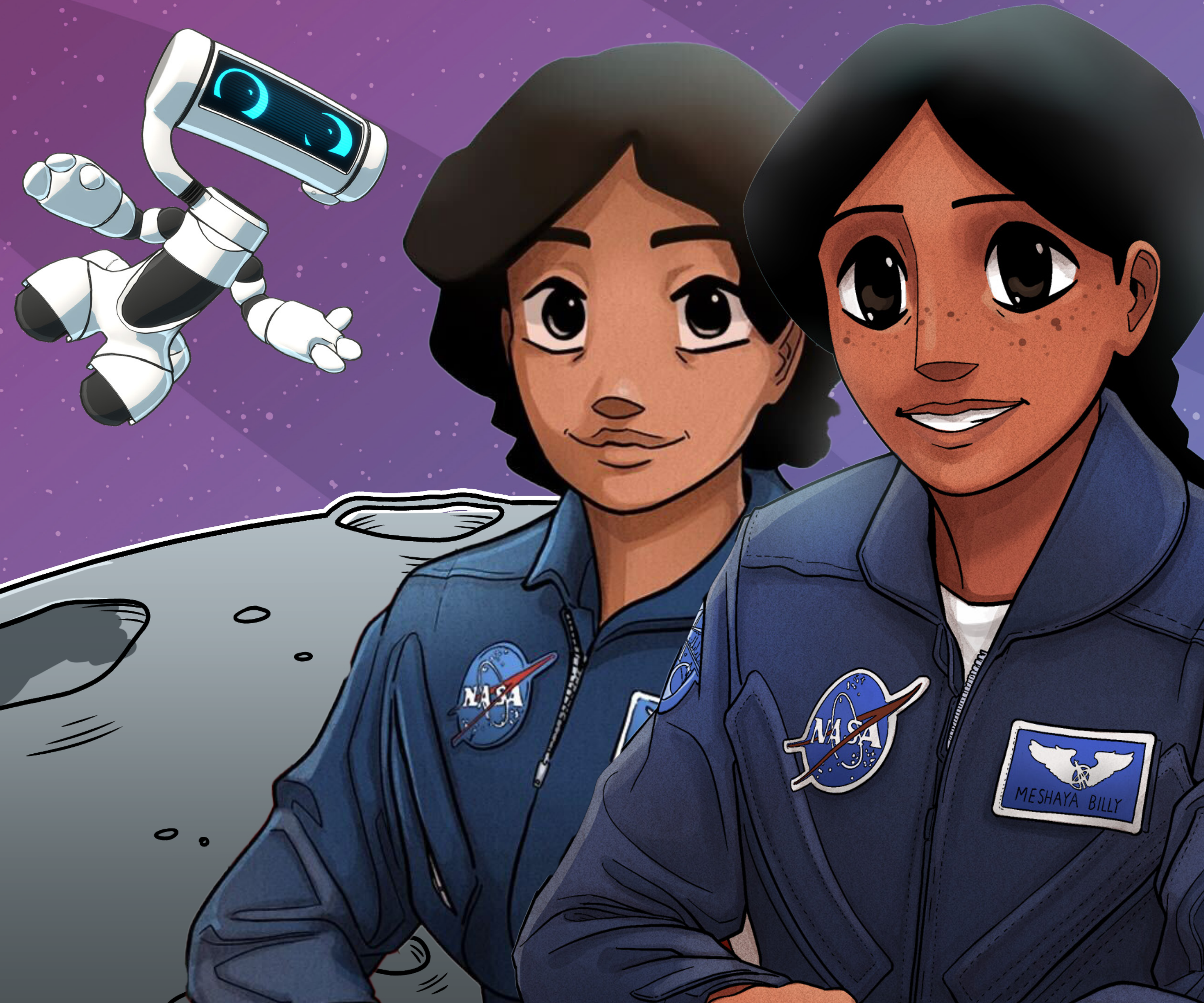
National Aeronautics and Space Administration

FIRST WOMAN
CAMP EXPERIENCE No. 2



NASA Office of STEM Engagement Next Gen STEM

Introduction

The set of hands-on activities within this guide accompany the **First Woman Issue #2: Expanding Our Universe** graphic novel, which tells the story of Callie Rodriguez, the first woman to explore the Moon. While Callie is a fictional character, the first female astronaut and person of color will soon set foot on the Moon. First Woman Issue #2: Expanding Our Universe begins with Callie, RT, and Dan in a treacherous situation on the Moon. This issue of the graphic novel series features a diverse crew of astronauts working together on the Moon's surface, learning and growing as a team, navigating the unexpected, and conducting experiments and technology demonstrations for the benefit of humanity. Readers see how teamwork and perseverance help the crew overcome the challenges of living and working on the Moon. Callie and her new team, Native American Astronaut Meshaya Billy and Canadian Astronaut Martin Tremblay, use their training and human ingenuity to deploy a next-generation space telescope.

