High School, Unit 4 Lesson 3: Rovers

Challenge Guiding Question: How can we use experiments, models, and rehearsals here on Earth to understand other solar system objects and plan a successful mission to the Moon?

Unit Level Question: *How can robotic systems aid in the exploration of our Earth and other solar system objects?*

Lesson Level Question: *How do we combine what we know about the surface of the Moon and the structure and function of our rover to complete a safe and successful rover mission?*

Lesson Summary: First, students will build and program a robot to plan a successful mission to the Moon. Then, they will use the Engineering Design Process to build a test bed and modify the rover's wheels. Next, they will use size and scale factors to compare VIPER and their rover, and test beds with the surface of the Moon. Finally, groups will document their work in this lesson.

Notes for Adapting This Lesson to Remote Learning: *For the "Explore" section, merge students' ideas and create a slope test bed/ Moon surface for the students. For the "Elaborate" section, have students brainstorm wheels to replace or test, and test it out on the screen.*

Materials Needed

Lesson Links	**Materials Available from NESSP** **https://nwessp.org/nessp-companion-course-supplies/**	**Materials Provided by the Teacher**	
• NASA's Simulated Lunar Operations Laboratory • VIPER Hits SLOPE Lab Video	Robots (Note: NESSP is mainly supporting LEGO SPIKE Prime, Mindstorm EV3, and MakeBlock, but schools/programs with different robots can use any robot with programming capabilities.)	-Printed Engineering Design Process (EDP) handout -pencil -Journal for MDL -Pencil -laptop/computer -Pair of Scissors -Tape -Glue -Materials to build ramps (18' long and 12' wide):	(Optional): "Lunar Dust Course" • 18" long and 12'' wide Cafeteria-type tray or large, shallow baking pan • "Most like" Regolith material that was identified in Unit 2 Lesson 1 (flour, corn starch, sand, salt, or baby powder)

		● Board ● Cardboard ● Wood ● Foam -Comparing Scale Factor handout -wheels

Before The Lesson

- If your students are engaging in the Artemis ROADS Student challenge, review MO-07.
- Decide ahead of time if your students will test drive their rovers on different "regolith bed" environments or not. This can be quite messy, so if you plan to do this, plan for containment and clean-up of your regolith material!
- CHARGE robots (yellow hub for LEGO SPIKE Prime, white hub/brick for LEGO EV3, and AA batteries for MakeBlock) prior to lesson (and prior to each day's class)!
- **Engage**: Also, double check to make sure there are no missing parts in the robot kit, and if needed, refer back to the Canvas page for building the robot.
- **Explore**: Before the lesson, access students' work from Unit 2 Lesson 1 - where students brainstormed a list for the rover's wheel design. Print out Engineering Design Process (EDP) handout.
- **Explain**: Print out Comparing Scale Factor handout.
- **Elaborate**: CHARGE robots (yellow hub for LEGO SPIKE Prime, white hub for LEGO EV3, and AA batteries for MakeBlock) prior to lesson!

High School Standards

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.		
Asking Questions and Defining Problems (Engage) Ask questions to clarify and refine a model, an explanation, or an engineering problem. **Planning and Carrying Out Investigations (Explore)** Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. **Using Mathematics and Computational Thinking (Engage**	Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.	**Cause and Effect** Systems can be designed to cause a desired effect. **Systems and System Models** Systems can be designed to do specific tasks.

through Elaborate) Create algorithms (a series of ordered steps) to solve a problem. (Middle School Element) **Analyzing and Interpreting Data (Explain)** Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. **Constructing Explanations and Designing Solutions (Explore through Elaborate)** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Obtaining, Evaluating, and Communicating Information (Evaluate)** Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	(HSETS1-2)	

Other Content Standards (Math, Computer Science, ELA, 21st Century)

Mathematics (Common Core State Standards)
CCSS.MATH.CONTENT.HSG.SRT.C.8 Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.
CCSS.MATH.CONTENT.HSG.MG.A.3 Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Computer Science (Washington State Standards)
3B-AP-09 Implement an artificial intelligence algorithm to play a game against a human opponent or solve a problem.
3B-AP-21 Develop and use a series of test cases to verify that a program performs according to its design specifications.
3B-AP-23 Evaluate key qualities of a program through a process such as a code review.

