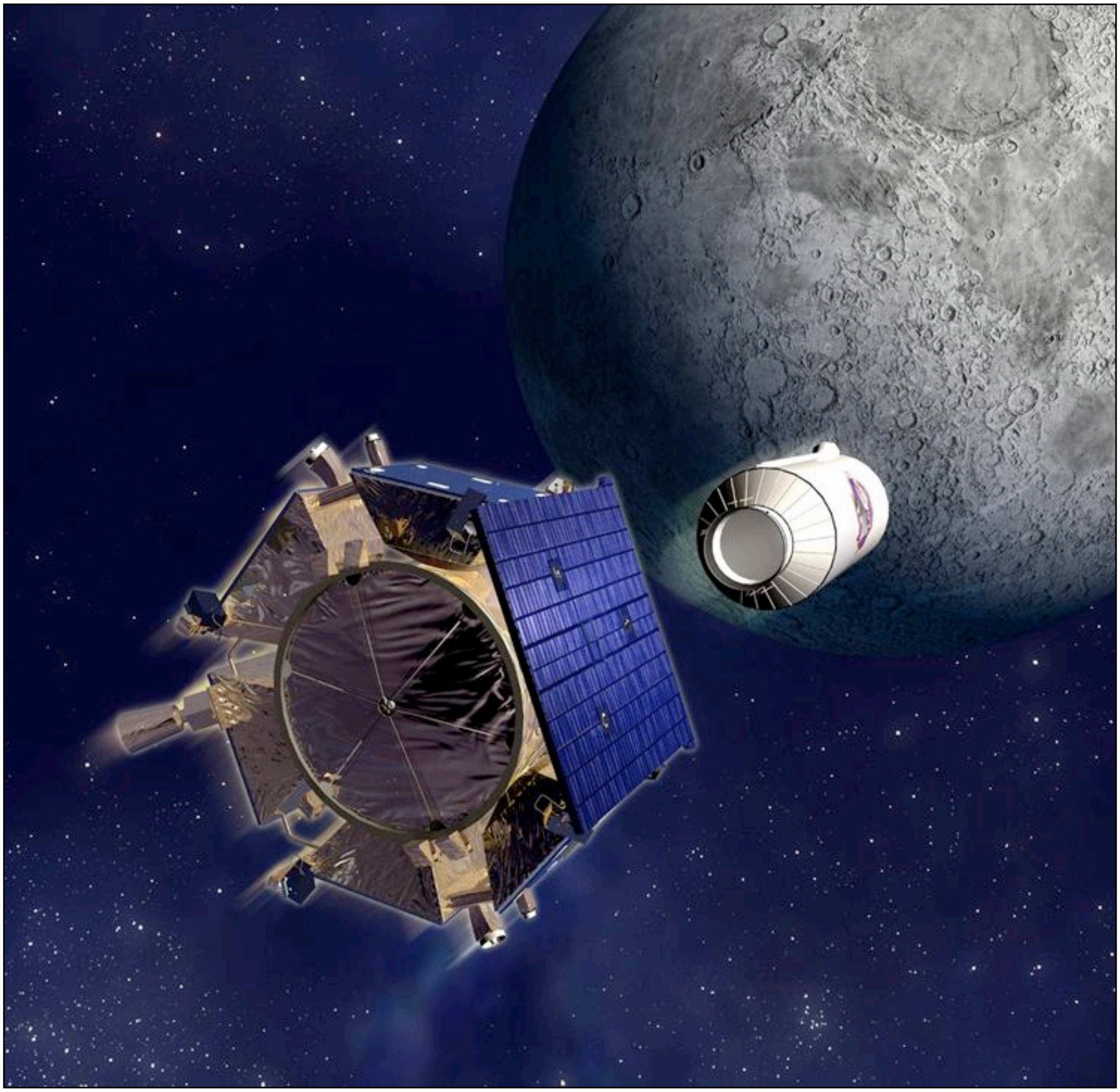
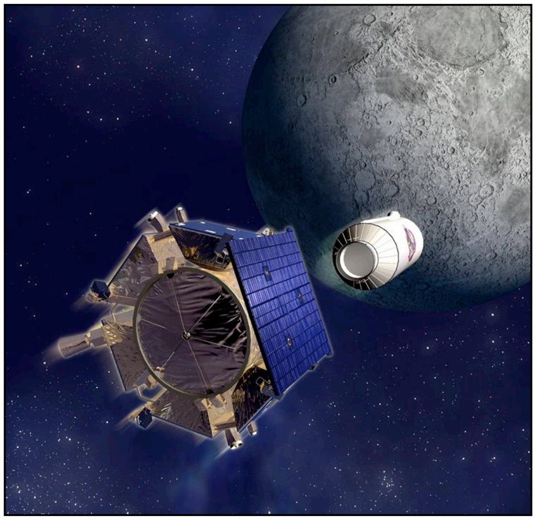
Cratering the Moon