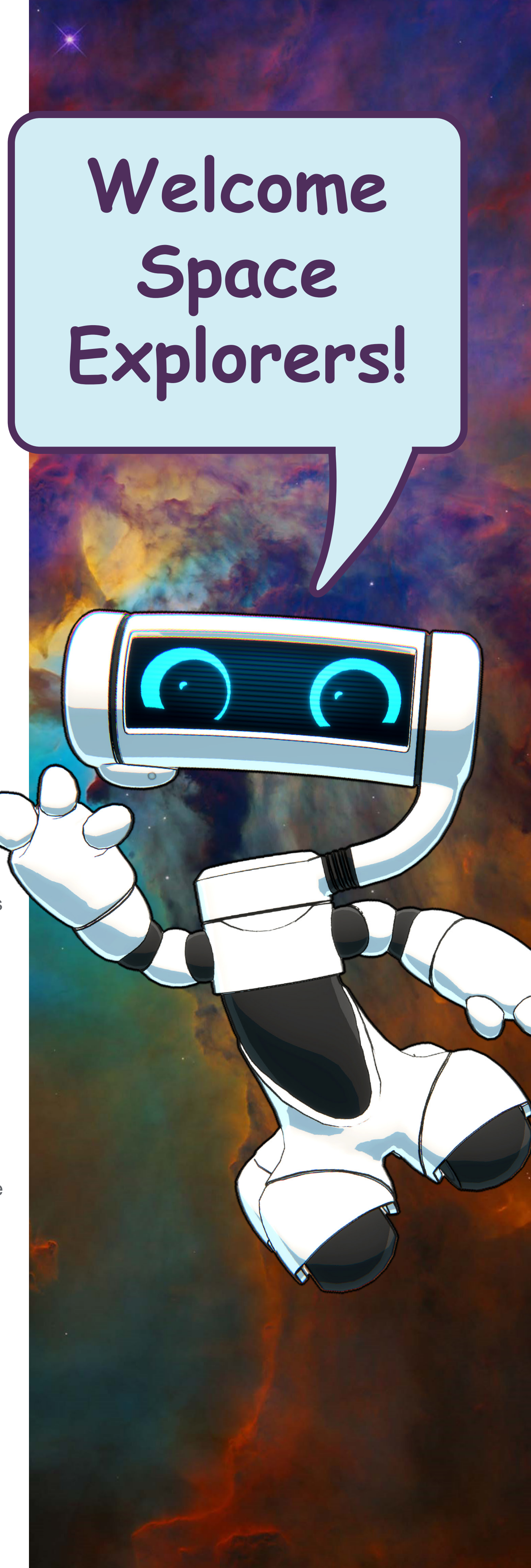
This camp experience is intended for use by K-12 students in informal education settings such as after school programs, summer camps, Science, Technology, Engineering, and Mathematics (STEM) nights, and weekend workshops. This First Woman Camp Experience Guide No. 2 will bring the excitement of NASA's science and technology missions to the Artemis generation explorers!

What Is Artemis?

Artemis, in Greek mythology, was the twin sister of Apollo and goddess of the Moon. Today, her name represents NASA's efforts to return astronauts to the lunar surface.

Through Artemis missions, NASA hopes to land on the Moon and use innovative technologies to explore more of the lunar surface than ever before. NASA will collaborate with commercial and international partners to establish the first long-term presence on the Moon. Additionally, NASA's scientists and engineers will utilize intelligence acquired from Artemis missions to take the next giant leap: sending the first astronauts to Mars.

Artemis III will land the first woman and person of color on an area of the lunar surface humans have not yet traversed: the lunar South Pole. This is an ideal location for a future Artemis Base Camp given its potential access to ice and other mineral resources. The unexplored lunar southern polar regions provide unique opportunities to unlock secrets surrounding the history and evolution of our Earth, Moon, and solar system.



Camp Introduction

NASA is exploring the Moon, Mars, and beyond. So, what drives this exploration? **Technology!** Developing space technologies for future missions is the responsibility of NASA's Space Technology Mission Directorate (STMD). Pushing the boundaries of exploration, NASA's future missions hinge on crucial technological advancements: dust mitigation, water ice digging, sustainable infrastructure, and in-situ resource utilization. The activities in this guide focus on these four challenges. NASA is actively researching and seeking innovative solutions to these challenges to allow for a sustained lunar presence.

Electrostatic Moon Duster

During the Apollo missions, astronauts faced a high risk of dust-related damage to space hardware and astronaut health. The lunar surface is covered by a layer of dust particles called regolith. **Lunar regolith**, or **lunar dust** as it is commonly called, was created over billions of years by the bombardment of the solid lunar crust by meteoroids, solar UV flux, solar wind, and radiation. During impacts from micrometeorites, some of the surface particles formed into agglutinates, which are fused particles of impact glass, rock, and mineral fragments. These dust particles can be stirred up during robotic and human exploration activities or released by natural processes such as meteorite impacts. Apollo astronauts noted that lunar dust particles readily stuck to surfaces such as spacesuits, optical lenses, and thermal blankets, causing numerous problems. Apollo mission spacesuits were damaged by abrasive lunar dust, and several astronauts noted that Moon dust was resistant to cleaning efforts; even vigorous brushing could not remove it. Fortunately, today NASA is exploring the use of non-contact, electrostatic, dust-charging technology to protect the Agency's important space assets without restricting mission parameters. NASA's Artemis program is developing extensive resources along with advanced technologies to enable a sustained lunar presence. Mitigation of lunar dust adhesion will be central to these efforts as well as to Artemis' success.

Digging on the Moon

As NASA travels to the Moon and beyond, a sustainable infrastructure must be established to ensure a lasting lunar presence. This will allow for greater exploration and study of the Moon. Astronauts will live and work in space for longer periods of time, which means that their access to supplies will be less immediate.

What if we could generate products from local materials that are on the Moon's surface? This practice is called **in-situ resource utilization** (ISRU). Before Artemis astronauts land on the Moon, robots will scout the surface and collect information about the lunar South Pole.

Camp Vocabulary

Additive manufacturing - A process of joining materials to make objects from 3D model data, usually layer upon layer.

Icy-regolith - Ice and regolith mixture found on the Moon.

In-situ resource utilization (ISRU) - A practice of generating products with local materials.

Lunar dust - A very fine layer of regolith, or fragmented rock material, that is static and adheres to exposed surfaces.

Regolith - The loose, fragmental material on the Moon's surface.

Sustainable infrastructure - Equipment and systems that are designed to meet the population's essential service needs — including roads, bridges, telephone pylons, hydroelectric power stations, etc. — based on all-round sustainable principles.