3A-CS-02 Compare levels of abstraction and interactions between application software, system software, and hardware layers. (P. 4.1)
3A-NI-04 Evaluate the scalability and reliability of networks, by describing the relationship between routers, switches, servers, topology, and addressing. (P. 4.1)
3A-AP-13 Create prototypes that use algorithms to solve computational problems by leveraging prior student knowledge ~~and personal interests~~. (P. 5.2)
3B-AP-16 Demonstrate code reuse by creating programming solutions ~~using libraries and APIs~~. (P. 5.3)

Lesson Plan

Phase	High School	Materials/Prep
Engage (340 Min)	***Students will build, program, and test their rovers to prepare for the final mission.*** This segment of the lesson includes six parts, including one that is optional:	VIPER Video (1:09 Min): https://www.youtube.com/watch?v=ROWPoRXLvo4

	• Engineering Design Process - Ask (20 minutes) • Engineering Design Process -Imagine (40 minutes) • Building Rover (45 minutes) • TRAINING - Programming Rover (30-90 minutes) • Programming and Testing Rover (45 minutes) • OPTIONAL: Rover Color Sensor (30-90 minutes) SAY: VIPER, is a NASA acronym for Volatiles Investigating Polar Exploration Rover and it is a mobile robot that will go to the South Pole of the Moon to get a close-up view of the location and concentration of water ice that could eventually be harvested to sustain human exploration on the Moon, Mars, and beyond. Tells students that they will watch a video about VIPER and pause throughout the video for students to discuss the following prompt questions: • What/who is VIPER? • Where is VIPER going and what will it do? • What problems might VIPER encounter? What are some solutions are you already thinking about? For the last question, make a direct call back to Unit 2, Lesson 1 when students compiled a list of questions about which features on the Moon surface might be dangerous to people or Moon rovers, and why. Tell students to use restate some of the sentence frames from Unit 2, Lesson 1 below: _______ could be dangerous on the Moon because ________ _______ could cause problems for a person or rover because _______ Tell students that they will be using NASA's Engineering Design Process to address the engineering question, how do we build a ramp that mimics the Moon's surface? Then, explain the six steps of the Engineering Design Process (Ask, Imagine, Plan, Create, Test, and Improve) and that students will use an Engineering Design Process (EDP) handout to keep track of their design process. **ASK (20 Min):** *Students identify the problem, requirements that must be met, and constraints that must be considered*. Allow five minutes for students to individually write down problems that VIPER might encounter on their EDP handout (see handout below). Then, give students 10 minutes to talk to their group to identify problems that VIPER might encounter on the Moon's surface. Afterward, call on each group to name 1-2 problems that they believe VIPER might encounter on the Moon's surface. Recall back to the Regolith and Slope Exploration in Unit 2, lesson 1 where students investigated the properties of the regolith or Moon dust and explored features of Shackleton Crater. Ask students to discuss in partners or small groups:	**Engineering Design Process:** *https://www.nasa.gov/audience/foreducators/best/edp.html)* **ASK:** Printed Engineering Design Process (EDP) handout Pencil Spanish Version: Folleto del proceso de diseño de … **Building Rover:** Rover Laptops/computers Software and Building Instructions **TRAINING - Programming Rover:** LEGO Mindstorm EV3 and LEGO SPIKE Prime Training U4L3 Slides **Other Programming Lessons links:** Other robots: MakeBlock Programming examples Vex IQ programming examples Basics with EV3: Robot Trainer | MINDSTORMS EV3 Unit Plan Basics with LEGO SPIKE Prime: Competition Ready | SPIKE Prime Unit Plan EV3 Programming Lessons from Beginner to Advanced: https://ev3lessons.com/en/index.html LEGO SPIKE Prime Lessons: https://primelessons.org/en/