NASA Quest Challenge Educator Guide



Spring 2008

Cratering the Moon



Target Audience: Grades 4 and higher

Estimated Time: 1–2 hours per week (6–8 weeks)

Actual time spent on this Challenge will depend on available time, resources, and student designs.

Objectives:

- Students will design and build a launching device that will cause a projectile to excavate subsurface layers of "lunar soil."
- Students will conduct an inquiry experiment to determine the optimal angle of impact for effective, subsurface "lunar soil" excavation based on the area of the resulting ejecta blanket and the layers of soil revealed.
- Students will understand the strengths and weaknesses of using experimental simulations as predictive tools.
- Students will become familiar with NASA's Lunar CRater Observation and Sensing Satellite (LCROSS) mission and understand the mission's primary goal: to search for frozen water in one of the Moon's permanently shadowed craters.
- Students will understand that humans need water to survive and, therefore, finding water on the Moon is important for future human lunar exploration.
- Students will understand the types of tasks (or work) that scientists and engineers perform.

Materials:

- **Lunar Target Station materials**

  (Instructions and sample on pp.12–13)

  - Large aluminum roasting pan *or* similar wide, shallow container such as a cardboard box lid
  - 2-3 types of soil-like substances of contrasting colors and textures (Examples: flour, sand, perlite, cocoa powder, cornstarch, kitty litter, sawdust, potting soil, etc. The "soils" will be layered and should contrast each other.)
  - Large drop cloth that contrasts with the "soil" (Examples: sheet, shower curtain, plastic table covering, etc)
- **Rulers, meter sticks, or measuring tape**
- **Protractors**
- **Safety glasses** *(if design warrants them)*
- **Projectile** *(see note on p. 6)*
- **Digital camera** *(if available)*
- **Area grid of 1-inch squares** *(p. 14)*
- **Impact Experiment Data Sheet**(pp.15-16)
- **Assorted building materials for the launching device** *(materials will vary based on student designs)*

Education Standards:

National Science Education Standards

Content Standard A: Science as Inquiry—Fundamental Abilities Necessary to do Scientific Inquiry

K–4

- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations.

5–8

- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.

Content Standard B**:** Physical Science

K–4

The position and motion of objects can be changed by pushing or pulling.

5–8

Unbalanced forces will cause changes in the speed or direction of an object's motion.

Content Standard E: Science and Technology—Abilities of Technological Design

K–4

- Propose a solution.
- Implementing proposed solutions.
- Evaluate a product or design.
- Communicate a problem, design, and solution.

5–8

- Design a solution or product.
- Implement a proposed design.
- Evaluate completed technological designs or products.
- Communicate the process of technological design.

American Association for the Advancement of Science

The Nature of Science—Scientific Inquiry

3–5

Results of scientific investigations are seldom exactly the same, but if the differences are large, it is important to try to figure out why.

6–8

If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables.

The Nature of Technology—Design and Systems

3–5

Even a good design may fail. Sometimes steps can be taken ahead of time to reduce the likelihood of failure, but it cannot be entirely eliminated.

6–8

- Design usually requires taking constraints into account.
- The most common ways to prevent failure are pre-testing parts and procedures, over-design, and redundancy.

National Council of Teachers of Mathematics

3–8 Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Develop and evaluate inferences and predictions that are based on data.

3–8 Problem Solving

Solve problems that arise in mathematics and in other contexts.