Technology - The application of scientific for achieving practical goals. The products resulting from human efforts, including tangible and intangible tools.

Volatiles - Volatiles are the group of chemical elements and chemical compounds that can be readily vaporized.

Waypoints - A stopping place on a journey.

The Polar Resources Ice Mining Experiment-1 (PRIME-1) will be the first in-situ resource utilization demonstration on the Moon. The data from PRIME-1 will help scientists understand in-situ resources as well as assist in NASA's search for water at the Moon's poles. Additionally, PRIME-1 will help identify and assess the abundance and quality of water in lunar areas expected to contain ice.

Print a Lunar Habitat

ISRU can also be used on a much larger scale. The infrastructure required for a lunar base to support sustained missions will involve large scale construction projects. Large storage facilities will need to be built containing materials and resources harvested and produced on the Moon. Additionally, landing pads and roads will need to be constructed to mitigate the abrasive regolith that could be blown around during launches and landings and picked up through general transportation. Finally, habitats need to be constructed to provide space for astronauts to live and work as well as safety from the constant bombardment of solar and cosmic radiation. It would be virtually impossible to transport all the resources needed to build this infrastructure from Earth. Instead, NASA and its partners have been developing ways to use lunar regolith as a basis for creating a concrete-like material on the Moon. Turning this lunar concrete into structures will be accomplished by new **additive manufacturing** techniques. NASA partners are already working on architectural designs for a lunar base camp and are developing automated 3D printers to build the camp on the lunar surface. These technologies are currently being tested in a large vacuum chamber using lunar simulant (i.e., simulated lunar regolith) to closely mirror the conditions of the lunar surface.

Finding Our Way with VIPER (Volatiles Investigating Polar Exploration Rover)

After the PRIME-1 mission, VIPER will explore the Moon's extreme environment in search of ice and other potential resources. VIPER will look for ice water as a resource on the surface and subsurface of the Moon at varying depths and temperature conditions. VIPER's findings will also inform future Artemis landing sites by determining locations where water and other resources can be harvested to support a long-term lunar presence. VIPER instruments use spectrometers, which analyze the light emitted or absorbed by materials to identify their composition.

VIPER will contain numerous tools including the Neutron Spectrometer System (NSS) which will indirectly detect potential ice present in the lunar regolith. Additionally, the Regolith and Ice Drilling Exploring New Terrains (TRIDENT) will dig up regolith cuttings from as deep as three feet below the lunar surface. The Near-Infrared Volatiles Spectrometer System (NIRVSS) will detect the nature of hydrogen in the lunar soil. Finally, following touchdown, the Mass Spectrometer Observing Lunar Operations (MSolo) will assess gases in the environment to understand which are from the lunar surface and which were introduced by the lander itself. All these instruments will work together to accomplish the mission's goal of prospecting for resources such as water on the Moon.

CAMP OVERVIEW

First Woman Camp Experience No. 2

Activities

1. Electrostatic Moon Duster
2. Digging on the Moon
3. Print a Lunar Habitat
4. Finding Our Way with VIPER

Sample Camp Schedule

8:00 – 8:10 a.m. .... Welcome - Introduce participants to Artemis by showing either of the videos below.

- "**Why the Moon?**" (4:33)
- "NASA's **Artemis I Moon Mission: Launch to Splashdown Highlights**" (2:02)

8:10 – 8:30 a.m. .... Icebreaker - Show the video below.

- "**Frank Rubio "First Woman" Graphic Novel on the International Space Station**" (3:09)

Note: Allow 15 minutes to explore the First Woman Graphic Novel hard copies/ or App/XR

8:30 – 10:00 a.m. .... Activity 1

10:00 – 10:15 a.m. .... Break

10:15 – 11:15 a.m. .... Activity 2

11:15 a.m. – 12:15 p.m. .... Lunch/Recess

12:15 – 1:00 p.m. .... Activity 3

1:00 – 1:15 p.m. .... Break

1:15 – 2:45 p.m. .... Activity 4

2:45 – 3:15 p.m. .... Wrap up

3:15 – 3:30 p.m. .... Artemis video - "**What's Next for NASA: Artemis II Crewed Mission Overview**" (3:19)

Resources

First Woman Graphic Novel

First Woman Graphic Novel in Spanish

Comprehension Questions

Note: This guide can be sectioned into a day, week, or month experience based on goals of the student group.

Option A: 1 Day Experience (shown above)

Option B: 1 Week Experience (1 per day, M-TH Camp)

Option C: 1 Month Experience (1 activity per week)

Why the Moon?

Artemis I Moon Mission: Launch to Splashdown Highlights

Frank Rubio "First Woman" Graphic Novel on the International Space Station

What's Next for NASA: Artemis II Crewed Mission Overview

First Woman Graphic Novel

First Woman Graphic Novel in Spanish

Comprehension Questions

Activity 1: Electrostatic Moon Duster

Prep time: 20 minutes **Activity time:** 90 minutes

Summary: NASA's Artemis program will develop extensive resources on the Moon 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' success.

Learning Objective: Participants will identify properties of lunar dust which make it so problematic and discover ways to mitigate dust.

Outcome: Participants will develop a dust mitigation prototype given NASA's design criteria and constraints.

Activity 2: Digging on the Moon

Prep time: 20 minutes **Activity time:** 90 minutes

Summary: As NASA explores the Moon, and before Artemis astronauts land on the Moon, robots will scout the surface and collect information about the lunar South Pole. PRIME-1 will be the first in-situ resource utilization demonstration on the Moon.

Learning Objective: Participants will explore the properties of water and compare ice to the icy-regolith found on the Moon.

Outcome: Participants will design and build a drill bot that will dig through simulated icy-regolith.