	• What did we learn during the regolith exploration? • How will the regolith and slope exploration help us test our rovers? As a whole-class, select students to reflect back on the regolith and slope exploration lesson. Afterwards, tell students that the previous lessons will help students to test their robots/rovers by creating "Moon's surface" in upcoming lessons to build slopes (in the "Explore" section) and test their rovers with the Moon regolith they investigated (optional in the "Explore" section). **IMAGINE (40 Min):** *Students brainstorm solutions and research ideas. They also identify what others have done.* SAY: SLOPE Lab, is a NASA acronym for Simulated Lunar Operations Laboratory. SLOPE Lab is located in Cleveland and is home to multiple sandboxes that mimic the lunar and Martian terrain to evaluate the VIPER's traction performance and limitations of current rover designs. Tell students that they will watch a video about the SLOPE Lab and prompt them to think about the following questions: • What did you notice in the SLOPE Lab? • What did you notice about VIPER's performance, particularly its tires performance and traction in the sandboxes? Play video (2:09 Min): https://www.youtube.com/watch?v=8GvldWevWCw SAY: This is how NASA tests the rover before it gets to the Moon. How can we perform tests here that will help us predict how VIPER and other rovers will perform on the Moon? You will use the guiding question to brainstorm solutions and research ideas on what others have done from previous rover missions. Your group will read "The Moon is Not Mars - VIPER's Unique Challenges" (digital or printed copy). Record your group's thoughts and ideas on the Engineering Design Process (EDP) handout, you'll have 25 minutes to do so. In partners, groups or whole-class, have students imagine, "How could we test our rovers here on Earth based on what we have learned so far?" **Building Rover (45 MIN):** *Students will build their robot.* Then, tell students that they build their robot as a group and each student will take turns building the rover. Divide the class into groups and assign roles (i.e., robot builder, reads instructions, programmer, rover tester) for students to take turns building, programming, and testing the rover (Note: Be aware of unconscious bias. For example, if only male students volunteer to build or dominate the building process. Be intentional of having female students build and/or program the robot as well.) Have students use their laptop to access the software and building instructions. See written Software and Building Instructions for specific robots.	**Programming and Testing Rover:** Journal for MDL pencil

	TRAINING - Programming Rover (30 - 90 Min): *Students will program their robot.* Before engaging in this lesson, create a clearing in a classroom area or find an open area in the building for groups to program and test their rovers. Tells students that they will learn about fundamental programming skills related to moving their rover. Depending on the classes' robot, use the corresponding robot link to have students get trained in programming their rover. ● ***LEGO MindStorm EV3****:* The "Moves and Turns" lesson in the "Robot Trainer" Unit. (45 - 90 Min) ● ***LEGO SPIKE Prime****:* The "Training Plan 1" Lesson in the "Competition Ready" Unit. (30 - 45 Min) ○ For LEGO rovers, go to the web or desktop app to find the training unit ("Moves and Turns" for EV3 and "Training Plan 1" for SPIKE Prime) or have students follow the slides for visual instructions ● ***MakeBlock***: Code with Blocks or Python (45 - 90 Min) ● **Vexcode VR** is another valuable resource if group members want to gain additional experience without a robot. It is a web-based virtual coding environment that allows students to learn block- or text-based code using a virtual robot. ● (**For other robots**, individual lessons for each of these tasks can be found in the Other Programming Lessons links) **Programming and Testing Rover (45 Min):** *Students will program and test their robot to execute different maneuvers.* After groups have completed the training, tell students that they will program and test their rover. If the class has the LEGO rovers, they will start a "New Project" on the homepage by clicking on "New Project" and have students mostly refer to the "Movement" & "More Movements" CodeBlocks (color-coded pink), but are also welcomed to include other CodeBlocks (motors, display, sound, events, control, sensors, operators, variables, and my blocks). Other robots, have students create a new coding program. Students will develop blocks of code that they can transmit to their rover to execute the following maneuvers (note: these maneuvers did not have to be in this specific order, just as long as groups have these CodeBlocks): ● Drive forward in a straight line 1 meter/ 100 centimeters ● Drive forward a straight line a specific distance ● Drive backwards in a straight line a specific distance ● Turn left or right -90/90 degrees ● Turn left or right -45/45 degrees ● Code that can easily modified that tells the robot to drive forward (or backward) a specified distance and turn a specified amount Continue to circulate and monitor if students need additional help or have clarifying questions. After students have created their CodeBlocks, have them screenshot or take a photo of their codes. The images or screenshots of these CodeBlocks should be included in the MDL along with a description of	