3–8 Connections

Recognize and apply mathematics in contexts outside of mathematics.

Background:

In the Fall of 2008, NASA is scheduled to launch its first mission back to the Moon since Lunar Prospector visited there in 1998. NASA will launch the Lunar Reconnaissance Orbiter (LRO) to conduct investigations that will prepare for and support future human exploration of the Moon. LRO will spend at least one year in low polar orbit around the Moon, collecting detailed information about the lunar environment to help determine potential locations and available resources for future robotic—and eventually human—lunar missions.

Identification of water is very important to the future of human activities on the Moon. The Lunar CRater Observation and Sensing Satellite (LCROSS) will travel aboard the same launch vehicle as the LRO. In early 2009, LCROSS will aim the spent Centaur upper stage of the launch vehicle at the permanently dark floor of one of the Moon's polar craters to test the theory that ancient ice lies buried there. The Centaur impact will eject a plume of materials from the crater that spectrometers aboard the LCROSS spacecraft will be able to analyze for the presence of water. LCROSS will study these materials as it flies directly through the plume of ejecta. The LCROSS spacecraft will then also crash into the Moon, acting as a secondary impactor creating more ejecta for Earth-based and orbital detectors to analyze.

ADDRESSING MISCONCEPTIONS

Students may wonder whether the LCROSS impact could harm or change the orbit of the Moon. The surface of the Moon has endured a constant stream of bombardment throughout its existence and has numerous massive craters that are 60+ miles in diameter. If the Moon has been able to withstand an impact at 20,000 miles per hour leaving a residual crater of this magnitude, then we can rest assured that the relatively small LCROSS impactor striking the Moon at a mere 5,600 miles per hour and creating a crater five meters deep with a diameter one half the length of a football field will not negatively affect the Moon.

Scientists conduct research, perform experiments, and explore environments. Engineers solve problems and design, build, and test devices. During the LCROSS mission, scientists will search for frozen water on the Moon and engineers will design a device that will help the scientists conduct their research. Since scientists and engineers cannot directly test their device on the Moon (that would be too expensive and wasteful), they will conduct an “experimental simulation” by building and testing a device here on Earth instead. Conducting simulations allows engineers to identify the weaknesses of their design and to test variations of and modifications to their design more safely, more economically, and in a more accessible environment. However, experimental simulations have limitations. For example, a design or experiment here on Earth cannot fully represent or replicate the extreme environment and lower gravity of the Moon.

The Challenge:

1. *Present the Challenge to students*

NASA PROBLEM

Scientists and engineers design solutions to real-life problems. NASA is designing an impactor that will collide with one of the Moon's permanently shadowed polar craters in early 2009 to see if water (ice) can be found. Finding water (ice) is very important for future human exploration of the Moon. The goal of this mission is to eject the maximum amount of subsurface material from the crater where ice is most likely to be found. In order to determine the angle of impact that will achieve the greatest amount of subsurface ejecta, NASA needs to develop a means for testing the impact on Earth.

CHALLENGE

As junior engineers, your task is to design and build a small-scale, Earth-based launching device that can propel a standard projectile at various angles, creating a crater in "lunar soil." Then, using the launching device, you will conduct an experiment to determine the angle of impact that excavates the greatest amount of subsurface "lunar soil."

CRITERIA

Engineers have criteria they have to meet, which are like rules of a game that must be followed. Here are the criteria for the Cratering the Moon challenge:

- Form a design team. Each team member must contribute to the team effort.

- Design and build a small-scale, Earth-based launching device.
    a. The launching device must be designed to launch the projectile at different angles including 15º, 45º, and 70º.
    b. The launching device should release the projectile in such a way that it impacts the lunar soil with *approximately* the same amount of force each time, regardless of height, distance, and/or angle.
    c. The launched projectile must create a measurable crater in the "lunar soil."

- Establish and use a uniform testing process to determine which angle of impact excavates the greatest amount of subsurface ejecta based on the area of the ejecta blanket and the layers of soil revealed.

2. *Design launching device*

- Allow teams of students the freedom to explore, to learn from failure, and to consider iterations of their design(s). Sketching would be appropriate during this stage.