Activity 3: Print a Lunar Habitat

Prep Time: 20 minutes **Activity Time:** 45 minutes

Summary: It would be virtually impossible to transport the resources needed to build a lunar habitat from Earth. Instead, NASA and its partners have been developing ways to use lunar regolith as a basis for creating a concrete-like material on the Moon to create a lunar Base Camp.

Learning Objective: Participants will learn about the potential to use materials already available on the lunar surface to construct a lunar base.

Outcome: Participants will design and construct a model lunar habitat using an additive manufacturing process with simulated lunar concrete.

Activity 4: Finding Our Way with VIPER

Prep time: 20 minutes **Activity time:** 90 minutes

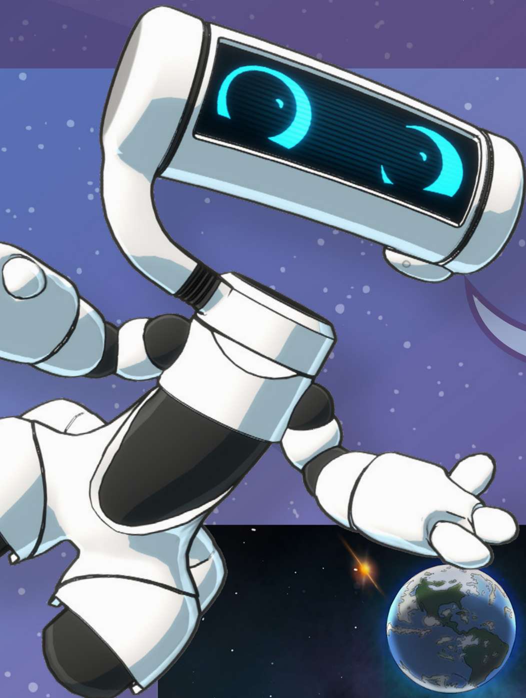
Summary: VIPER must navigate across the rugged terrain of the lunar South Pole while surviving ever-changing extremes in lighting and temperature as well as periods of communication blackouts. This scenario requires complex and dynamic route planning and waypoint driving to maximize the scientific return while keeping the rover in working condition until the end of its mission.

Learning Objective: In this robotic challenge, participants experience the processes involved in creating a communication protocol for, while learning about the challenges faced when, operating a Moon rover.

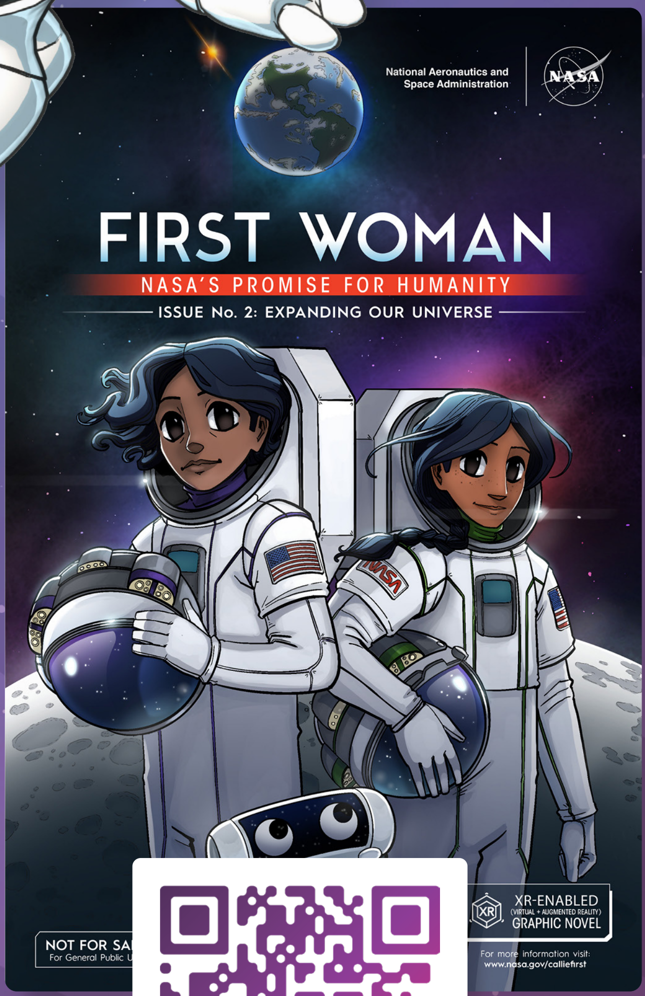
Outcome: After learning basic programming skills, participants will work together in a mission team to operate a robotic vehicle not directly in view of the driver or operations team to problem solve and accomplish their common goal.

FIRST WOMAN

CAMP EXPERIENCE



Expanding Our Universe picks up where we left off with Callie, RT, and Dan in a treacherous situation on the Moon. Callie and her new team, Astronaut Meshaya Billy and Canadian Astronaut Martin Tremblay, use their training and human ingenuity to deploy a next-generation space telescope. We see how teamwork and perseverance help the crew overcome the challenges of living and working on other worlds.



English

Español

MISSION BRIEFING

Activity 1 - Electrostatic Moon Duster

Prep Time: 20 minutes

Activity Length: 90 minutes

Task: Participants will research, design, build, and test a lunar dust mitigation device.

By the end of this activity participants will

Identify properties of lunar dust which make it so problematic and develop a dust mitigation prototype given NASA's design criteria and constraints.

Safety Considerations

Ensure:

- Participants practice safe cutting techniques and scissor handling when building their tools. Confirm participants carefully support the piece being cut and are careful with placement of supporting hand.
- Participants are mindful of any potential student allergies regarding the supplies used in this activity
- Participants avoid moving around the room with scissors
- Participants use caution and wear protective goggles when building and testing the tool design
- Participants wash hands after handling simulant regolith and minimize stirring up dust from the flour/powder. Keep dust to a minimum.
- Participants review the Safety Data Sheet (in materials section) for the simulant regolith that is being used
- Students should use the balloon pump to blow up the balloon. Students may only use their mouth if they are certain they do not have a latex allergy.