	what each block of code does. Groups should also save their CodeBlocks and write comments to keep track of what each block of code does. For those participating in the challenge, this will be helpful for the Final Challenge (MO—10). **OPTIONAL: Rover Color Sensor (30 - 90 MIN)** Students will use the robots color sensor to take scientific data by measuring the color of the surface. The following LEGO lessons provide a quick introduction to the color sensor: ● ***LEGO Mindstorm EV3:*** The "Colors and Lines" lesson in the "Robot Trainer" Unit. (45 -90 Min) ● ***LEGO SPIKE Prime*:** The "Training Plan 3" lesson in the "Competition Ready" Unit. (30 - 45 Min) ● **MakeBlock:** Case 2 -Black Color Detection (30 - 45 Min) Students with more experience programming robots or extra time can take on additional challenges of modifying their rover so that it can pick up a ~1"x1" sample and carry it onboard. This will require a little more programming and an extra motor. Students can learn more about this by checking out the following LEGO lessons: ● *LEGO Mindstorm EV3:* The "Grab and Release" in the "Robot Trainer" Unit. (45 - 90 Min) ● *LEGO SPIKE Prime:* The "Training Plan 2" lesson in the "Competition Ready" Unit. (30 - 45 Min) ● MakeBlock: Case 6- Control of Robotic Clamp Claw (30 - 45 Min) To close the lesson, prompt groups to discussion the following questions (10 Min): ● Did you encounter any barriers in building and setting up your robot? If so, what did you do to overcome these barriers? ● What did you try but it didn't work? ● What did your exploration of the programming CodeBlocks reveal to you? **CHARGE ROBOT**: After using the robots, charge the robots' hubs for the next lesson.	
Explore (200 Min)	***Students will use the Engineering Design Process to create and iteratively test a complex system involving their robot and test conditions of the Moon's surface.*** This segment of the lesson includes five parts, including one that is optional: ● Engineering Design Process - Plan (20 minutes) ● Engineering Design Process - Create (50 minutes) ● Programming Rover (45 minutes) ● Test Rover (40 minutes) ● OPTIONAL: Lunar Dust Course (40 minutes) Tell students that they will watch a video of test environments for rovers in the Mars Yard. Ask students to pay close attention to the slopes and then ask, "what do you notice?". Play video. As a whole-class, have students discuss the test environment slopes in Mars Yard and SLOPE lab.	Mars Yard video: https://www-robotics.jpl.nasa.gov/gallery/mars-yard-tour-video/ **PLAN:** -Printed Engineering Design Process (EDP) handout -Pencil Spanish Version: Folleto del proceso de diseño de … **CREATE:**

	PLAN (20 Min): *Students choose two or three of the best ideas from their brainstormed list found in Unit 2 Lesson 1 (MO-03) and sketch possible designs, ultimately choosing a single design to prototype for the slope test course.* Call back to MO-03 (Unit 2 Lesson 1: Investigating the Moon's surface). In this section, students will take what they learned in MO-03 to create conditions like those they will find on the Moon. Students will continue the Engineering Design Process by planning then designing a slope test course, and then students will later consider wheel designs in the "Elaborate" section. Ask students to silently reflect on the question, "How will you re-create the range of slopes that you found in MO-03?" Next, tell groups that they will design and build a ramp that is adjustable in steepness to test their rover's climbing ability to drive up and down the slope. Later, they will plan and design for the rover's wheel designs that they explored in MO-03. Tell students to individually sketch or list out two or three best ideas on their Engineering Design Process (EDP) handout. The final designs to be constructed should be a group decision or a compilation of multiple designs. This activity is designed to facilitate creative thinking. There are no right or wrong answers. **CREATE (50 Min):** *Students build a working model, or prototype, that aligns with design requirements to make it as much like what they found in Unit 2 Lesson 1 (MO-03) as possible.* Once students have compiled their single design prototype to design an adjustable ramp, give students materials for building their ramps for traversing over the range of slopes. Noting that each group will build 18" long and 12" wide ramp(s) on a test environment using their materials. Remind students that the materials are used to construct steep slopes to test the rover's ability to climb up steep slopes. Distribute materials: ● Pair of Scissors ● Tape ● Glue ● Materials to build ramp(s) (measurement 18''long and 12'' wide): ○ board, cardboard, wood, and/or foam After students build an adjustable ramp, students will program their rover to ascend and descend safely. **Programming Rover (45 Min)** Recall back to the "Engage" section where students completed a training to program their rover using CodeBlocks. Tell students that they will apply their training to create new CodeBlocks to program their rover to ascend and descend from the adjustable ramp safely. If the class has the LEGO rovers, they will start a "New Project" on the homepage by clicking on "New Project" and have students mostly refer to the "Movement" CodeBlocks (color-coded pink) and "Motors" & "More Movements" CodeBlocks (color-coded	-Pair of Scissors -Tape -Glue -Materials to build adjustable ramp (18" long and 12" wide): ● Board ● Cardboard ● Wood ● Foam **Programming Rover:** -Rover -Laptop/computer **(Optional) "Lunar Dust Course":** -18" long and 12'' wide Cafeteria-type tray or large, shallow baking pan for Regolith test "course" -"Most like" Regolith material that was identified in Unit 2 Lesson 1 (flour, corn starch, sand, salt, or baby powder)

