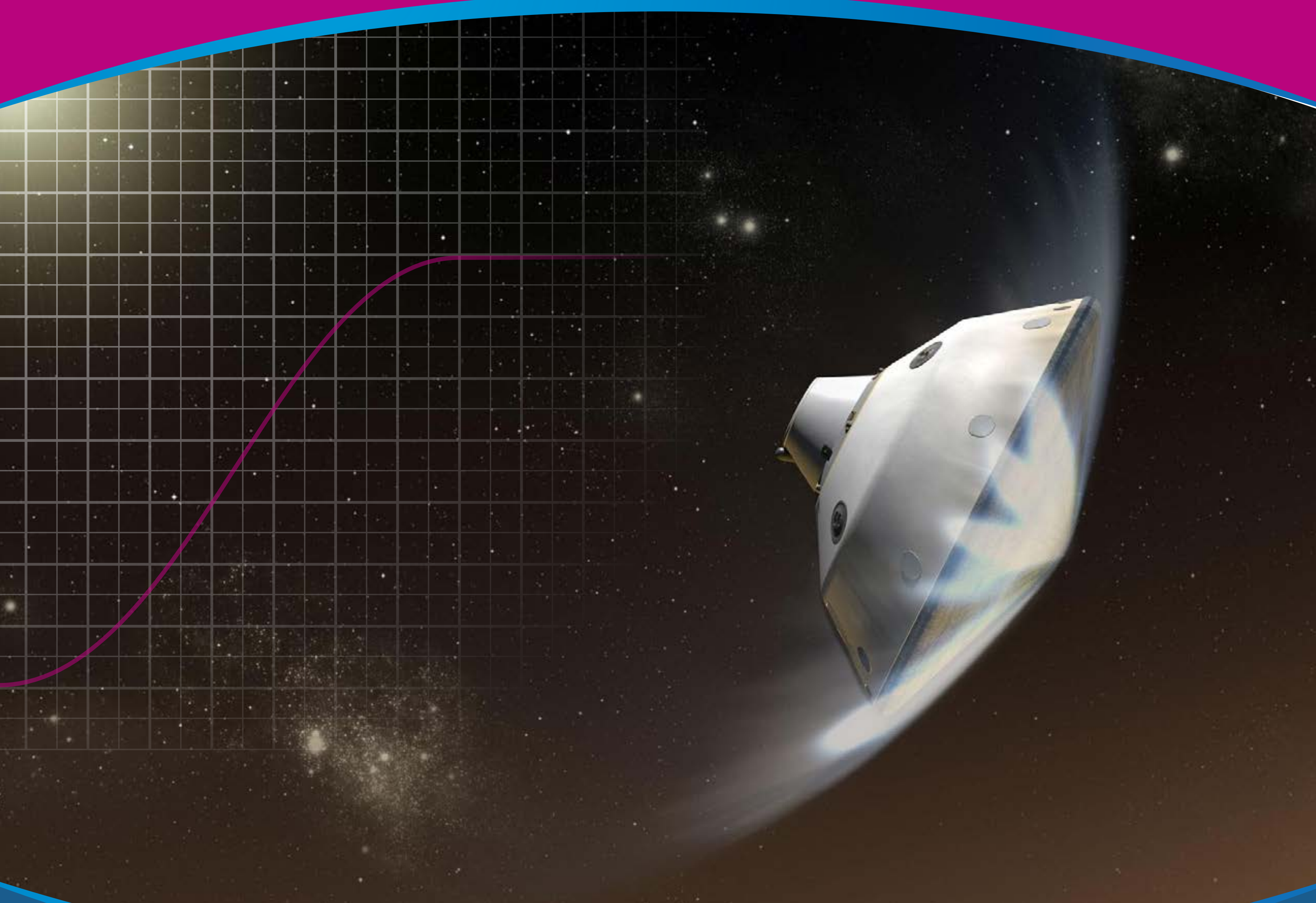
National Aeronautics and
Space Administration

BEST

NASA'S BEST STUDENTS
Beginning Engineering, Science, and Technology
LESSON SERIES

