FUTURE U.

Virtual Field Trip | Testing the Limits

Objectives

Students will:

- **Identify** STEM careers that match their skills, interests, and experiences.
- **Describe** how test and evaluation engineers must be able to identify problems, create solutions, think critically, effectively communicate as part of a team, and apply new technologies and skills.
- **Explain** how different categories of materials testing determine the mechanical, thermal, electrical, and chemical properties of the material.
- **Summarize** practical applications of various types of materials (metals, ceramics, plastics, composite materials, etc.).
- **Make** a claim and support it with evidence and reasoning from an experiment.

Overview

"Testing the Limits," explores the vital role testing plays in the creation of Boeing's products and systems. The VFT will transport students to a variety of Boeing test centers around the United States where they will not only meet and interact with Boeing's test and evaluation engineers, but also witness the novel ways these experts test the limits of aerospace to ensure quality, reliability, safety, and performance.

The VFT will be organized around the five categories of materials testing conducted at various Boeing test centers:

- Structural Testing
- Wind Testing
- Environmental Testing
- Electromagnetic Testing
- Non-Destructive Testing

With each testing category, students will analyze how the tests determine the mechanical, thermal, electrical, and chemical properties of the material to gauge what its limits are. Students will also look at non-destructive testing methods that do not adversely impact the material.

Time Frame

Two-to-three class periods

National Standards

Next Generation Science Standards: Disciplinary Core Ideas
Middle School National Standards

ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ETS1-1)

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. (MS-ETS1-4)

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)
- Models of all kinds are important for testing solutions. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. (MS-ETS1-3)

  The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

High School National Standards
HS National Standards

- **Next Generation Science Standards (NGSS)**
  - **ETS1.B: Developing Possible Solutions**
    - There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- **International Technology Education Association (ITEA)**
  - **Standards for Technological Literacy (STL)**
    - Standard 2: Core Concepts of Technology
    - W: Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.
    - BB: Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

Pre-VFT Activity

Materials

- Device with internet access and ability to project the activator video, one for instructor
- Materials and Testing Matching Activity cards, cut out and shuffled, one per student

Begin by introducing the concept of materials testing: *the process through which engineers determine the mechanical, thermal, electrical, and chemical properties of a material to ensure the quality, reliability, safety, and performance that material in specific applications (products) for which it will be used*.

Then, show the video: Improved Helmet Design (3 min. 47 sec.)

Ask students to consider the following questions as they watch:

1. What materials are being tested?
   (A: Multi-layered polymer helmets; foam, plastic)

2. What tests are conducted?
   (A: Impact tests to determine how the helmet design holds up and dissipates the energy when it is struck)
3. How is testing a football helmet different from testing a bicycle helmet?
   (A: Whereas bicycle helmets can dissipate energy by fracturing, or cracking, and be replaced, football helmets must be designed and tested to withstand and dissipate impact each time they are used.)

Then, call on students to volunteer their answers to the questions. Explain that materials testing is used to ensure the quality, reliability, safety, and performance of all types of materials in many different products, and that the types of tests are different depending upon the material and how it will be used (its application).

Next, randomly distribute the *Materials and Testing Matching Activity* cards and explain that students will participate in a short matching activity to find another student with a corresponding material or type of test to complement the one on their card. Give students two to three minutes to walk around the room and find a match for their card. Have students stand together with their partner once they have found them to get a sense of when most students are done. Conduct a short full class debrief in which you ask students to describe how they found their partner. What was their reasoning for the match that they made? *Note:* There are no "right" answers, but some matches will make more sense than others. Encourage students to think about how the material may be used, and how the match they made fits that application).

During the Virtual Field Trip

Two activity options are available for students to obtain information as they watch the Virtual Field Trip. Each includes an extension activity that can be completed after the VFT.

Activity 1: Applying Your Knowledge and Skills to Careers in Engineering

Inform students that the professionals they will hear from during the Virtual Field Trip will describe some of their daily responsibilities and STEM phenomenon that drives their field. While watching the *Testing the Limits Virtual Field Trip,* direct students to complete the table on the *STEM Careers Behind Materials Testing* capture sheet. After the VFT, students can brainstorm their personal talents and interests, as well as complete the *Career Profile Research* extension activity handout by conducting independent internet research.

Materials

- *STEM Careers Behind Materials Testing* capture sheet (one per student)
- *Career Profile Research* extension activity handout (one per student)
- Internet access

Activity 2: Materials Testing in Action

Explain that students will now watch the *Testing the Limits Virtual Field Trip* to see Boeing professionals conducting materials testing in real research facilities across the country. Direct students to complete the table on the *Materials Testing* capture sheet as they watch. Students should identify the five types of testing presented in the first column: *Structural Test, Wind Test, Environmental Test, Electromagnetic Test, and Non-Destructive Test*. For each type of test, they should identify at least one material that undergoes that type of test and at least one application or product for each material. After the VFT, instruct students to choose one of the types of testing they saw in the VFT and answer the questions that follow.