	blue). Other robots, have students create a new coding program. Students can decide how to navigate the slopes test course, but ultimately will need to create a basic code where students only need CodeBlocks for moving forward/backward, rotation(s), the length, and motor speed to ascend and descend safely on the ramp/slope. Students can make modifications to their rover's movement capabilities and/or adjusting the ramp's slope. Circulate and monitor each group. Once groups have their beds nearly completed, give groups 10 minutes to display and discuss their strategies for building an adjustable ramp for their course. Take a picture of each group's model. **TEST (40 Min):** *Students evaluate the solution through testing, they collect and analyze data, they summarize strengths and weaknesses of their design that were revealed during testing.* SAY: Similar to how engineers use full scale test environments like the Mars Yard to test rovers bound for Mars or the SLOPE Lab to test VIPER bound for the Moon, groups should use their slope test course to test and adjust the steepness of the ramp so the rover can climb and descend safely (and through the regolith if the class are doing the Lunar Dust Course). Groups should evaluate how changes to the slope test course and driving characteristics affect their rover's ability to drive in the challenging lunar environment. Write at least 3 modifications of the slope test course on your Engineering Design Process (EDP) handout and carefully document how your group modified the course and the results of their tests. As a whole-class, tell groups to display their slope test course and rovers. Have students discuss strategies they used to program their rover's capabilities and make changes to their adjustable ramp/slope. This will allow them to share their problem solving and design strategies. Ask students how this activity helped them learn more about the testing process of a complex system involving their rover, slope test course, and test conditions? **CHARGE ROBOT**: After using the robots, charge the robots' hubs for the next lesson. OPTIONAL(40 Min): **Lunar Dust Course** *Note: Materials similar to lunar regolith can be messy. If this won't work in your learning environment, ask groups to skip the "lunar dust course" and just modify the wheel without testing it in regolith-like material (or pick something less messy). During the final challenge, the regolith portion of the course will be separate and optional. Groups will also be allowed to make a "pit stop" and remove the rovers' dusty modified wheels and replace them with the original wheels as they navigate the rest of the challenge course.* Groups can build a "Lunar Dust Course" using the easy-to-acquire material that the group identified to have properties similar to the lunar regolith simulant (flour, corn starch, sand (very fine to fine), salt, or baby powder).	

