Fermilab Education and Public Engagement Activity: Engineering

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Activity Name Space Lander Challenge	
Grade Level **6-8**	**Unit Topic Connection** Space/Gravity/Forces and Motion

The Hook

Today, you will be designing a rover that will safely land on a planet/moon.

-What factors will you need to consider when landing a rover safely?
-How thin is the atmosphere where you are landing your rover?
-What kinds of problems could affect the outcome of the landing?
-What landforms will you need to be aware of in choosing a location for landing?

https://youtu.be/UkpUa3Pg550 (Introduction up until minute 6:04)

7 minutes of Terror video: Play up until minute 1:13 if you want a cliffhanger.

Scenario/Background Information

Students use the engineering design process to create a lander to safely keep their "rovers" safely inside a cup as it is dropped from various heights. The challenge incorporates key science concepts of shock-absorption, gravity and drag forces, deceleration, impact velocity, and stability.

Video Resources for Students
Landing Animation

Students should have some understanding of independent and dependent variables as well as the engineering process before they start this engineering challenge.

Forces on a Lander

GRAVITY

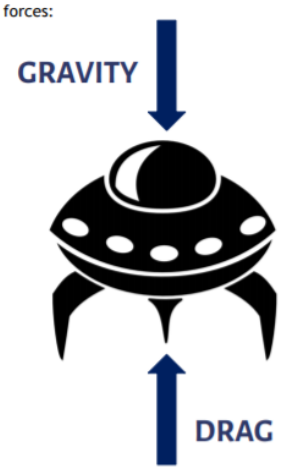
The force of gravity is a constant in our lives, always pulling us towards Earth. Every planetary object, whether Earth, Moon, or Mars has a gravitational pull. The larger the planet, the stronger the gravity.

Moon = 1/6 gravity of Earth

Mars = 1/3 gravity of Earth

Astronauts landing on the Moon will experience less of a gravitational pull compared to those landing on Mars. And likewise, landing on Mars will have less of a gravitational pull than landing on Earth.

As the lander falls, it will experience these forces:



DRAG

As the lander falls to the surface of Mars, the surrounding atmosphere will create an upward friction force. A spacecraft with a larger surface area will experience a greater drag force.

Think about what happens when you put your hand out of a car window. As you open your palm, you experience a greater drag force from the air.

The amount of aerodynamic drag will depend on the atmosphere of the planet. Mars has a thinner atmosphere than Earth so it will produce a smaller aerodynamic drag force on a lander. The Moon has no atmosphere so drag due to air is not a factor. The Lunar Module that landed on the Moon during the Apollo program had to fire thrusters downward to slow it down for a soft landing.

Safety

Use scissors carefully.

- Do not insert any items in your ears or nose.
- Do not insert any items in an electrical outlet.

Student Question/Problem/Challenge

Challenge: Create two different designs and analyze which model safely keeps a "rover" inside a cup as it is dropped from various heights.

Problems:

Where will you put your center of mass?

How will you create air resistance when landing your cup?

How will you minimize energy being transferred to the ball?

How will you reduce the speed of the cup in the air and once it contacts the ground?

Criteria:

- Use a ping pong ball, a cup, and a base.

- The ball cannot leave the cup.
- Must modify below the base.
- Must be dropped from a height of 1 meter.

Constraints:

- materials-maybe setting a price for each material needed or limit the amount of materials like tape, no hot glue, gorilla glue (superglue)
- time frame for building - 1-2 days

Learning Goals/NGSS Performance Expectations

NGSS Design Middle School

What will you need?

Supplies	Setup
• cup • ping pong or marshmallow *see groups below for more supplies needed	Gather materials for groups. Tips Develop a rubric for assessment purposes.

Process

Start with a standard model: cup, construction paper, tape, ping pong ball/marshmallow

Students observe what happens with the standard model.