MEDLI2

Mars Entry, Descent, and Landing Instrumentation 2



EXPLORE SPACE TECH

BEST

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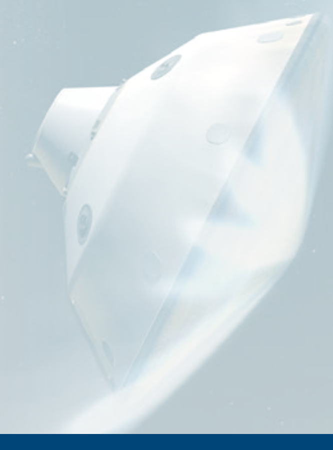


MEDLI2

Mars Entry, Descent, and Landing Instrumentation 2

EDUCATOR GUIDE

CHALLENGE

Design and test a heat shield to protect the MEDLI2 sensors during a Mars entry simulation.

Materials

Items required for this activity:

- Scissors
- Tape
- Rulers
- Digital scale or balance
- Hair dryer (one per testing station)
- Tongs (one set per testing station)
- Stopwatch (one per testing station)
- Thermometers (at least two per testing station)
- Oven mitts (one per station)
- Unwrapped candy bars without nuts (the nuts interfere with the temperature probes)—mini or fun size (at least two per team; use the same type for the whole class for consistency)

Provide students with a selection of materials to choose from:

- Index cards/newspaper
- Cotton balls/bubble wrap
- Electrical tape
- Steel wool
- Spackling compound
- White glue
- Styrofoam scraps (packing peanuts, food trays)
- Wire mesh/cloth (see note below)
- Cardboard scraps (milk cartons, shoeboxes, coffee cups, boxes, etc.)

Pre-Activity Setup

The wire mesh/cloth can provide structure and stability to shield devices. It doesn't matter which type you purchase, but ideally you would want something that will not conduct the heat (which will be more expensive) and give structure to the shield device. This is a major design element. If your activity budget allows, offer a variety and the students could select which is better. These can be found online or at your local hardware store.

Set up hair dryer stations around the room for testing. Remember that the testing area may become warm with the hair dryers running on high heat; if that is an issue, set up in a ventilated area. If using multiple hair dryers, be sure to check ahead of time that they can run at the same time without overloading a circuit. It is also helpful to mark on the tables where the heat shield should be placed and where the hair dryer should be placed (at least 10 centimeters apart). This will ensure consistency at all testing stations.

Depending on the type of thermometers available, plan ahead how students will mount them to collect internal and external temperature.

Motivate

- If your students need an introduction to Mars, NASA has a video series called Mars in a Minute—student-friendly videos about traveling to Mars, the environment on Mars, landing on Mars, and general questions about Mars:

  https://www.youtube.com/playlist?list=PL56421C9A51D1F427

  For more on NASA's Mars Exploration Program and missions, visit:

  https://mars.nasa.gov/

  The "Seven Minutes of Terror" video can be found here:

  https://www.youtube.com/watch?v=Ki_Af_o9Q9s

- Discuss the Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) suite of engineering sensors. Learn about MEDLI2 here:

  https://www.nasa.gov/directorates/spacetech/game_changing_development/projects/MEDLI-2

- The MEDLI2 sensors will collect data during the Mars 2020 Perseverance rover's entry through the planet's atmosphere to enable improved designs of future entry systems for robotic and crewed missions. The spacecraft will enter Mars's atmosphere traveling at about 12,500 miles per hour. MEDLI2 will collect data during the last 7 minutes of flight, also known as the "7 minutes of terror", leading up to when the rover lands on the surface of Mars. MEDLI2 builds upon entry data collected by the MEDLI instrument flown aboard the *Mars Science Laboratory (MSL)* mission in 2012.
- NASA engineers not only look to create the best designs, but also the ones that are cost-efficient and can be developed in a reasonable timeframe.
- Challenge the students to design a heat shield to protect the MEDLI2 sensors (candy bar). The surface area of the heat shield cannot exceed 40 cm^2.
- The heat shield must protect the MEDLI2 sensors (candy bar) from heat and turbulence (hair dryer). The sensors must survive for 7 minutes without melting.
- Review the concepts of heat transfer, heat load, thermal resistance, and turbulence.

