

LESSON

Satellite Shield

Grade Levels: 4-8

Duration: 60 min

Learners explore the properties of materials by designing a barrier that will protect a satellite from colliding objects. They test out multiple combinations of materials and collect data on the results to determine which materials are the most effective at shielding the satellites from the hazards of space debris.



Outline

Frame the Challenge	15 min total
Activate Prior Knowledge	10 min
Introduce the Challenge	5 min
Activity	45 min total
Material Investigation	10 min
Prototype (Build and Test)	20 min
Share Solutions	10 min
Debrief	5 min

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Concepts/Skills

Physics of colliding objects, absorbing impact, energy, velocity, material investigation, data collection

Objectives

Students will:

- Design a barrier that can protect the satellite from high-velocity impacts with space debris.
- Explore design considerations based on material characteristics.
- Collect data on each material combination they test.

Materials and Preparation

Materials

- [Satellite Shield Observation Sheet](#) (1 per team)
- Pencils (2 per team)
- *Optional:* Device to project a video



Building Materials

Look for items that match the categories. See the suggestions below for ideas. Try to provide several different types of items for each category.

Use the table below for inspiration. Don't limit yourself to the items on this list — be creative!

<i>(per class of ~32 students)</i>	
Lightweight, Flexible Materials <i>(50+ total)</i>	Connectors <i>(100+ total)</i>
<ul style="list-style-type: none"> • Aluminum foil • Fabric • Newspaper or magazine pages • Paper towels • Plastic bags • Straws • Tissue Paper • Wax paper 	<ul style="list-style-type: none"> • Binder clips • Binder rings • Clothespins • Paper clips • Pipe cleaners • Plastic clips • Plastic laundry hooks • Rubber bands • Twist ties
<p> Tip: Don't use tape or glue. This allows for faster iteration, more reuse of materials, and less mess.</p>	




Tools & Test Item <i>(One set per team)</i>	Test Area Supplies <i>(per class)</i>
<ul style="list-style-type: none"> • Container (plastic storage container, shoebox, etc.) • Penetrable material (wrapping paper, tin foil, tissue paper, etc.) • Rubber band (1 per container) • Scissors 	<ul style="list-style-type: none"> • Cardboard tubes (enough to create a 18-24 inch (.46-.61 m) long tube) • Masking tape • 3 or 4 small items with slightly sharp end (nails, pushpins, bamboo skewers, screws) • 3 or 4 writing utensils (pencils, pens)

See our [educator guides and videos](#) for more design challenge facilitation techniques. For this lesson check out:


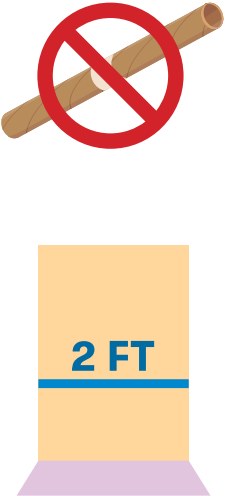
- **Prototyping** - Test, Reflect, Iterate
- **Data Collection** - Reflecting on your Design

Test Area Set-up

1. Follow the instructions below to create the testing items:

<p>Make the launch tube by taping cardboard tubes together, creating one long tube around 2 ft (.61 m) long.</p>	
<p>Create the space debris testers by using tape or rubber bands to attach the item with a sharp end to the writing utensil.</p>	
<p>Create the satellites by using rubber bands to secure a piece of penetrable material over the open end of each container. <i>*Pre-cut more pieces of the penetrable material to replace after tests as needed.</i></p>	

2. Place space debris testers and launch tube on a testing table.
 - To ensure safe prototyping practices, the testing table should be located at least 10 ft (3.05 m) away from the building and material tables.
3. When teams are ready to test, they will bring their satellite to the testing table, position the launch tube directly over their satellite, and drop one space debris tester down the tube.

Testing Variations			
<p>Balloon Astronaut</p> <p>Another way to approach this design challenge is to ask teams to build a protective suit for a balloon “astronaut.”</p> <p>We recommend using a 7 ft (2.13 m) PVC pipe for testing, as it generally takes more kinetic energy for the space debris to pop the balloon.</p>	 <p>7 FT PVC pipe</p> <p>Balloon “astronaut” with protective shield</p>	<p>Testing Without the Tube</p> <p>If desired, this activity can be also conducted by dropping the space debris directly down on the test item without the tube. To ensure consistency when testing, place a piece of tape on a wall 2 ft (.61 m) from the ground and ask learners to drop the space debris tester from that height.</p>	 <p>2 FT</p>



Caution: Sharp Test Item

This design challenge involves dropping a space debris tester (an item with a slightly sharp end) down a tube. To prioritize safety during prototyping, make sure that students are aware that they should...

- wait for the team before them to finish before approaching the testing area.
- always hold the space debris tester sharp side down.
- only drop one space debris tester per test.
- never remove the space debris testers from the testing area.

In some settings, it may be necessary for students to be supervised at the testing area for this challenge. The facilitator can offer support to groups as they come up to test or call teams over to test and check in if it seems like more support is needed.