Sprints: The whole class is divided into teams and each team will conduct tests on a particular variable. Then, the teams share out to the whole class their results. This saves time for everyone so that the final concepts for a solution can be determined quicker.

Divide students into teams. Brainstorm variables that would affect the landing. (type of paper, parachute types, shock absorbers, air bags, etc...)

Each student in the group will test a variety of materials. Groups will create 3 different prototypes changing only their independent variable and report out their results to the class. Each student should video record their landings. Students should also graph their data.

Group 1: type of base/paper

- Paper plate
- construction paper
- tag board

- plastic plate

Group 2: air bags
- balloons
- sandwich bags
- grocery bags
- bubble wrap/packing materials

Group 3: shock absorbers
- folded index card (fan design)
- styrofoam blocks/ cotton balls
- coiled pipe cleaners
- straws & rubber bands

Group 4: parachutes
- tissue paper
- grocery bag/Ziplock bag
- handkerchief
- notebook paper
- string

Distance	Success?	Write or Draw Improvement Ideas
	Yes / No	
	Yes / No	
	Yes / No	
	Yes / No	
	Yes / No	

Using class data from each of the groups, students will create a new prototype, test it, and create another. Students should record each landing. It will help them analyze their results.

Wrapping it up

(Provide suggestions for classroom discussion and pacing from lesson to lesson as well as connecting to the curriculum unit topic and learning goal.)

NASA Mars Rovers Webpage for extra reading and discussion.

SuperNova Stacked Ball Energy transfer

Students can share out their results and the class can discuss factors that contributed to successes and failures.

Extension

Impact Velocity

As the lander falls, its energy is governed by the equation: $gh = \frac{1}{2} v^2$

h = the height from which the lander was dropped

v = velocity (speed) of the lander on impact

g = gravitational constant which is dependant on the size of the planet

Circle the gravity constant (g) for the planet used in your scenario.

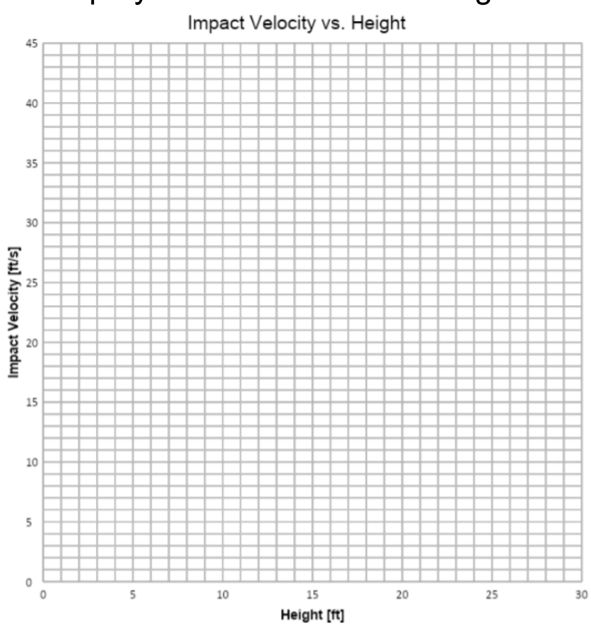
- Earth = 32 ft/s^2 or 9.8 m/s^2
- Mars = 12.1 ft/s^2 or 3.7 m/s^2
- Moon = 5.3 ft/s^2 or 1.6 m/s^2

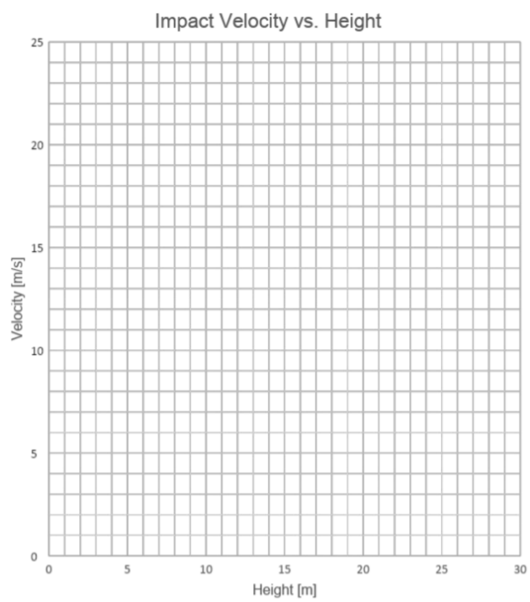
1. Solve the equation for v, the velocity on impact.