Materials

- One student handout per team
- Scratch paper and writing utensils
- Latex balloons or Styrofoam plates to act as the helmet of an astronaut on the Moon
- Safety scissors (rounded tip)
- Computers/devices with internet access or fact sheet handout for research
- Electrostatic charge creator (have a variety of these items for student choice): The following materials tend to give up electrons when brought in contact with other materials. That means they will have increased positive (+) charges (e.g., air, dry human skin, leather, fur, wool on PVC, glass rod, human hair, nylon, latex balloons, silk, aluminum, paper).

Activating Prior Knowledge

- How do we know so much about the Moon? Specifically, lunar dust (regolith)? Give participants time to share their thoughts.
- Have participants rub a balloon on their hair and observe what happens. What do they notice? What is causing their hair to stick to the balloon? What invisible force was created?
- What properties of lunar dust make it a problem for astronauts?

Connection to NASA

In NASA's Artemis program, the mitigation of lunar dust adhesion will be central to these efforts and to Artemis' success. To learn more about NASA's Dust problem, check out this link: "**Dust: An Out-of-This World Problem**" (1:20) (QR below)

MISSION GUIDANCE

GO

- Discuss the challenge and constraints
- The testing station and the building station should be in separate areas

MAYBE

- Show the following describing dust problems and mitigation: **Lunar/Crater Surface – Dust Mitigation System: NASA 360** (QR Below)
- Have the students read: **Dust an Out of this World Problem**

NO GO

- A design requiring more than one person to operate
- A tool design that can only be tested once
- Give participants suggestions or show examples of other dust mitigation devices

Dust: An Out-of-this-World Problem

Dust Mitigation System: NASA 360

The following materials tend to attract electrons when brought in contact with other materials. That means they will have increased negative (-) charges (e.g., wood, amber, hard rubber (comb), nickel, copper, brass, silver, polyester, styrene (Styrofoam), saran wrap, scotch tape, vinyl).

- Analytical balance: These are typically suitable for masses of 0.1mg up to 200g and are more precise than precision balances.
- Simulant for the lunar dust (e.g., salt, wheat flour, packing peanuts, baking powder, QUIKRETE®, polystyrene beads)
  See Safety Data Sheets below:
  - **Salt Safety Data Sheet**
  - **Wheat Flour Safety Data Sheet**
  - **Baking Powder Safety Data Sheet**
  - **QUIKRETE® Safety Data Sheet**
  - **Polystyrene Beads Safety Data Sheet**

Preparation

1. Gather materials.
2. 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®, Polystyrene Beads).
3. Group students into teams of two to four. Consider assigning roles and tasks to individual students within the team.
4. Print one student handout for each team.

Procedure

1. After watching the videos Dust: An Out-of-this-World Problem and Dust Mitigation System: NASA 360, Teams will brainstorm a solution to the dust problem and develop a strategy to mitigate this problem for future work on the Moon.
2. This activity will simulate an astronauts helmet covered in lunar dust. The helmet will be represented by a latex balloon or Styrofoam plate. Teams will create an electric charge (by rubbing the helmet on hair or dry skin) and place the helmet in the lunar testbed being sure to have it covered as much as possible with the lunar simulate. The challenge will be to build a tool using available materials to remove (or mitigate) the lunar dust from the balloon with minimal contact using the invisible force of electrostatics.
3. Allow teams to see the available materials to build their dust mitigation tool. The tool must be able to be used by one person.
4. Teams will create a sketch of their proposed design.
5. One participant from each team will gather their needed materials.
6. Teams will have at least 30 minutes to construct a tool using the materials provided and the sketches they have created. The teams' tool should be a dust mitigation device that can be used by a single astronaut. The tool should be able to withstand multiple tests.
7. Now that the teams have created a dust mitigation tool, explore the lunar testbed and experiment with the new tool. Be sure to record mass one (1) of the helmet (Latex Balloon or Styrofoam plate alone). After the regolith simulant is added to the "helmet" using electrostatic force, find mass two (2) (balloon plus the addition of the regolith simulant via static charge). Use the tool and dust mitigating procedures to remove as much regolith simulant as the team can in five seconds or less.

Extension

- Allow students time to redesign their dust mitigation tool
- Design a new dust mitigation device to attempt to improve dust removal time

Challenge 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?
- What design changes did you make and how did they improve your tool's performance?
- What was something about another teams' model that impressed you?
- Was there a problem with lunar dust in the First Woman graphic novel? Explain?

Salt Safety Data Sheet

Wheat Flour Safety Data Sheet

Baking Powder Safety Data Sheet

QUIKRETE Safety Data Sheet

Polystyrene Beads Safety Data Sheet

MISSION BRIEFING

Activity 2 - Digging on the Moon

Prep Time: 20 minutes

Activity Length: 60 minutes

Task: Participants will be challenged to compare the properties of ice with simulated icy-regolith, like the icy-regolith found on the Moon's south pole, and design and build a robot drill that will dig through the simulated icy-regolith.

By the end of this activity participants will

Compare and contrast the properties of ice to simulated icy-regolith, like the icy-regolith found on the Moon's south pole, and design and build a robot drill that will dig through simulated icy-regolith.