Materials

- *Materials Testing* capture sheet (one per student)

Post-VFT Activity

YOU Test the Material: Spaghetti

This hands-on activity allows students to explore what happens when you bend spaghetti (or any other material): some parts experience tension, meaning they are being pulled apart, while other parts undergo compression, or being pushed together.

Remind students that some materials break more easily under either tension or compression, so engineers and materials scientists study how materials break. Improved understanding through structural testing allows engineers to not only choose the right materials for the job, but also figure out how well those materials will hold up to the specific task and how long they're going to last. In the VFT, students learned about static testing, which applies various forces to a material to help determine its failure, or breaking, point.

Explain to students that they will use static testing on a "beam" of bundled strands of spaghetti. As they hang weights from it, the beam will start to bend—putting the bottom strands in tension and the top strands in compression. They will need to make careful observations as they slowly add weights to determine which spaghetti strands start to break first. Then, students will complete a Claim, Evidence, Reasoning *(Spaghetti Testing CER)* graphic organizer to address the question: *Do you think spaghetti will break first in tension or compression?*

Materials

- *Spaghetti Testing CER* graphic organizer (one per student)
- Boxes of spaghetti (1–2 boxes per class, depending on class size)
- Two objects of equal height, such as chairs, tables or large cardboard boxes (per group)
- Scissors or single hole punches (one per group)
- Thick string or twine (cut into 8"–10" pieces, one per group)
- Paper clip (one per group)
- Large plastic or paper cup (one per group)
- Objects to use as weights, such as coins, metal washers, or marbles (enough for each group's tests)
- Rubber bands or tape (for each group)
- Safety goggles (for each student)

Procedure

- Have each group set up two equal-height chairs, tables, or cardboard boxes so they are parallel to one another, with a gap in between them that is just a few centimeters narrower than the length of a piece of spaghetti. The objects should have sufficient height to allow for the cup to hang from the beam of spaghetti without touching the ground.
- Instruct each group to bundle together five pieces of spaghetti to form a beam. They can do this by wrapping their ends together with rubber bands or tape.
- Each group should cut or hole-punch two small holes toward the top of the plastic or paper cup, just under the rim, on opposite sides from one another. Then, insert a loop of string through the two holes in the cup to make a handle.

- Students should then bend their paper clip into either a "C"- or "S"-hook shape and tie the ends of their string handle to the bottom of the paper clip hook. This will allow them to hang the cup from the beam of spaghetti.
- Each group should place their spaghetti beam horizontally across the gap between their two objects and hang their cup from the beam using the paper clip hook that they made.
- **At this point, pause and instruct groups to discuss what they think will happen when they start adding weight to the cup. How much weight will the bundled strands of spaghetti hold? Will the strands break all at once or one at a time? Will the strands at the bottom or top of the bundle break first? Will the breakage occur first because of tension (pulling apart) or compression (pushing together)? Finally, based upon their discussion, instruct students individually to write a claim statement in the first box of their Spaghetti Testing CER graphic organizer that answers the question: *Do you think spaghetti will break first in tension or compression?***
- Direct each group to slowly start adding weight (in the form of coins, marbles, washers, or whatever they are using) to the cup. Remind them to support the cup when dropping in each weight. Then, gently lower the cup until the string pulls on the spaghetti beam. Each group should keep adding weight until the beam of spaghetti begins to break. Instruct each group to observe carefully (watch and listen) to what happens as they add weight and record their observations (answering the discussion questions above from the pre-lab group discussion) on the back of their CER graphic organizer. Let them know they will use their observations to complete the Evidence section of the graphic organizer.

Observation Analysis and CER

Lead students in a discussion after their test of the beam to include the following:

- Students should observe that the spaghetti strands toward the bottom of the beam started to break first. This is because the strands are under tension (being pulled apart and extended) from the weight of the cup. When spaghetti is bent beyond the maximum load it can withstand with a hanging weight at the bottom, it fractures, and the break usually results in multiple pieces. On the other hand, the spaghetti strands at the top of the bundle are under compression and tend to break later.
- This material is brittle, meaning that it tends to break easily instead of bending (as opposed to a ductile material such as a metal, which will change its shape before it breaks). Therefore, when one piece of spaghetti breaks, all the other pieces might quickly follow in a cascade of fractures. This type of brittle failure is what engineers want to avoid in structures, such as bridges.

Instruct students to complete the *Spaghetti Testing CER* graphic organizer. Remind them that their CER should include the following components: A claim that answers the question, evidence from students' observations, and reasoning that involves a rule or scientific principle that describes why the evidence supports the claim. Remind students to provide a concluding statement in the Reasoning section that ties together the original claim and the evidence to convince the reader. If their claim was incorrect, let students know that they should just explain why in the Reasoning section.

Materials and Testing Matching Activity

Instructor Directions: Print enough copies so that each student has one card, either a material or type of test. Cut out and randomly distribute. If necessary, you can duplicate cards; just make sure to have an even number of Material and corresponding Type of Test cards. If you have an odd number of students, keep one card cut out for yourself and let students know that someone will match with you.