- Ask questions that guide students in terms of working as a team and addressing the criteria. *(See Appendix page 11 for possible discussion questions.)*

- If you are doing this activity in conjunction with the Spring 2008 NASA Quest Challenge, then encourage students to post questions to NASA scientists and engineers while they are working on their initial designs.

3. *Collaborate, redesign, and build launching device*

- Once initial designs are completed, have the teams share and discuss their designs with the class. *(See Appendix page 11 for possible discussion questions.)*

- As a class, discuss which design elements might be combined from the various teams' launching devices to create one or two optimal final designs. Unite the class to build* the finalized launching device(s).

- If you are doing this activity in conjunction with the Spring 2008 NASA Quest Challenge, then submit a digital image along with a written description/explanation of the class's one or two launching device final designs to NASA Quest for feedback from NASA engineers and for inclusion in the Challenge web pages.

CHOOSING A PROJECTILE

After designing their launching device, students will need to select a standard projectile that is safe, reusable, and appropriate for their design. To maintain safety, the selected projectile should be relatively soft.

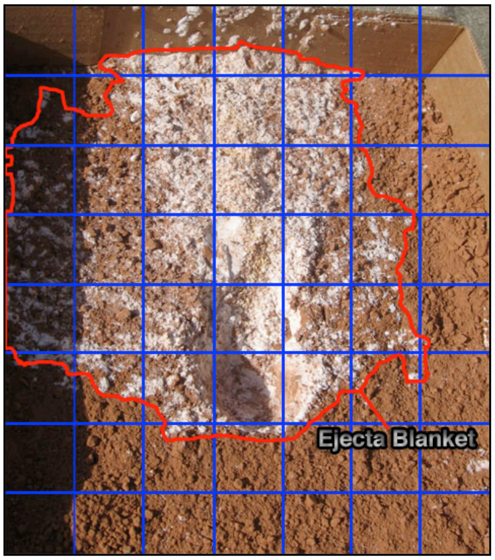
The shape, size, and nature of the projectile will depend on the design of the students' launching device; however, this chosen projectile should remain "constant" in the angle of impact experiment so that only the angle of impact varies.

***NOTE:** The types of building materials that students use will depend on the design of the students' launching device.

4. Determine the best angle of impact

Using the final design of their launching device, students will conduct an experiment to determine the **angle of impact** that results in the greatest ejection of subsurface "lunar soil." To assess the effectiveness of the various angles of impact, students will **measure the area of the ejecta blanket*** and **observe the layers of soil that are revealed.** *(See Appendix pp.12–13.)*

- Force of impact, the projectile, the lunar soil in the Lunar Target Station, etc. should remain constant in the experiment so that only the angle of impact varies.
- Conduct multiple trials at each angle to ensure reliability and reproducibility.
- Measure the depth and diameter of each crater and the area of the ejecta blanket*. Record your measurements on the Impact Experiment Data Sheet. *(Appendix pp.15–16)* If time allows, make sketches or take pictures of the craters and label the dimensions.



***NOTE:** The ejecta blanket is the pattern formed by the underlying subsurface soil that is displaced and made to cover the topsoil around the perimeter of the crater. In the experiment, if the subsurface soil is light (flour) and the topsoil is dark (cocoa), then the ejecta blanket should be the opposite pattern with the lighter subsurface soil lying on top of the darker topsoil.

One way that students can measure the area of the ejecta blanket is to use a transparency grid placed on top of the crater and surrounding ejecta. *(See Appendix p.14 for grid pattern.)* With this method, students can measure the area or partial area of each 1-inch square and then add the areas together.

If you are doing this activity in conjunction with the Spring 2008 NASA Quest Challenge and have submitted final designs and supporting data, then NASA scientists and engineers will provide feedback on design and experiment results during the final web cast and will compare these to the designs they are working on and the experiment they will conduct in early 2009.

5. Analyze data and draw conclusions

- After multiple trials have been conducted at various angles, students should analyze and discuss the data and draw conclusions based on this data. Discuss how the data could be graphed and how the conclusions could be presented.
- If you are doing this activity in conjunction with the Spring 2008 NASA Quest Challenge, then submit a digital image of the graphs students create along with a written description/explanation of their results to NASA Quest for feedback from NASA scientists and engineers and for inclusion in the final web cast.