Safety Considerations

Ensure:

- Participants are mindful of any potential student allergies regarding the supplies used in this activity
- Participants wear eye protection when building and digging in the simulated icy-regolith
- Participants practice safe cutting techniques and scissor handling when building their tools. Confirm participants carefully support the piece being cut and are careful with placement of supporting hand.
- Participants avoid moving about the room with scissors or other sharp objects
- Participants tape the terminal ends of the batteries with electrical tape when they are not stored in their original packaging
- Participants tape all bare wire and exposed electrical connections with electrical tape
- Students must review their build with the educator before turning it on

Materials for Drill Bot

- Battery powered toothbrush (one per team). Note to educator: Check out local discount stores for this item.
- Foam noodle or plastic cup
- Rubber bands
- Electrical tape
- Metal washers or pennies
- Plastic spoon
- Craft sticks
- Chop sticks

Activating Prior Knowledge

- Give teams four to six regular ice cubes as well as four to six icy-regolith ice cubes (water and sand mixture). Tell students they will compare how ice cubes and icy-regolith ice cubes melt under different conditions. Share this question with students: What is the difference between ice and icy-regolith?
- Ask students to predict what will happen to the ice and icy-regolith under the following conditions: (Icy-regolith ice cubes will melt faster than regular ice cubes in each of the conditions below, but especially in the hot water)
  - Both placed in a dish of room temperature water
  - Both placed in a dish of hot water
  - Both placed under running room temperature water
  - Both placed under running hot water
- Ask students the following questions:
  - Which ice cubes melted faster, icy-regolith ice cubes or regular ice cubes?
  - How were your predictions similar to or different from the results?

Connection to NASA

PRIME-1 will be the first in-situ resource utilization demonstration on the Moon. The data from PRIME-1 will help scientists understand in-situ resources as well as assist in NASA's search for water at the lunar poles. Additionally, PRIME-1 will help identify and assess the abundance and quality of water in lunar areas expected to contain ice. Play introduction to **In-situ Resources with RT** (0:35) (QR below)

MISSION GUIDANCE

GO

- Students must only use the materials provided by the educator.
- Students must not apply any additional weight to the drill with their hands.

MAYBE

- Share **Melting Ice Experiment** (QR below)
- Share the video "**The Polar Resources Ice Mining Experiment-1**" (2:37) (QR below)

NO GO

- Students cannot use their hands to move the drill, the vibration of the toothbrush component should be doing the work.
- Students cannot apply any objects, other than what was provided, to add weight to the drill.

In-Situ Resources with RT

Melting Ice Experiment

PRIME-1

- Push pin
- Paper clips
- Eye protection

Materials for simulated Icy-regolith:

- Container (ice cube tray, plastic cup, etc.)
- Sand
- Water

Preparation:

1. Gather and prepare all listed supplies.
2. Make copies of the worksheet. Make sure all links are accessible.
   a. **How Will We Extract Water on the Moon? We Asked a NASA Technologist.** (1:39)
   b. **The Polar Resources Ice Mining Experiment-1 (PRIME-1)** (2:37)
3. Group students into teams of three to five. Consider assigning roles and tasks to individual students within the team.
4. Water preparation for icy-regolith:
   a. Fill half the container with water and half with sand. Place container in the freezer overnight.
   b. Simulated icy-regolith taken out of the freezer must be used immediately.
5. Assemble the drill bot using the instructions on page 12.

Procedure:

1. Allow students to see all the materials before building their robot drill.
2. Have student teams create a sketch of their proposed robot drill, complete with labels and descriptions of the materials used.

Have students keep in mind the following questions:

1. How will you ensure that the digging device will not break?
2. What mechanism will you use to ensure that the drill is breaking up the water ice?

After reviewing each group's drawing, allow students to retrieve the needed materials to construct their drill.

1. Have teams construct their drill bot and ensure students are following safety protocols. Their robot drill must use only one device for digging (e.g., chopsticks, craft sticks, paper clip).
2. Once students have created their own robot drill, allow them to test their drill on the simulated icy-regolith. Ensure teams are not adding any additional weight to their drill bot and are not using their hands to move the drill around, let vibration move the drill.

Ask these questions:

- Is the design working as expected?
- What can be improved to change it?
- What are the weaknesses in the design and what can be done to overcome the weaknesses?
- Do you think additional weight needs to be added to the drill? If so, where would you add it?

Extensions:

- Have participants design and create a drill using simple machines or a robotics kit
- Include a small object in the icy-regolith, such as a penny, for the students to excavate with their robot drill
- Explore the **Break the Ice Challenge**
- Explore **Polar Resources Ice Mining Experiment-1** (PRIME-1)

Challenge Questions:

- What are some of the difficulties your team faced during the initial design and build process and how did you overcome them?
- Were you surprised at how difficult it was to dig through simulated icy-regolith?
- What impressed you about another teams' model?
- How were you able to improve your design? What changes did you make and how did they improve your bot's performance?
- How could these technologies have helped Callie and RT in their challenges? (Refer back to NASA's **First Woman** graphic novel)

How Will We Extract Water on the Moon? | PRIME-1 | Break the Ice Challenge | Polar Resources Ice Mining Experiment -1

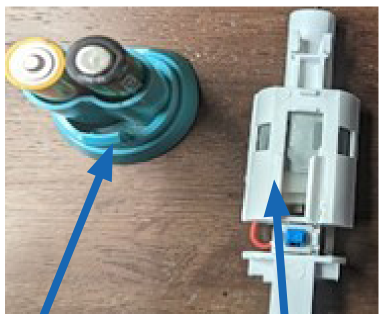
Directions for assembling the drill bot

1. Assemble all supplies needed.
2. Remove the bottom end of the electric powered toothbrush. Remove the battery compartment. The motor will be underneath the battery compartment. Do not use a sharp object to pop the motor loose. Use eye protection for this step.
3. There will be 2 separate compartments that will need to be taped together with electrical tape for a complete motor.

Note: Each toothbrush motor looks different, so the motor removed may not look like the one below.