Material FABRIC STRAP	**Type of Test** STRUCTURE TEST—TENSION (PULLING APART)
Material STEEL CAR HOOD	**Type of Test** STRUCTURE TEST—COMPRESSION (PUSHING TOGETHER)
Material METAL GIRDERS	**Type of Test** STRUCTURE TEST—BENDING
Material FOOTBALL HELMET	**Type of Test** STRUCTURE TEST—DUCTILITY (HARDNESS/ BRITTLENESS, CAN IT WITHSTAND IMPACT?)
Material ACRYLIC AIRPLANE WINDOW	**Type of Test** WIND TEST—WIND NOISE/ACOUSTIC VIBRATION
Material EXTERIOR PANELS ON THE INTERNATIONAL SPACE STATION	**Type of Test** ENVIRONMENTAL TEST—TEMPERATURE EXTREMES
Material SPACESUIT FABRIC	**Type of Test** ENVIRONMENTAL TEST—SOLAR RADIATION
Material AIRPLANE FUSELAGE (BODY)	**Type of Test** ELECTROMAGNETIC TEST—LIGHTNING STRIKE
Material A NEW MACHINE ABOUT TO GO INTO SERVICE	**Type of Test** NON-DESTRUCTIVE TEST—DEFECT TESTING

Careers in Materials Testing

(This page to be completed during the virtual field trip)

The Testing the Limits Virtual Field Trip features a variety of Boeing test centers around the country. The VFT moves between locations to interview diverse, skilled, test and evaluation professionals at Boeing. During the VFT, they not only explain how testing determines the characteristic and behaviors of materials such as metals, ceramics, plastics, and composite materials under a variety of conditions, but also uncover why it is important to determine the suitability of these materials for various applications.

The Boeing employees you will hear from during the Virtual Field Trip will describe some of their daily responsibilities and STEM phenomenon that drives their field.

While watching the Testing the Limits Virtual Field Trip, complete the table below.

List **two** responsibilities of each professional featured.			
Wind Tunnel Testing	Aeroacoustics Test Engineer	**1.**	**2.**
	Test Engineering Manager	**1.**	**2.**
	Manager, Polysonic Wind Tunnel	**1.**	**2.**
	Test Engineer	**1.**	**2.**
In your own words, how would you describe what it looks and sounds like to work at a wind tunnel testing facility.			

List **two** responsibilities of each professional featured.			
Environmental Testing	Test and Evaluation Engineer	**1.**	**2.**
	Lead Spacecraft Systems Engineer	**1.**	**2.**
	Lead Spacecraft Assembly Test & Launch Operations Engineer	**1.**	**2.**
	Lead Assembly Test & Launch Operations Engineer	**1.**	**2.**
In your own words, how would you describe what it looks and sounds like to work at an environmental testing facility.			
Electromagnetic Testing	Lightning Test Engineer	**1.**	**2.**
In your own words, how would you describe what it looks and sounds like to work at an electromagnetic testing facility.			
Structural Testing	Instrumentation Engineer	**1.**	**2.**
In your own words, how would you describe what it looks and sounds like to work at a structural testing facility.			

List **two** responsibilities of each professional featured.		
Non-Destructive Testing	In-Process Test Engineer	**1.** **2.**
In your own words, how would you describe what it looks and sounds like to work at a non-destructive testing facility.		

After watching the Testing the Limits Virtual Field Trip, answer the reflection questions below, matching your own background/opportunities to the careers highlighted.

List **two** careers from the Virtual Field Trip that are most interesting to you based on your background and interests.

_____

_____

How do these careers help ensure the quality, reliability, safety, and performance of materials?

_____

_____

_____

_____

Career Profile Research

Directions: Conduct internet research to further explore a career that you learned about in the Virtual Field Trip. Record your notes below.

CAREER NAME	
Brief Description	
Training & Skills Required	
Salary Range	
Related Careers	
Current Job openings, if available	
Current classes I am taking that impact this career	
How this career matches my interests/skills/strengths	
Training opportunities I would need in the future to pursue this career	

Materials Testing Capture Sheet

Directions: As you watch, complete the table below during the VFT. After the VFT, answer the questions that follow.

Type of Testing What category of testing did you see presented in the VFT?	**Materials** What material(s) do you see in this part of the VFT?	**Applications** How are these materials going to be used?

Choose one of the types of tests from the first column:_____

Answer the following questions about the type of test you chose:

1. What other materials are you familiar with that you can also test in this way?

2. What uses/practical applications are there for these kinds of materials?

Claim-Evidence-Reasoning (C-E-R)

Student Graphic Organizer

Question: Do you think spaghetti will break first in tension or compression?

C **(Claim)** Write a statement that responds to the question.	
E **(Evidence)** Provide scientific data to support your claim. Your evidence should be appropriate (relevant) and sufficient (enough to convince someone that your claim is correct). This can be bullet points instead of sentences.	
R **(Reasoning)** Use scientific principles and knowledge that you have about the topic to explain why your evidence (data) supports your claim. Or, if your claim was incorrect, use this section to explain why and how the evidence shows that. This part must be in complete sentences.	