Preparation

1. Collect, organize, and set up building materials.
2. Print the [Satellite Shield Observation Sheets](#).
3. Build a solution (or solutions) yourself, with other educators, or with kids you know. This will allow you to practice with the materials and tools and to anticipate student questions.



Frame the Challenge

Activate Prior Knowledge (10 min)

1. Start by exploring what learners already know about **space debris**, or human-made space junk.
 - *What do you think the word "debris" means?*
 - *What do we know about space debris? How is it made?*
 - *What kinds of items make up space debris?*
 - *Where is most space debris located?*
2. Inform learners that most space debris is **orbital debris**, revolving around the Earth's orbit.
 - If learners need more context, see [Additional Resources](#) on the next page.
 - *Optional:* Project this NASA [video](#) to visually show what the debris currently looks like around the Earth.
3. Ask **Guiding Questions** to explore the problems caused by orbital debris.
 - *Why might orbital debris be dangerous for spacecrafts, satellites, or an astronaut doing a spacewalk?*
 - *What could happen if orbital debris collides with a spacecraft or satellite at high **speeds**?*
 - *What could help decrease the damage of high **velocity** impact from orbital debris?*
4. Have them consider what could be done to protect the more than 5,465 satellites in space as of April 2022. (Want to know the current number? Check out the [Union of Concerned Scientists](#) website, which tracks space traffic.)



Additional Resources: Orbital Debris

As of 2021, there are [more than 25,000 pieces](#) of debris larger than a softball orbiting the Earth. Orbital debris travels at high speeds (approximately 15,700 mph in low Earth orbit), creating a high potential for catastrophic collisions with spacecraft and satellites. In fact, the International Space Station has to maneuver its position a couple times every year just to avoid being hit by orbital debris. Check out the resources below to learn more about the problems with orbital debris.

- [“Space Debris and Human Spacecraft,”](#) National Aeronautics and Space Administration (NASA) website
- [“NASA Orbital Debris Program Office,”](#) NASA website
- [“ ‘We’ve left junk everywhere’: why space pollution could be humanity’s next big problem,”](#) The Guardian
- [“McKinsey for Kids: Space junk - it’s out of this world,”](#) McKinsey & Company website.
- [“Space collision: Chinese satellite got whacked by hunk of Russian rocket in March,”](#) SPACE.com



Real-World Connection: Colliding Objects




In this design challenge, students are exploring how to minimize the **impact** of two colliding objects: space debris and a satellite. A collision is an event in which two or more bodies exert forces on each other. Damage to the satellite occurs when it is unable to absorb the impact **energy** resulting from the space debris colliding with it at high speeds. For other real-world examples, consider crumple zones in cars, padding in football helmets, or even [packing materials](#) in shipping boxes.

Introduce the Challenge (5 min)

1. Introduce the design scenario:

You and your team of satellite engineers are tasked with designing a protective barrier that can shield a satellite from orbital debris. Your team will need to collect data on different material combinations to see which properties are most successful at preventing colliding debris from damaging the satellite.

2. Introduce the design problem, criteria, and constraints.

Design Problem	Design a barrier for a satellite that will protect it from being hit by small space debris moving at high speeds.	
Criteria	<ul style="list-style-type: none"> • Protective barrier must fit snugly on the satellite. • Must consist of at least two different kinds of materials. 	
Constraints	<ul style="list-style-type: none"> • Only use light-weight, flexible materials. • Maximum of four layers may be used. • There’s a time limit! 	

3. Turn learners' attention to the testing area. Demonstrate a test on a "satellite" without any protective barrier by placing the tube on top of it and sending the space debris testers down the tube.
 - Review the [safety procedures](#) with learners to ensure best practices during testing.
4. Show learners the [Observation handout](#) where they will record each material combination they test.
 - Emphasize that rather than continuing to adjust and retest the same design, their goal is to test multiple materials combinations they believe could be potentially effective at preventing damage from the space debris testers.
5. Let learners know that they will spend the first few minutes exploring the materials and discussing what properties they think they should include in their design before they get their satellites.



Investigating Materials

Exploring materials is an important aspect of engaging in an engineering project. Spending time investigating the properties of the materials can help learners make informed decisions about what they are creating.

Considering materials carefully is uniquely important for engineers working on satellites and other items going into space, which has extremely harsh conditions and requires costly fuel during the launch phase. Try these tips for encouraging learners to deeply explore their materials:

- Ask learners to do a materials investigation brainstorm before they start building. Have each person select a different material and share ideas for how it could be used in their group's solution. For more details, check out our [Brainstorming Tech Tip \(PDF\)](#)
- Encourage learners to "think with their hands" by tinkering with and manipulating materials while they come up with ideas and imagine solutions.
- Create real-world connections by introducing learners to careers in Materials Science. These scientists investigate materials to develop new products and solve problems.