Ask

- Answer any questions they have related to today's challenge.

Imagine

- Brainstorm ideas about what material characteristics will work best to protect the simulated sensors (candy bar).

Plan

- Students will draw out their ideas for a heat shield and will plan how they will conduct the testing.
- All drawings and preliminary project budgets should be approved before building begins.

Create

- Be sure students are keeping up with material costs as they create their designs.

Experiment

- Students will follow the directions on the Experiment and Record and the Quality Assurance sheet to complete their experiment testing. The students will document what happens at 1-minute intervals. For safety, be sure that students are using tongs to hold heat shields in place.

Improve

- After completing the first round of testing, students will make modifications to their designs to improve protection of the MEDLI2 sensors (candy bar).
- Remind students to include updates to the budget if they had to purchase more materials or use the testing facility.

Challenge Closure

Engage the students in a discussion by reviewing all of the data and posing the following questions:

- Which design characteristics provided the most protection to the sensors?
- Compare your preliminary budget projection to your final budget. What did you learn?
- In what ways were you able to maximize resources of time, budget, and performance?
- What information could engineers working on this project learn from your team's results?
- What other tests or calculations could you do before making your recommendations to the engineering team?
- What do you think would be the best way to present your results?

MEDLI2 sensors, electronics, and harnessing are installed on the Mars 2020 heat shield, shown here from the inner surface of the heat shield. The MEDLI2 harness has a circuitous routing to avoid the wheels of the Perseverance rover. There are 7 pressure transducers and 11 locations for thermocouple measurements on the Mars 2020 heat shield. (Credit: NASA/JPL-Caltech)

Safety Concerns

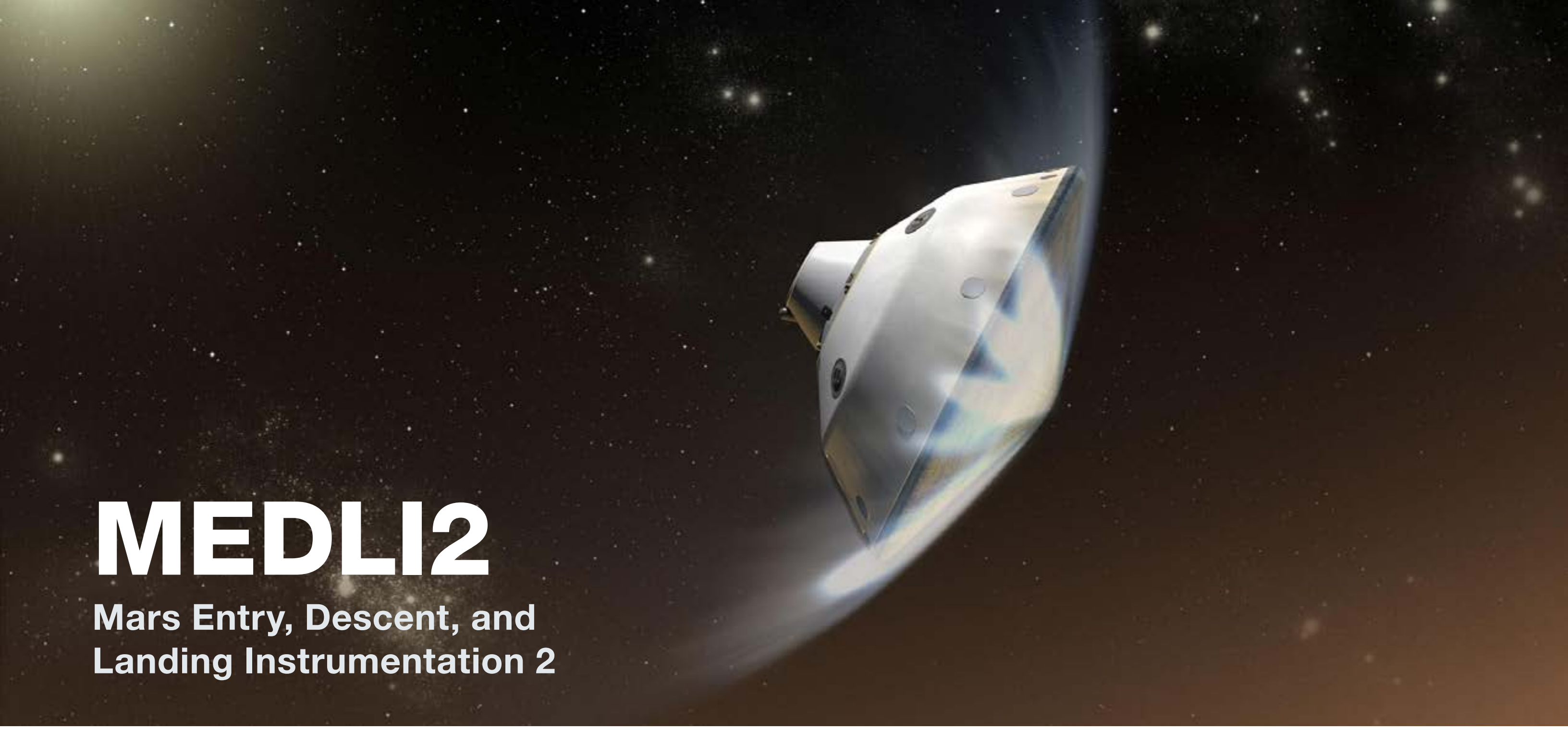
In this activity, keep commonsense safety in mind. Possible things to be aware of:

- Check ahead of time that all hair dryers can operate at the same time without blowing a circuit.
- Students should use caution when operating hair dryers. They should not touch the hot parts of the hair dryer or shield.
- Students should use tongs to hold heat shields in place.
- Be aware of candy and nut allergies. If necessary, other materials, like wax or ice, could be used instead.

More Fun with Engineering

Here are some possible student answers for the extension activity:

- What factors would NASA engineers have to take into consideration, that were not simulated in today's activity? (Heat shield charring, surface conditions, atmosphere, etc.)
- How could you have altered your testing to minimize these uncertainties? (Push limits to see how much the materials could handle—longer heat, various temperatures of heat at the same time, etc.)
- How do these uncertainties impact budget, performance, and time constraints?



MEDLI2

Mars Entry, Descent, and Landing Instrumentation 2

Illustration showing the entry of a spacecraft into Mars's atmosphere.

Background

The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) will collect data during the *Mars 2020 Perseverance* rover's entry through the planet's atmosphere to enable improved designs of future entry systems for robotic and crewed missions. The spacecraft will enter Mars's atmosphere traveling about 12,500 miles per hour. MEDLI2 will collect data during the last 7 minutes of flight, also known as the "7 minutes of terror," leading up to when the rover lands on the surface of Mars. In total, 28 sensors are across the heat shield and backshell of the Mars 2020 entry vehicle.

Expanding upon groundbreaking entry data collected by the MEDLI instrument flown aboard the *Mars Science Laboratory (MSL)* mission in 2012, MEDLI2 seeks answers to questions generated from examining MEDLI/MSL data. Close analysis of MEDLI2 flight data is vital to future human and robotic exploration of the Red Planet. Additionally, understanding aerothermal environments, thermal protection system performance, and aerodynamic performance characteristics of the Mars 2020 vehicle extends to designing entry systems for other destinations, such as Venus, Titan, and the gas giants.

More information can be found at:

https://www.nasa.gov/directorates/spacetech/game_changing_development/projects/MEDLI-2

The Challenge

Your mission is to design a heat shield system to protect the MEDLI2 sensors.

The design constraints:

- Use only the materials provided to create a heat shield system.
- The surface area of the heat shield cannot exceed 40 cm^2.
- The heat shield must protect the integrity of the sensors for 7 minutes while documenting observations and temperatures (internal and external) once per minute.

