Activity One: Electrostatic Moon Duster

EDUCATOR NOTES

Learning Objectives

Students will

- Identify the properties of lunar dust that make it so problematic
- Develop a dust mitigation prototype given NASA's design criteria and constraints
- Measure the extent of electrostatic fields using a homemade device

Challenge Overview

In this activity, students explore the engineering design process as if they were actual engineers working with NASA's Dust Mitigation engineering team. In this challenge, students will research, design, build, and test a lunar dust mitigation device.

Suggested Pacing

60 to 90 minutes

National STEM Standards

Science and Engineering (NGSS)	
Disciplinary Core Ideas • MS-ETS1-2 Engineering Design Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. • MS-ETS1-4 Engineering Design Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. • MS-PS2-3. Motion and Stability: Forces and Interactions Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. • MS-PS2-5 Motion and Stability: Forces and Interactions Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. ***Crosscutting Concepts*** • Cause and Effect	***Science and Engineering Practices*** • Constructing Explanations and Designing Solutions: Apply scientific ideas or principles to design an object, tool, process, or system. • Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. • Engaging in Argument from Evidence: Argumentation is the process by which explanations and solutions are reached. • Obtaining, Evaluating, and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.
Technology (ISTE)	
Standards for Students • Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts, and make meaningful learning experiences for themselves and others. • Innovative Designer: Students use a variety of technologies within a design process to identify and solve problems by creating new, useful, or imaginative solutions.	***Standards for Students (continued)*** • Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.
Mathematics (CCSS)	
Mathematical Practices • MP.2 Reason abstractly and quantitatively. (MS-ETS1-4)	

Challenge Preparation

- Read the Introduction and Background section for this guide and the Educator Notes for this activity
- Have videos cued up for introduction of the challenge
- Prepare the suggested whole class demonstrations – regolith formation demonstration and electrostatic demonstration
- Group students into teams of two to four. Consider assigning roles and tasks to individual students within the team. See the Teamwork section at the beginning of the guide for suggestions.

- Gather materials needed to complete the challenge
- Create a “lunar testbed" for students to practice collecting regolith simulant. This could be a small pan or plastic bowl filled with regolith simulant (e.g., salt, wheat flour, packing peanuts, baking powder, QUIKRETE®, glitter)
  - **Salt Safety Data Sheet:**
    - www.intrepidpotash.com/wp-content/uploads/2017/02/Carlsbad-Salt-SDS-3-13-2017-.pdf
  - **Wheat flour Safety Data Sheet:**
    - http://s3.amazonaws.com/media.agricharts.com/sites/1846/Flour/SDS%20All%20Purpose%20Wheat%20Flour%20CO-EHS-1512-03.pdf
  - **Baking powder Safety Data Sheet:**
    - http://lkstevens-wa.safeschoolssds.com/document/repo/9d575b2d-3d18-449d-8d06-d74d75f411dc
  - **QUIKRETE® safety data sheet:**
    - www.quikrete.com/pdfs/msds-e drypackagedportlandcement.pdf
- Print one student handout for each team
- Review “The Lunar Regolith” Science Paper by Planetary Scientist Sarah Noble : https://ntrs.nasa.gov/api/citations/20090026015/downloads/20090026015.pdf *Note: The paper above is at a higher reading level, if used please help students navigate this text.*

***NOTE:** It’s suggested that, prior to this lesson, the educator might conduct a lesson on static electricity and have the groups build an electroscope (i.e., a device that detects if there is an electrical charge and how big the charge is).*

Materials

- One student handout per team
- Scratch paper and writing utensils
- Scotch tape for electrostatic demonstration
- Computers/devices with internet access or fact sheet handout for research
- Simulant for the lunar dust (e.g., salt, wheat flour, packing peanuts, baking powder, QUIKRETE®, glitter)
- Electrostatic charge creator: The following materials tend to give up electrons when brought in contact with other materials. That means they will have an increase of positive (+) charges. (e.g., Air, dry human skin, leather, fur, Styrofoam plates, wool on PVC, comb, glass rod, human hair, nylon, latex balloons)
- The following materials tend to attract electrons when brought in contact with other materials. (e.g. Wood, amber, hard rubber (comb), nickel, copper, brass, sliver, polyester, Styrofoam, saran wrap, scotch tape)
- Analytical balance: These are typically suitable for masses of 0.1mg up to 200g. They are more precise than precision balances but can’t bear as much load.