Assessment:

CHALLENGE OBJECTIVES

Assess student learning and discovery by discussing the following questions with your students:

- What did you learn through designing and building your launching device according to a set of criteria?
- Based on your experiment, what angle of impact was the most effective at excavating the greatest amount of lunar soil? Why?
- What are the strengths of your design (launching device)? What are your design's limitations?
- How might your launching device and the outcomes of your experiment here on Earth vary from the actual mission and experiment conducted on the Moon?
- Even though your design might behave differently in outer space or achieve different outcomes, were you still able to learn something by constructing an Earth-based simulation?
- What did you learn about NASA's Lunar CRater Observation and Sensing Satellite (LCROSS) mission?
- What is the primary goal of the LCROSS mission?
- Why is it important for scientists to search for water on the Moon?
- What types of tasks (or work) do scientists do? What do engineers do?

ENGINEERING DESIGN AND SCIENTIFIC INQUIRY

Discuss engineering design and scientific inquiry to assess students' understanding of these fundamental processes.

Major concepts of the engineering design process

- Engineers start out with a set of parameters *or criteria* to which they must adhere.
- There is no "right" order to this engineering design process. Some engineers start by drawing or sketching, some first conduct research, others begin by brainstorming, and others start by building and testing small models or conducting experimental simulations. Many tests and changes are made before a final design is completed.
- Failure is very important to the engineering design process. Often more is learned from failure than from success. It is important to learn what doesn't work first through experimental simulation rather than after the actual full-sized design is built. Testing and refining materials, shapes, and overall designs is very important to engineering.

Discussion questions

- How did you come up with ideas for possible launching device designs?
- How many of you found a successful solution with your very first design? How many of you built more than one design? Why?
- Why do you think it might be important for NASA to first learn all the things that don't work by conducting an experimental simulation on Earth rather than build the actual lunar impactor without any initial testing?

REDUNDANCY

One way to reduce risk is through redundancy. For example, when NASA sent the Mars Exploration Rovers, NASA purposely built two rovers instead of one in case one rover failed. LCROSS will have some redundancy as well. The impactor will be carried by the shepherding spacecraft after it separates from LRO. This shepherding spacecraft will send the impactor into the Moon and take measurements of the resulting plume. The shepherding spacecraft will then act as an impactor itself, also crashing into the Moon for a second impact.

Major concepts of scientific inquiry

- If more than one variable changes at the same time in an experiment, then the outcome of the experiment may not be clearly attributable to any one of the variables.
- Results of scientific investigations are seldom exactly the same, but if the differences are large, then it is important to try to figure out why. Repeating an experiment is important to ensure that results are reliable.

Discussion questions

- What did you do to maintain the same setup in every trial of your experiment? What did you change? Why is it important to only change one variable at a time?
- Why do we do each experimental trial more than once?

RELIABILITY AND REPRODUCIBILITY

If a trial is done only once, then it is difficult to know if the results are an outcome of the experiment or a fluke, accident, or mistake due to equipment failure, unusual conditions, or operator error. If a trial is repeated a number of times, the chance that the results are due to some unexpected condition or mistake will be smaller. Furthermore, if the experiment can be repeated by many groups of people in different places and with different equipment, then the results are even more believable. We call this reliability and reproducibility.

Extension:

Have students design and carry out other experiments with their Earth-based launching device. For example, they might try to determine the projectile mass or shape that results in the most ejection of “lunar soil.”

Resources:

- Activity adapted from the following NASA Impact Crater lesson included in Exploring the Moon – A Teacher’s Guide with Activities, NASA EG-1997-10-116-HQ http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html
- Lunar Planetary Institute “Making Impact Craters” lesson: http://www.lpi.usra.edu/education/explore/shaping_the_planets/activity_glance2.shtml
- Other Lunar Reconnaissance Orbiter activities: http://www.lpi.usra.edu/education/explore/LRO/activities/
- Lunar Reconnaissance Orbiter (LRO): http://lunar.gsfc.nasa.gov/
- Lunar CRater Observation and Sensing Satellite (LCROSS): http://lcross.arc.nasa.gov/

Appendix

DISCUSSION QUESTIONS

The design process

- What ideas do you have for your design?
- How might you come up with some ideas?
- Which idea do you want to pursue and test?
- How do you think your design is going to work?
- Have you tested the design?
- What problems are you having with your design?
- Have you thought about what you want to change? (Encourage students to change one thing at a time so they can see what changes make a difference).
- Will your design work the same way every time?
- How can you make your design more stable, strong, or more reliable?
- Can you add to your design to make it more interesting or attractive?
- Has everyone on your team helped with the design? How?
- Does your design meet all of the criteria?