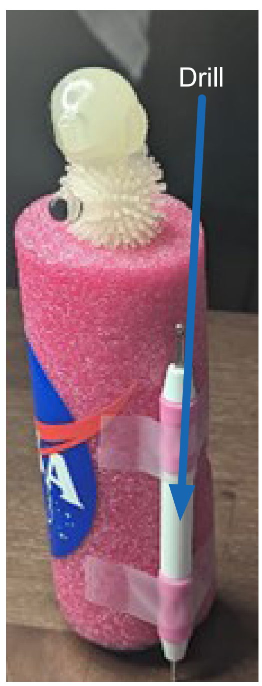
4. Once the motor and battery compartment are taped together using electrical tape, insert the two parts into your noodle. *Note: It is easier to cut a small hole in the front of the noodle to allow access to the on/off switch for the motor. All exposed connections must be taped. The power must be off and completely taped with electrical tape to cover all exposed wires and conductive (metal) parts and exposed connections. All students must have the educator review their "build" before it is used to ensure all exposed conductive parts have been taped.*

Motor to be removed



Battery compartment Motor

Battery compartment Electrical tape Motor



1. Test to make sure that the drill bot can move easily before adding the drill or any decorations.
2. Add your drill and test using the water ice provided. The students will decide what their drill will be (e.g., plastic spoon, craft stick, etc.).

Here are some examples of problems students may encounter and some suggestions:

- The drill bot moves too fast around the icy-regolith
    - The student should consider adding some weight (washers or pennies may be used). Students need to determine where the weight should be added to make the drill bot more stable.
- The motor is not rotating freely
    - The student can enlarge the hole of the foam noodle to allow for more vibration for movement

An alternative to using an electric toothbrush

- Battery Packs : 1.5V AA Battery Holder Case with on/off switch
- Motors : Vibration motor DC 1.5-6V 5200 RPM
- AA Batteries

MISSION BRIEFING

Activity 3 - Print a Lunar Habitat

Prep Time: 20 minutes

Activity Length: 45 minutes

Task: In this engineering design challenge, participants will gain understanding of the necessity for ISRU to support sustainable lunar surface exploration. Additionally, participants will design and construct a model lunar habitat using an additive manufacturing process with simulated lunar concrete.

By the end of this activity participants will

- Gain understanding of the necessity for ISRU to support sustainable lunar surface exploration
- Design and construct a model lunar habitat using an additive manufacturing process with simulated lunar concrete

Safety Considerations

Ensure:

- Participants are mindful of any potential student allergies regarding the supplies used in this activity
- Participants practice classroom safety while performing this activity and avoid creating slip hazards due to spills. Any floor areas that may get wet should be protected from foot traffic.
- Participants practice safe cutting techniques and scissor handling when building their tools. Confirm participants carefully support the piece being cut and are careful with placement of supporting hand.
- Participants avoid moving around the room with scissors or other sharp objects
- Students should use the balloon pump to blow up the balloon. Students may only use their mouth if they are certain they do not have a latex allergy.

Materials

- One student handout per team
- Scratch paper and writing utensils
- Large sheet of sturdy cardboard per team (approximately 24x24 inches)
- Large disposable cake decorating bags
- Large bowls
- Sink
- Paper Towels
- Scissors (Consider utilizing rounded tip scissors for younger participants)
- Large spoons or spatulas

Activating Prior Knowledge

- What are the basic human needs essential for survival on Earth?
- Are these basic survival needs currently available on the Moon? If not, which need(s) are missing?
- Share and discuss the following questions:
    1. How much indoor space do you require to live? How much indoor space does your whole family require?
    2. What kind of separate spaces are needed in a house? (e.g., kitchen, bathroom, bedrooms, living room).
    3. If you had to downsize your living space, how could you minimize separate spaces? (e.g., share bedrooms, sleep in living room, smaller kitchen/ bathroom).
- "**Teams Build 3D-Printed Habitats for Moon and Mars**" (1:18) (QR below)

Connection to NASA

NASA and its partners have been developing ways to use lunar regolith to create a concrete-like material on the Moon. Turning this lunar concrete into structures will be accomplished by new additive manufacturing techniques. NASA partners are already working on the architectural designs for a lunar base camp and developing the automated 3D printers that will be used on the lunar surface to create them. Play the **Lunar Outpost RT Video** (0:30) (QR below)

MISSION GUIDANCE

GO

- Designs must contain necessary areas for a crew of four astronauts. Designs must fit on the cardboard sheet provided
- Teams may use inflated balloons or cardboard scraps to construct the habitat roof

MAYBE

- Faces of Technology: **Meet Diane Linne** (1:00) (QR below)

NO GO

- Using anything besides the provided materials
- Exceeding the size of the floor plan of 12x18 inches

3D Printed Habitats

Lunar Outpost RT Video

Meet Diane Linne

- Balloons
- Extra scraps of cardboard
- Small objects such as marbles, pebbles, or coins
- Sand or gravel

Dough ingredients:

- 2 cups flour
- 1/3 cup oil
- 1 cup salt
- 2 cups cold water
- 4 teaspoons cream of tartar
- Optional: Food coloring (about 20 drops)

Preparation:

1. Group students into teams of three to five. Consider assigning roles and tasks to individual students within the team. Gather and prepare all listed supplies.
2. Make dough ahead of time as a pre-activity following the instructions below:
   - Combine all ingredients and knead until smooth.
   - Store in an airtight container.