Materials for Optional Electroscope

Note: Items to design an electroscope (i.e., small plastic bottle with a narrow neck, scissors, pliers with a wire cutter, copper wire, aluminum foil, sponge, foam tray, piece of felt, optionally a hole punch)

Safety

- Ensure students are practicing safe cutting techniques and scissor handling when building their tools
- Ensure students carefully support the piece being cut and are careful with placement of supporting hand
- Students should avoid moving around the room with scissors
- Ensure students use caution and wear protective goggles when building and testing the tool design
- Ensure students wash hands after handling simulant regolith
- Ensure students minimize stirring up dust from the flour/powder. Keep dust to a minimum.
- Ensure students review the Safety Data Sheet for the simulant regolith
- If you have any student with a latex allergy, have allergic students wear non-latex plastic gloves and inflate the balloons with a balloon pump (or form small teams and give the balloon handling part of the activity to non-allergic students).

Introduce the Challenge

- Provide context for this activity using the Introduction and Background section in this guide
- How do we know so much about the Moon? Specifically, lunar dust (regolith)? Give students time to share their thoughts.
- Share the following videos:
  - *"Lunar and Meteorite Sample Disk Program"*: https://youtu.be/xYMuQPWvufg (share the first 2:45 min)
  - *"The Best Gift of All – A Box of Moon Soil"*: https://Moon.nasa.gov/resources/393/the-best-gift-of-all-a-box-of-Moon-soil/ (1:23)
  - *"Lunar/Crater Surface – Dust Mitigation System"*: NASA 360 https://youtu.be/xXFmsZTH4C8 (1:20)
- Explain the challenge to students:
  - Each team will use the available materials to build a functioning dust mitigation removal tool
  - The tool must be designed to mitigate as much lunar dust simulant as possible
  - It may be helpful to provide the Rubric for Engineering Design Process (Appendix A) to teams prior to building
  - After teams have tested and perfected their working dust mitigation tool, they will develop a user manual or instruction guide for the tool. Various platforms, such as a brochure, poster, or digital presentation, can be used for their manual.
- See the References and Resources at the end of the Educator Notes for further information on lunar dust mitigation tools if students need more ideas about the tools they will be inventing

Criteria	Constraints
Use of tool must not require more than one person.	Students must only use materials supplied by the educator.
Teams must create a presentation or user manual about the use of their new tool.	Teams will only have 5 seconds to remove simulant from their helmet.
Document the mass of regolith simulant before and after tool use.	

Facilitate the Challenge

? ASK

NASA's Artemis program will develop extensive resources on the Moon starting in 2024 and will require advanced technologies to enable a sustained lunar presence. Mitigation of lunar dust adhesion will be central to these efforts and to Artemis's success.

- Have students buddy read "Dust: An Out-of-This World Problem" and answer the comprehension questions:
  - www.nasa.gov/feature/glenn/2021/dust-an-out-of-this-world-problem

Conduct the following demonstrations

- **Regolith Formation Demo:**
  - www.nasa.gov/pdf/180567main_ETM.Regolith.Formation.pdf (To create food substitute, use dirt or red clay like the type from baseball fields) ***NOTE:*** *When food is used in the classroom, please keep in mind food insecurities or allergies. We want to create a more equitable and inclusive learning environment for all students, regardless of their socio-economic background or food access.*
- **Electrostatic Demonstrations** pg. 9-10 (labeled pg. 5-6): Sticky Tape Static Electricity: (Optional)
  - https://www.nasa.gov/stem-content/imagineticspace-sticky-tape-static-electricity-activity/

Have students research moon dust and electromagnetic properties. Have students talk in teams about the comprehension questions:

- How did lunar dust (regolith) form?
- Why is lunar dust (regolith) such a huge problem?
- What are some possible solutions to this problem?

IMAGINE

Ask students:

- What do you think might be a solution to the dust problem?
- Can your team develop a strategy to mitigate this problem for future work on the Moon?
- What items would you need to build this tool?