	Tell groups that they will create a Lunar Dust Course measuring 18''long and 12'' wide. Have students recall MO-03 when students used foldscopes to identify samples that were similar to the lunar regolith simulant. Now, students will use that sample (depending on what the groups selected) to make a "sandbox" similar to SLOPES lab. Students can explore NASA's Simulated Lunar Operations Laboratory for inspiration. Have students refer back to "Plan" to reconstruct their slopes and wheels. Then, record the test and modifications they made onto their Engineering Design Process (EDP) handout Circulate and monitor groups, reminding students to record their test improvements on the Engineering Design Process (EDP) handout. As a whole-class, tell groups to display their Lunar Dust Course and rovers. Have students discuss strategies they used to revise their rover's capabilities and test beds. This will allow them to share their problem solving and design strategies. Ask students how this activity helped them learn more about the testing process of a complex system involving their rover, regolith/ "lunar dust", and slopes? Have each group share aloud. **CHARGE ROBOT**: After using the robots, charge the robots' hubs for the next lesson.	
Explain (45 Min)	***Students will make a formal comparison between their robot and the VIPER rover as well as between their slope test course and the surface of the Moon.*** Show students U2L1 slides 10 -14 and have students consider the slope or "steepness" of the different paths down into Shackleton's Crater slope in relation to the adjustable ramp students designed and built. Ask students the questions below and discuss as a whole-class: ● How steep a slope do you think our robots will be able to ascend and descend? ● Do you think going down or going up will be easier or safer? Distribute Comparing Scale Factor handout. Tell students that they will make a formal comparison of the rover size and slopes' size. Tell students to work together to measure their robot's size and then discuss the size differences from their robot to the VIPER rover. Ask students to explain: ● Consider the size of VIPER compared to your robot; if we were going to build a scale model of the Shackleton crater slope, how long would it be? Then, have students recall back to U2L1, and write down the slope calculations they found. This will help them think about the test they completed. Have students measure, label, and draw three slopes from their robot's adjustable ramp measurements. Be sure that students' measurements are in the same unit (kilometers, meters, or centimeters). After students have measured their three slopes and drew it on their Comparison Size Factor handout, ask to explain students: ● What does that scale factor translate to for our slopes (ANS: unchanged) and distances (ANS: scaled down by the same factor) on the Moon?	U2L1 Slides Spanish Version: U2L1 Slides - Spanish Version *Comparing Scale Factor* handout Spanish Version: Comparación de factores de escala Pencil ruler/ measuring stick

	As a whole-class, have each group explain the size comparison of the slope test course and the surface of the Moon.	
Elaborate (45 Min)	***Students will use the final Engineering Design Progress to improve their rover wheels and reflect on building a rover and test course.*** **IMPROVE:** *Based on the results of their tests, students make improvements on their design. They also identify changes they will make and justify their revisions.* **Explore Wheels** Call back to MO-03 (Unit 2, Lesson 1), when they tested the regolith samples. Ask students, “Do different wheels or tracks produce different results on slopes and/or in regolith beds? Have groups discuss in pairs for 10 minutes. As a whole-class, have each group share aloud whether wheels or tracks produce different results on slopes or regolith beds based on what they have tested so far. Next, have students return to the Wheels Interaction website: https://www.nasa.gov/specials/wheels/ and discuss as a group the different wheels. Then, have groups make iterations to their rover’s wheels by writing challenges and changes in their Engineering Design Process (EDP). Students can test their wheels in a variety of conditions, try different wheel or track options, or modify their existing wheels to improve performance. If the school has a 3D printer, have students print wheels for their rover. To close the lesson, ask each group to share aloud whether different wheels or tracks produce different results on slopes?	Laptop/computer Rover Wheels
Evaluate (15 Min)	***Students will record their findings from this lesson in their MDL and speculate ways to make their test conditions more like the actual VIPER mission on the moon.*** Include the items below (also what they would change to make their mission more like the VIPER mission. From MO-07: ☐ An image or a description of blocks of code developed to complete the basic maneuvers above. Groups should also describe challenges they encountered learning to code and how they addressed them. ☐ Images of any test courses they have built. ☐ MDL: Documentation of the Engineering Design Process including problems identified, ideas generated, prototypes built, and the results of testing their rovers.	