Sharing designs

- What materials and methods worked best? Why?
- What resulted in the deepest craters? Why?
- How can you be sure that the amount of force you use each time is the same? Which designs are best at this?
- Which designs result in the most consistent results?
- Which designs allow the projectile to be launched from different angles consistently and easily?
- What challenges did you face? How did you or could you correct this problem?

SETTING UP THE LUNAR TARGET STATION

Students will create their Lunar Target Station by layering 2–3 soil substances inside a large aluminum roasting pan or similar container. To make the crater analysis easier, the soils should vary in texture and color. For example, start with one bottom layer of kitty litter, then add one middle layer of flour, and finish with one top layer of cocoa powder. Each layer should conceal the layer below.

CHOOSING A CONTAINER

The type of container used will depend on the design of the launching device. Some students may need a container that has a shallow lip while other students may need a container that is wide, making it an easier target to strike.

LAYERING THE SOIL

It is important to layer the soils in such a way that after impact, the underlying subsurface soil will demonstrate a measurable ejecta blanket over the contrasting topsoil, allowing students to observe if they have excavated the deeper "lunar soil." In this regard, the Lunar Target Station is a sort of mini-experiment within the Challenge. Students will need to experiment with the thicknesses of the soils in their container to see which setup works the best, keeping in mind that the thickness may vary from layer to layer. For example, when setting up their "lunar surface," students should test to see that the top layer is not so thin that every launched projectile penetrates to the deepest subsurface soil, but also not too thick so that the projectiles never penetrate the topsoil to create the desired ejecta blanket. If the projectile always reaches the bottom or, alternatively, if the projectile never reaches the contrasting subsurface layer, then nothing is learned. *(See images next page.)*

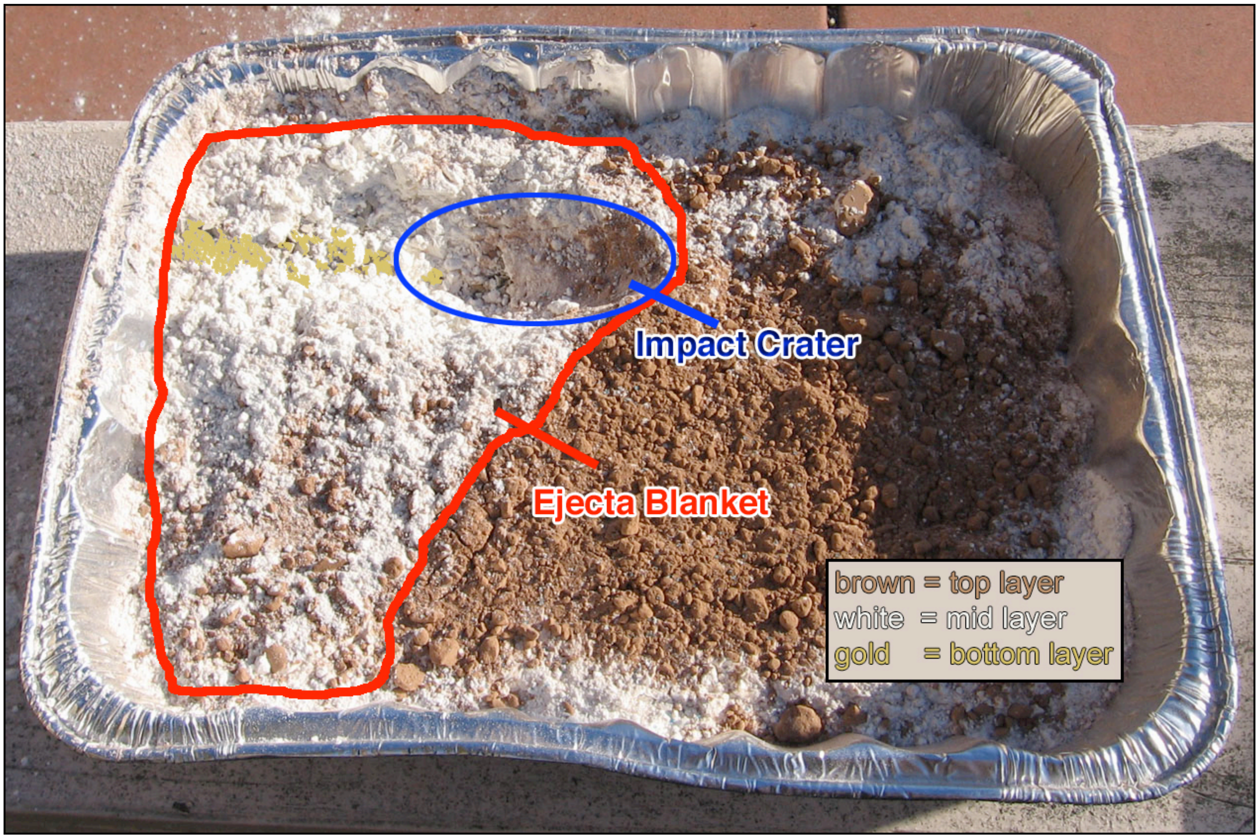
To save time and resources, during initial testing of the launching device students may choose to use only one "lunar soil" substance in their Lunar Target Station, as they will merely be testing to see if their design results in a measurable crater. Later, as students test for the best angle of impact, they will need to work with the multi-layered "lunar soil" in their Lunar Target Station so that they can see if and how the different layers are excavated.