PLAN

Have each team member sketch a design for a dust mitigation tool

- Share the following guidelines for each sketch:
  - Label each major part of the tool
  - State the purpose of the tool
  - List the materials the tool will be made from
- Explain that the final design must incorporate at least one design idea from each team member

CREATE

- Be sure to confer with students during the activity.
- Allow teams at least 30 minutes to construct their new tools using the materials provided and the sketches they have created
- Each team's new tool should be a dust mitigation device that can be used by a single astronaut
- Ensure the teams are creating a tool that can be tested multiple times

TEST

- Now that teams have created their own dust mitigation tool, allow them some time to explore the lunar testbed and experiment with their new tools
- Ensure teams record mass 1 of helmet (Latex Balloon or Styrofoam plate alone).
- After the regolith simulant is added using electrostatic force (by rubbing their "helmet" in the regolith simulant to make the electrostatic force and make the regolith stick),find the new mass, mass 2 (Styrofoam plate plus additional regolith simulant).
- Have the teams use their tool and dust mitigating procedures to remove as much regolith simulant in 5 seconds or less

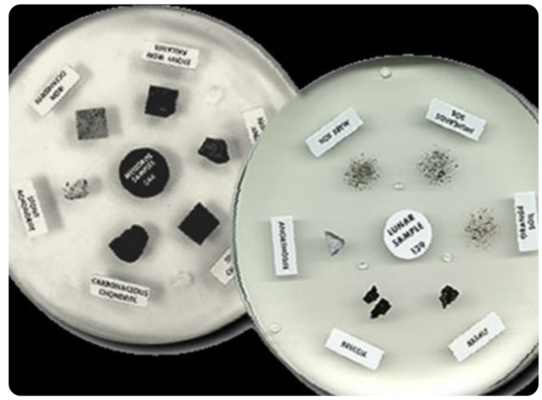
IMPROVE

This phase of the engineering design process is generally intuitive to students. However, some students may need a little help in troubleshooting their designs if failures occur. Be sure to visit and spend time with each team and ask probing questions:

- Is the design working as expected? What can you do to improve your design?
- Where are the weaknesses in the design, and what can be done to strengthen the tool?

Share With Students

Brain Booster

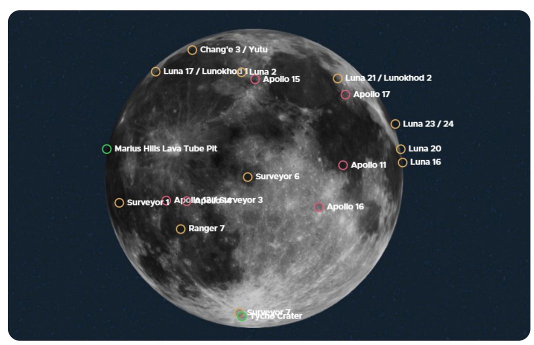


Picture of lunar and meteorite disk

The Lunar and Meteorite Sample Disk Program is intended for K-12 classrooms, or qualified museums and libraries.

Learn more: https://ares.jsc.nasa.gov/interaction/lmdp/

On Location



Picture of interactive Moon and places explored

Earth's Moon is the only place beyond Earth where humans have set foot. Yet we still have so many unanswered questions about it, and this is one of the reasons NASA is going back with the Artemis Program. Explore more using this interactive site.

Learn more: https://solarsystem.nasa.gov/moons/earths-moon/in-depth/

SHARE

- Have students discuss the following questions with their team:
  - What were some difficulties your team faced during the initial design and build process, and how did you overcome them?
  - Were you surprised by the performance of your tool? Explain.
  - How were you able to improve your tool during the redesign phase? What design changes did you make, and how did they improve your tool's performance?
  - What was something about another team's model that impressed you?
- To share their dust mitigation tool with others, teams should develop an instruction manual for the tool using their choice of a variety of platforms, such as posters, brochures, digital presentations, and notebooks
  - Optional: Have student groups share the tool they have invented with other classes or grade levels
  - Optional: Share student results on social media using #NextGenSTEM. Be sure to include the module and activity name

Extensions

- Have the students interact with Classifying Moon Rocks website: https://ares.jsc.nasa.gov/engagement/interactives/classifying%20moon%20rocks/story.html
- Tune into Kennedy Space Centers Lunabotics Competition: www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html

References and Resources

- New "Moon Duster" will help clean NASA assets in space | Science Mission Directorate: https://science.nasa.gov/technology/technology-highlights/new-moon-duster-will-help-clean-nasa-assets-in-space#:~:text=A%20team%20at%20NASA%2FJet,and%20spacesuits%20on%20the%20Moo
- Electrostatics and Surface Physics Lab: www.nasa.gov/content/electrostatics-and-surface-physics-laboratory

Activity One: Electrostatic Moon Duster

STUDENT HANDOUT

Your Challenge

In this challenge your team will research, design, build, and test a lunar dust mitigation device.