For more ideas on how to use materials see the [Materials Strategies for Engineering Design Tech Tip \(PDF, Video\)](#)

Design Challenge



Materials Investigation (10 min)

1. Divide students into teams of three or four.
2. Have teams collect materials. Ask them to spend this time playing with the materials to learn more about their physical components, properties or characteristics.
3. While teams are exploring the materials, encourage them to be curious about which properties may be most effective for solving this problem:
 - *Is the material stretchy or stiff? How flexible does it need to be?*
 - *Do you think this material might be good at absorbing impact? Why?*
4. When they are ready, have teams call you over and share a couple of observations they made about the materials and why they think they will be effective at protecting the satellite.
5. Once the team shows they are ready to proceed, give them a satellite and a [Satellite Shield Observation Sheet](#).



Prototype (Build and Test) (20 min)

- As teams build and test, ask open-ended questions to encourage learners to reflect on how they are using the materials:

Just Getting Started	<ul style="list-style-type: none"> • How many layers (maximum of four) does the barrier need to be successful? • What kinds of materials do you think should be on the outside? Inside? • Do you think the satellite would be better protected if the materials are attached tightly? Loosely?
Problem-Solving After Testing	<ul style="list-style-type: none"> • Did the space debris damage any layer(s) of the barrier? Why do you think this happened? • What kind of material combinations have you tried so far? • Are there ways you could change your design or use of materials?
Pushing Design Further	<ul style="list-style-type: none"> • Do you think that the satellite would be protected from all types of space debris? • What do you think would have happened if the space debris was even bigger? • What do you think would happen if the space debris was dropped from a greater height?

- Encourage teams to test as often as possible. Help them make observations during testing.
 - Remind learners to record their results for each test on their [Satellite Shield Observation Sheet](#).
 - Have teams continue testing throughout the entire prototyping time, even if they are successful. Remind them that their goal is to explore as many types of materials combinations as possible.
- Provide ten and five minute warnings. Bring the whole class back together when the time is up.



Share Solutions (10 min)

- Have the teams take turns sharing what they discovered during their material properties testing. Possible **Sharing Questions** could include:
 - Which material combinations were the most successful? Why do you think this combination worked well?
 - Which material combinations were the least successful? Why do you think these combinations did not work as well?
 - Was there anything else you would want to test if you had more time?
- After each team shares, invite the other students to give positive feedback on their designs and encourage them to share suggestions.



Debrief (5 min)

- Lead a short debrief with some of these questions. Possible **Debrief Questions** include:
 - Was anything consistently successful or unsuccessful in different team tests?
 - How would your team adjust your design if the space debris were bigger?
 - What material properties did we find are important for protecting the satellite?
 - Would you make changes to your design if the space debris was approaching faster (i.e., tested using a longer tube)?



Extension

- **Weight:** Consider adding weight to the space debris test items to see if the team's barriers can withstand various types of impact.
- **Distance:** Include different lengths of tube to see if their designs can withstand different drop heights. This can also be an opportunity to discuss how changes in distance affects the object's energy.
- **Compact and Attached:** Sophisticated satellites might be able to deploy protective barriers once they are in orbit. In this situation, the barrier would not need to fit snugly, but might need to be something that stays attached and does not increase the dimensions of the satellite significantly. Challenge teams to create barriers that don't increase the dimensions of the satellite by more than .79 in (2 cm).
- **Non-Newtonian Fluids:** Explore other methods for absorbing impact. Try launching the space debris into non-Newtonian fluids like shampoo or oobleck, a non-Newtonian liquid that acts like a liquid when at rest and like a solid when put under pressure.

Standards Connections

Next Generation Science Standards

Grades	Standard	Description
3-5	Engineering Design 3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5	Physical Science 4-PS3-1	Use evidence to construct an explanation relating the speed of an object to the energy of that object
6-8	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.
6-8	Physical Science MS-PS2-1	Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

Common Core State Standards

Grades	Standard	Description
4-8	Speaking and Listening x.1	Engage effectively in a range of collaborative discussions, etc.

Vocabulary

For more tips on vocabulary and common engineering terms, see our [Tech Tip: The Language of Engineering](#).

- **Collision:** An event in which two or more bodies exert forces on each other
- **Energy:** The capacity or power to do work
- **Impact:** The resulting force or energy when two or more objects collide
- **Orbital debris:** Space debris in the Earth's orbit
- **Space debris:** Defunct human-made objects in space
- **Speed:** The rate of motion at which an object is moving along a path
- **Velocity:** The rate and direction of an object's movement

Satellite Shield Observation Sheet

Team Name:

Date:

Welcome satellite engineers! Before we launch the satellite, we need your team to determine which combinations of materials are most successful at protecting it from the impact of space debris. Record the results from each test in the tables below.

Test #	Outer Layer Material	Inner Layer Material(s)	Did the space debris damage any of the layers?	Would the satellite have been protected from damage?
1				
2				

Test #	Outer Layer Material	Inner Layer Material(s)	Did the space debris damage any of the layers?	Would the satellite have been protected from damage?
3				
4				

<p>Our team's most successful materials</p>	<p>Our team's least successful materials</p>
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