ESTABLISHING SAFETY GUIDELINES (suggestions include…)

- Designate a testing location (outdoors, inside a large multi-purpose room, inside a gymnasium). If only one Lunar Target Station exists, then establish a schedule of testing times, allowing each group to test their devices and measure their craters one at a time.
- If working with more than one Lunar Target Station, then uniformly orient each station so that teams launch their projectiles in the same direction, away from other students. Create a chalk or tape line behind which students are restricted from crossing except when the teacher or a designated testing coordinator indicates it is safe to do so.
- Use safety glasses.

Sample Lunar Target Station #1 (undisturbed soil, no crater)

Sample Lunar Target Station #2 (disturbed soil, crater in upper left corner)



Team Members: ____

Team Name: ______________________________ Date: ____________________

Impact Experiment Data Sheet

Directions:

1. Using your team's launching device, propel a standard projectile into the Lunar Target Station three times at a 15° angle. Use the same projectile and approximately the same amount of force for every trial.
2. Measure and record the depth of the crater at its deepest point, the diameters of the crater, and the area of the ejecta blanket for every trial. (The ejecta blanket is the underlying subsurface "lunar soil" that is kicked up and made to fall back to the lunar surface on top of the topsoil of a contrasting color. ***Be sure to include your units of measurement!*** (inches, centimeters, millimeters, etc) Also record how many layers of soil were revealed.
3. Repeat this experiment at a 45° angle and again at a 70° angle etc.

Experiment Data:

15º angle of impact	Crater Depth	Crater Diameter (length)	Crater Diameter (width)	Area of Ejecta Blanket	# of layers revealed
Trial 1					
Trial 2					
Trial 3					

45º angle of impact	Crater Depth	Crater Diameter (length)	Crater Diameter (width)	Area of Ejecta Blanket	# of layers revealed
Trial 1					
Trial 2					
Trial 3					

70º angle of impact	Crater Depth	Crater Diameter (length)	Crater Diameter (width)	Area of Ejecta Blanket	# of layers revealed
Trial 1					
Trial 2					
Trial 3					

___º angle of impact	Crater Depth	Crater Diameter (length)	Crater Diameter (width)	Area of Ejecta Blanket	# of layers revealed
Trial 1					
Trial 2					
Trial 3					

Observations:

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Conclusions:

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