2. Calculate the impact velocity for various heights. Round to the nearest whole number.

Height	Velocity
1	
2	
3	
10	
25	

3. Graph your results for each height on the previous page. [Create a Graph]

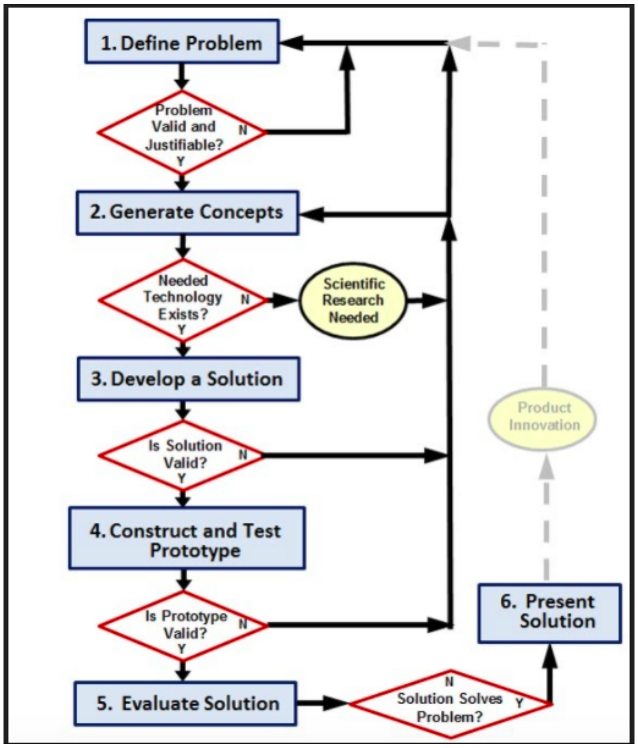




4. Connect the dots on your graph. What does the shape of the line look like?

Assessment

(This activity may serve as a performance assessment for a unit. How can the students apply their content knowledge and be aware of the many practices they utilized during the challenge activity? Provide suggestions on how to assess student success.



Suggestions may include student logbooks, including notes, data and reflection on their thinking.)

Take a video of the rover landing of all trials (flipgrid?)

Provide Data (Qualitative/Quantitative)

Standards Connections (Connect to learning goals/performance expectations.)

NGSS Disciplinary Core Ideas	**NGSS Science and Engineering Practices**	**NGSS Crosscutting Concepts**
		Connections to Engineering, Technology, and Applications of Science **Influence of Science, Engineering, and Technology on Society and the Natural World** The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1) All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1)

ETS1.A: Defining and Delimiting Engineering Problems The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (MS-ETS1-1) **ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results in order to improve it. (MS-ETS1-4) There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) Models of all kinds are important for testing solutions. (MS-ETS1-4) **ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design. (MS-ETS1-3) The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)	**Asking Questions and Defining Problems** Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables and clarifying arguments and models. Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1) **Developing and Using Models** Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4) **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3) **Engaging in Argument from Evidence** Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)	