Be sure you can observe any changes.

- The sensor (candy bar) should not be more than 5 cm from the shield.
- The heat source should not be more than 10 cm from the heat shield.
- Record temperature inside and outside the heat shield.

Reminder for All Challenges

- Be sure to document all testing results.
- Maintain documentation of all material costs.
- Make any necessary design changes to improve your results and retest.
- Complete all conclusion questions.

Team Name:
Team Members:
Date:

Our Team's Plan

Ask

Today you will design a heat shield that will protect sensors (simulated by a candy bar) during the descent of a space capsule.

Imagine

What is the general shape of your heat shield?

____

____

____

____

Plan

What materials will you use in your heat shield? Draw and label your heat shield. Be sure to include measurements!

Budget

Rental of test area (15-minute block of time): **$25,000**
Materials (1 gram of materials): **$10,000**

Description of Expense	Cost	Running Total

Use another sheet if necessary.

What is your preliminary total budget for your designs and testing?

Design One:

Redesign:

Were there any additional expenses during the building phase?

____

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____

Were there any additional expenses during the redesigns?

____

____

____

Experiment and Record

Conduct a 7-minute test on the heat shield. At 1-minute intervals, note your observations of what is happening while the test is taking place. For safety, use tongs when handling the heat shield.

Design One

Surface Area (show calculations) ____

Time Increments (minutes)	Temperature External (degrees)	Temperature Internal (degrees)	Observations
1:00			
2:00			
3:00			
4:00			
5:00			
6:00			
7:00			

Improve the design of your heat shield and repeat the experiment. Record your results for the redesign below. Update your expense report with additional costs.

Redesign

Surface Area (show calculations)____

Time Increments (minutes)	Temperature External (degrees)	Temperature Internal (degrees)	Observations
1:00			
2:00			
3:00			
4:00			
5:00			
6:00			
7:00			

Challenge Closure

1. Which design characteristics provided the most protection to the sensors?

2. Compare your preliminary budget projection to your final budget. What did you learn?

3. In what ways were you able to maximize resources of time, budget, and performance?

4. NASA engineers also must figure out under what conditions their designs might fail. By learning the maximum heat load on their design, they can identify under what other conditions this technology could be used (hotter temperatures, longer entries, etc.). Based on the data you collected in the 7-minute tests, how much longer do you think your design would be able to handle the turbulence and thermal stress?

Quality Assurance

Each team is to review another team's design and model, then answer the following questions.

Team Name	Yes	No	Notes
Were the sensors protected from the heat?			
Was the surface area equal to or less than 40 cm^2?			
Did the team correctly record data?			

1. List the specific strengths of the design.

____

____

____

2. List the specific weaknesses of the design.

____

____

____

3. How would you improve the design?

____

____

____

____

Inspected by: ______________________________

Signature: ______________________________

More Fun with Engineering

Activity One

It is very difficult to conduct experiments on Earth that simulate all of the aspects of a Martian entry. As a result, there are a lot of uncertainties in the engineering models. Engineers work to try to minimize the uncertainties as best they can. Make predictions to answer the questions below.

Activity Two

Repeat the activity. Try out different types of heat-sensitive materials to be used as your sensors. What were your results? Try running the test for 10 minutes. Try running it for 15 minutes. How well did your design stay intact and protect the sensors?

1. What factors would NASA engineers have to take into consideration that were not simulated in today's activity?

2. How could you have altered your testing to minimize these uncertainties?

3. How do these uncertainties impact budget, performance, and time constraints?

4. How could you balance the need to minimize uncertainties and stay within your budget and time constraints?

BEST is a lesson series produced by the Space Technology Mission Directorate.

Learn more at *www.nasa.gov/spacetech*.

About This Lesson

This lesson was prepared in collaboration with the
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Image Credits

Cover, Pages 1 and 1-1: Mars Science Laboratory spacecraft approaching Mars—NASA. **Page 3**: MEDLI2 sensors, electronics, and harnessing installed on the Mars 2020 heat shield—NASA/JPL-Caltech

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