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Document the mass of regolith simulant before and after tool use.	

? ASK

As a team, buddy read "Dust: An Out-of-This World Problem" and answer the comprehension questions. www.nasa.gov/feature/glenn/2021/dust-an-out-of-this-world-problem

- How did lunar dust (regolith) form?
- Why is lunar dust (regolith) such a huge problem?
- What are some possible solutions to this problem?
- Watch the educator's Regolith formation Demonstration and Electrostatic Demonstration

IMAGINE

- What do you think might be a solution to the dust problem?
- Can your team develop a strategy to mitigate this problem for future work on the Moon?
- What items would you need to build this tool?

PLAN

Have each team member sketch a design for a dust mitigation tool

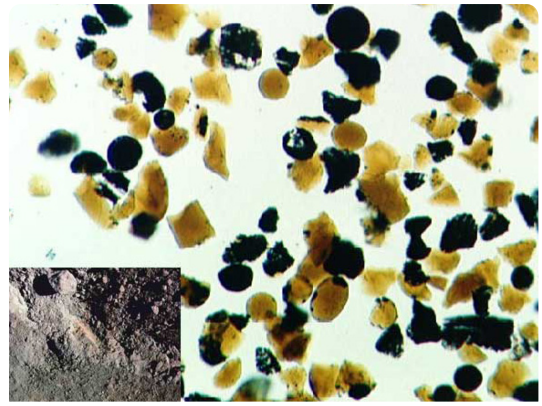
- Share the following guidelines for each sketch:
  - Label each major part of the tool
  - State the purpose of the tool
  - List the materials the tool will be made from
- The final design must incorporate at least one design idea from each team member

CREATE

- Your team will have at least 30 minutes to construct your new tools using the materials provided and the sketches you have created
- Your team's new tool should be a dust mitigation device that can be used by a single astronaut
- Be sure to create a tool that can be tested multiple times

Share With Students

FUN FACT!



Strange Orange Soil on the Moon; Credits: Apollo 17 Crew, NASA

How did orange soil appear on the Moon?

Learn more: https://apod.nasa.gov/apod/ap010523.html

CAREER CORNER

Sarah Noble - Planetary Geologist

NASA Solar System Exploration. Credits: NASA

"When I look up at the Moon it looks different to me, not just something that hangs in the sky, but a real place made of real rocks and dirt."

Learn more: https://solarsystem.nasa.gov/people/1740/sarah-noble/

TEST

- Now that your team has created a dust mitigation tool, explore the lunar testbed and experiment with your new tool
- Be sure to record mass 1 of helmet (Latex Balloon or Styrofoam plate alone)
- After the regolith simulant is added using electrostatic force, find the new mass, mass 2 (balloon plus additional regolith)
- Use your tool and dust mitigating procedures to remove as much regolith simulant as you can in 5 seconds or less

IMPROVE

This phase of the engineering design process is generally intuitive. Let your teacher know if you will need extra help in troubleshooting your design if failures occur. Ask yourselves these questions:

- Is the design working as expected?
- What can you do to improve your design?
- Where are the weaknesses in the design, and what can be done to strengthen the tool?

SHARE

Your team should discuss the following questions:

- What were some difficulties your team faced during the initial design and build process, and how did you overcome them?
- Were you surprised by the performance of your tool? Explain.
- How were you able to improve your tool during the redesign phase? What design changes did you make, and how did they improve your tool's performance?
- What was something about another team's model that impressed you?
- Optional: The above questions can be used as a written self-reflection for students.

Share your dust mitigation tool with others. You should develop an instruction manual for the tool using your choice of a variety of platforms, such as posters, brochures, digital presentations, and notebooks.