CCSS Math	**CCSS ELA**
CCSS.MATH.CONTENT.6.RP.A.1-3 CCSS.MATH.CONTENT.6.EE.A.1-3 CCSS.MATH.CONTENT.6.EE.B.5-7 CCSS.MATH.CONTENT.6.EE.C.9 CCSS.MATH.CONTENT.6.G.A.1-4 CSS.MATH.CONTENT.7.RP.A.1-3 CCSS.MATH.CONTENT.7.EE.B.3-4 CCSS.MATH.CONTENT.7.G.B.4-6 CCSS.MATH.CONTENT.8.EE.A.1-4	Comprehension and Collaboration: CCSS.ELA-LITERACY.SL.6.1 CCSS.ELA-LITERACY.SL.7.1 CCSS.ELA-LITERACY.SL.8.1 Presentation of Knowledge and Ideas: CCSS.ELA-Literacy.SL.6.4 CCSS.ELA-Literacy.SL.7.4 CCSS.ELA-LITERACY.SL.8.4

Resources and References

(List any useful links for teacher background information. List student resources that may be needed.)

We are one Fermilab
https://news.fnal.gov/wp-content/uploads/2018/10/we-are-one-fermilab.jpg

How Particle Physics Discovery Works
https://www.fnal.gov/pub/science/particle-physics-101/how-works.html

Fermilab Ecology
https://ecology.fnal.gov/

NGSS - Science and Engineering Practices https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Science, Technology, Engineering and Mathematics Career Cluster Knowledge and Skill Statements (2008)
https://cte.careertech.org/sites/default/files/K%26S-CareerCluster-ST-2008.pdf

CCTC - Career Ready Practices
https://cte.careertech.org/sites/default/files/CareerReadyPractices-FINAL.pdf

Project Lead the Way, Engineering Design https://www.pltw.org/our-programs/pltw-engineering-curriculum

PLTW Engineering Design Process -
- **https://drive.google.com/file/d/0BxARel-pKAjodmx5WmhLMFBITUk/view?usp=sharing**

- **https://docs.google.com/presentation/d/1Gf2Sa0hBWfwOK0X1x1JPmrFp6yYuAQ4YXR_Yqa69hCQ/edit?usp=sharing**

5Es
- **https://ngss.sdcoe.net/Evidence-Based-Practices/5E-Model-of-Instruction**

Claim, Evidence, and Reasoning
- **BSCS Scientific Explanation Tool - https://www.amnh.org/content/download/146458/2328830/file/Explanation_Tool_MASTER.pdf**
- **Rubric https://www.amnh.org/content/download/146460/2328840/file/Explanation_Tool%20RUBRIC.pdf**
- **Scientific Argument Tool - http://sepuplhs.org/pdfs/Argument_Tool_MARCH2016.pdf**
- **Rubric - http://www.argumentationtoolkit.org/uploads/2/1/4/1/21417276/evidence_rubric.pdf**
- **Sentence Starters for CER - http://www.thinksrsd.com/wp-content/uploads/2014/02/CER-Sentence-Starters-CER.pdf**
- **NSTA Resources on CER - https://learningcenter.nsta.org/mylibrary/collection.aspx?id=GBdqFKABr0U_E**

Vivify STEM -

- **https://www.vivifystem.com/**
- **https://static1.squarespace.com/static/54807be6e4b053bc20c8b2a0/t/5f05e9147714891102fcfefd/1594222870673/_Space+At+Home_+Space+Lander.pdf**
- **https://www.vivifystem.com/blog/2015/1/14/touchdown-lander**
- **https://vivifystem.mykajabi.com/space-club**
- **https://docs.google.com/presentation/d/146S6f360KQoT6DFzGBsbspC-4wBGuMik8o1cl906i3w/edit#slide=id.g82c8a782d2_0_50**

NASA - Countdown to Landing: Live Stream for Middle School Students

- https://youtu.be/io-3sDkLlv4
- https://www.jpl.nasa.gov/edu/events/2021/2/16/countdown-to-mars-landing-live-stream-for-middle-school-students/
- https://www.jpl.nasa.gov/edu/learn/project/make-an-astronaut-lander/

Design Squad -

- **https://pbskids.org/designsquad/build/touchdown/**

Space.com -

- **https://www.space.com/perseverance-rover-mars-parachute-secret-message-solved**