets with the whole group.

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.