	☐ An image of their final rover design and a description of how various design choices will help that rover drive in the lunar environment.	
Extend (Optional)	**If students are progressing with their programming, this Sliding Slope activity from LEGO can be an additional challenge**: [Sliding Slope | MINDSTORMS EV3 Lesson Plan]()	

HANDOUTS: Work them up here:

Engineering Design Process (EDP) handout **Name:**

ASK: What problems might VIPER encounter? (Write a list)

IMAGINE: Brainstorm Solutions (Write a list)

PLAN: Select 2 - 3 of Your Best Solutions (Draw it Out)

Design 1	Design 2	Design 3

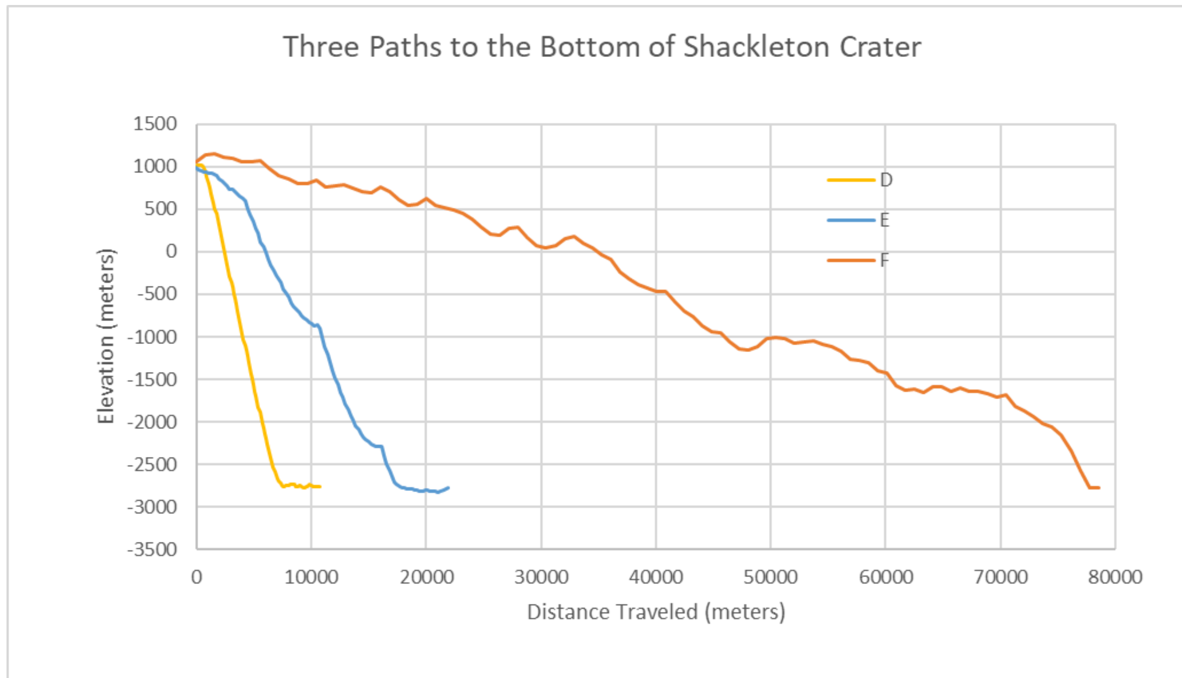
CREATE: Take a Photo of Group's Prototype

TEST: Summarize the strengths and weaknesses of your design.

IMPROVE: Based on results of the test, list the challenges and changes made to your rover, ramps, and wheels design.

	Challenges	Changes
Rover		**Modification 1:** **Modification 2:** **Modification 3:**
Ramps		**Modification 1:** **Modification 2:** **Modification 3:**
Wheels		**Modification 1:** **Modification 2:** **Modification 3:**
Other		**Modification 1:** **Modification 2:** **Modification 3:**
Optional (Lunar Dust)		**Modification 1:** **Modification 2:** **Modification 3:**

Comparing Scale Factors **Name:**______________________

<table>
<tr><th></th><th>Rover Size</th><th>Slope Size</th></tr>
<tr><td>NASA's VIPER Mission</td><td>Similar to the size of a golf cart:
Length/Width/Height: 1.5 meters by 1.5 meters by 2.5 meters</td><td>In Unit 2 Lesson 1 (MO-03), we found that the slope calculations for Shackleton Crater were …
____
____
____
</td></tr>
</table>

Prototype of NASA's VIPER Mission	Measure the rover's length, width, and height:	Draw, Label, and Calculate Slope in the Graph: Calculating Slope Be sure that your measurements are in the same unit (kilometers or meters). Slope = Rise/Run If you have two points, figure out the elevation difference between them (rise), and divide by the horizontal distance between them (run).