

Challenge

Design and test a heat shield to protect the MEDLI 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 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—mini or fun size (at least two per team; use the same type for the whole class for consistency. The nuts interfere with the temperature probes.)

Provide students a selection of materials to choose from:

- Index cards/newspaper
- Cotton balls/bubblewrap
- 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 Set-up

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 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 cm 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, environment on Mars, landing on Mars, and general questions about Mars. http://www.jpl.nasa.gov/education/curiosity_resources.cfm
The Jet Propulsion Lab website has all the latest developments on the Mars rovers <http://www.jpl.nasa.gov/education/marsrover.cfm>
The “Seven Minutes of Terror” video can be found at: <http://www.jpl.nasa.gov/video/index.php?id=1090>
- Discuss the Mars Science Laboratory, Entry, Descent & Landing Instrumentation (MEDLI) suite of engineering sensors. Here are videos about MEDLI: <http://www.youtube.com/watch?v=HGymf-HBi0A&list=PLBEXDPatoWBIT-c3LUe8IZ3Tv6rZNVol> and http://www.youtube.com/watch?v=H66lrGmE-5A&feature=youtube_gdata
- The MEDLI sensors measured the conditions experienced by the Mars Science Laboratory heat shield during entry into the Martian atmosphere in August 2012. The sensors placed on the heat shield collected temperature and pressure readings as well as atmospheric data. NASA is analyzing data to determine how to better design thermal protection systems on future spacecraft, like Orion.

- 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 MEDLI sensors (candy bar). The surface area of the heat shield cannot exceed 40 cm². The heat shield must protect the MEDLI sensors (candy bar) from heat and turbulence (hair dryer). The sensors must survive for seven 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.

MEDLI

Mars Science Laboratory Entry,
Descent, & Landing Instrument

For the Teacher

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 one-minute intervals. For safety, be sure 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 MEDLI 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?

Safety Concerns

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

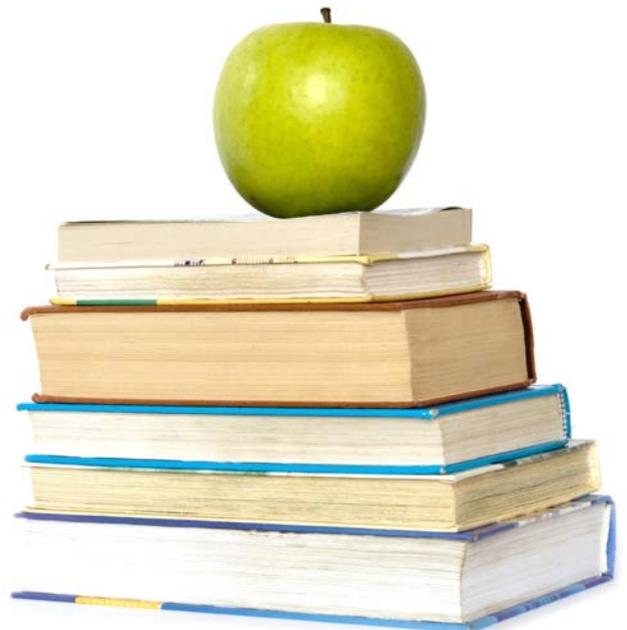
- Check ahead of time that all hair dryers can operate at the same time without blowing a circuit.
- Students should use caution when operating hair dryers. They should not touch the hot parts of the hair dryer or shield.
- Students should use tongs to hold heat shields in place.
- Be aware of any and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



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?

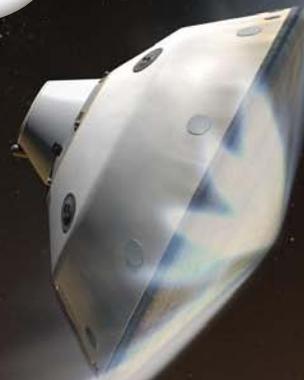


The Mars Science Laboratory Entry, Descent, and Landing Instrument (MEDLI) Suite is a set of engineering sensors designed to measure the atmospheric conditions and performance of the Mars Science Laboratory (MSL) heat shield during entry and descent to Mars. The MSL spacecraft successfully landed on Mars in August 2012. MEDLI provided important information that will be used in the design of future planetary missions.

The MSL spacecraft entered the Martian atmosphere at 13,000 miles per hour. The heat shield of MSL was much larger and

therefore heavier than previous missions to Mars. As portrayed in the “Seven Minutes of Terror” video, it was a turbulent entry to Mars and a great deal of thermal stress was put on the heat shield. Future missions (such as sending humans to Mars) will require larger payloads and will need larger capsules.

More information and videos can be found at: http://www.nasa.gov/mission_pages/tadm/medli/index.html#.Uidal2Q17io



The Challenge

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

The design constraints:

- Use only materials provided to create heat shield system.
- The surface area of the heat shield cannot exceed 40 cm².
- The heat shield must protect integrity of the sensors for seven 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 shield.

- The heat source should not be more than 10 cm from the heat shield.
- Record temperature inside and outside of heatshield.

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.

Experiment & Record

Team Name _____

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

Design One

Surface Area (show calculations)

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

Experiment & Record

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 what other conditions this technology could be used with (hotter temperatures, longer entries, etc.). Based on the data you collected in the seven-minute tests, how much longer do you think your design would be able to handle the turbulence and thermal stress?



Quality Assurance

MEDU

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?			

List the specific strengths of the design.

List the specific weaknesses of the design.

How would you improve the design?

Inspected by: _____

Signature: _____

More Fun With Engineering

MEDU

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 the question 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?

What factors would NASA engineers have to take into consideration, not simulated in today's activity?

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

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

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