** NOTE: Add more water if needed to make the dough more like icing to use in the cake decorating bags.*

3. Explain the challenge below to students:
   - Each team will be designing a habitat capable of sustaining a crew of four astronauts on the lunar surface
   - A 2D footprint of their design will be drawn onto a sheet of cardboard like a floor plan of a house.
     - Their 2D footprint will serve as the template for teams to “3D print” their habitats using simulated lunar cement (dough)
   - The size of the floor plan should not exceed 12x18 inches

Procedure:

1. Ask participants to imagine they will have to live and work in a habitat on the lunar surface in a team of four. Discuss the other types of spaces they will need in their habitat.
2. Ask participants to discuss what their design could look like. Remind them to consider the building process as part of their design. The whole structure must be “3D printed” from the ground up, using the simulated lunar cement (dough). Additional materials, such as an inflated balloon, may be used to support the roof during construction, but must be removed after the structure dries.
3. On sheets of paper, have each team draw plans of what their lunar habitat will look like. The drawing must include an exterior sketch to show its architectural shape and an interior floor plan to show the layout, with the purpose of each room clearly labeled.
4. Using their interior floor plan as a guide, have each team draw their floor plan on a large sheet of cardboard. Ensure the floor plan does not exceed 12X18 inches.
5. Allow participants to retrieve the dough and fill cake bags with approximately one cup of dough, then snip off the end of the bag with scissors.
6. Teams will build their habitat walls, layer by layer, by squeezing dough out of the cake bag along the floor plan they have drawn.
7. Once the teams have reached the maximum heights for their walls, and before they begin adding their roofs, have them pause and decide what they will be using for roof structures. (e.g., balloons could be inflated to create domes, cardboard can be cut to make arches or other shapes).
8. Once the teams have completed the roofs of their lunar habitats, allow them time to clean their workstations.
9. Teams will perform structural tests on their model. Record any damage to the model habitat.
   - Lightly shake the model to simulate a Moon quake
   - Drop a small object such as a marble, pebble, or coin on the model from a height of one meter to simulate a meteor impact
   - Toss a handful of sand and/or fine gravel at the model to simulate debris kicked up from the thrust of a landing or departing rocket

Extensions:

- Explore **In-Situ Resource Utilization (ISRU) and analog field testing**

Challenge Questions:

- What challenges did you face in the design and building of your lunar habitat model? How did you overcome these challenges?
- What was one contribution that each team member made to the project?
- What idea, design, or technique did you implement that was novel or creative?
- What impressed you about another teams’ model?
- Do you think the lunar Habitat in First Woman graphic novel was 3D printed? Why or Why not?

MISSION BRIEFING

Activity 4 - Finding Our Way with VIPER

Prep Time: 20 minutes

Activity Length: 90 minutes

Task: In this robotic challenge, participants experience the processes involved in engineering a communications protocol and learn about the challenges faced while trying to operate a Moon rover. After learning basic programming skills, participants will work in a mission team setting to operate a robotic vehicle while it is not directly in view of the driver or operations team.

By the end of this activity participants will

- Engineer a communications protocol and operate a VIPER rover prototype on a simulated Moon surface to locate various waypoints.

Safety Considerations

- Designate a specific area clear of other hazards or obstructions for the rover obstacle course. Consider using caution tape to protect the course area. Warn other groups nearby before a blindfolded participant begins to navigate the course. Continue to maintain awareness of anyone passing through or working nearby.
- Prioritize safety to prevent accidental falls. If a blindfolded teammate is about to step on an obstacle or may trip over an obstacle provide them with an immediate warning.
- Always have a teammate near the blindfolded teammate while they navigate the course to help correct them before they trip, fall, or step on a "rock sample" or other obstruction

Materials for (optional) Pre-Activity:

- Three blindfolds per team (Can be done without blindfolds - eyes closed etc.)
- Two clipboards and pencils per team
- One piece of blank paper per team
- Objects to represent waypoints and volatiles (i.e., small traffic cones, waypoint cutouts in Appendix B)
- One stopwatch per team
- Painter's tape to outline course and navigate

Preparation:

1. Show the optional VIPER videos below to the students for background knowledge on the mission.
   - **NASA Moon Rover Books Ride to the Moon** (1:57)
   - Ask the following questions:

Activating Prior Knowledge

Ask the participants:

- Have you ever gotten lost because of someone's directions? Maybe because the directions were too complicated, or it was too much to remember.
- What are some ways you can help simplify directions?
- Do you think robot/rovers get confused like humans when directions are not clear? Why or why not?
- Play "**Rover Races**" as an optional pre-activity

Connection to NASA

Launching as early as 2024 as part of the Artemis Program, VIPER is NASA's first lunar mobile robot. VIPER will allow us to determine how to harvest the Moon's resources for future human space exploration and will be a resource prospecting mission on the lunar south pole. VIPER will study several characteristics of the Moon's polar water over the course of its mission. The VIPER mission has two main science objectives. First, to characterize the distribution and physical state of lunar polar water and other volatiles in lunar cold traps and regolith to understand their origin. Second, to provide necessary data on the potential return of resources from the lunar polar regions.

MISSION GUIDANCE

GO

- Time and guidance commands cannot be changed from the original commands the Rover Driver wrote down in Rover Races.
- For every sample collected, subtract five seconds from the rover's time in Rover Races.

MAYBE

- Watch "**Mars in a Minute: How Do Rovers Drive on Mars?**" Mars in a Minute: How Do Rovers Drive on Mars? - YouTube
- To learn more about Rover communications: **Communications with Earth | Mission – NASA Mars Exploration**

NO GO

- Rovers should not leave the boundaries of the course.
- Wheels or feet should not roll over any obstacles. For each wheel fault, add one second to the rover's overall time.
- Teams are not permitted to use "non-computer" language.

Rover Races

How Do Rovers Drive on Mars?

NASA Mars Exploration

- How will VIPER travel to the Moon?
- How will VIPER land on the Moon?

– **NASA is sending a rover to hunt for water on the Moon** (1:09)
– **Tour of NASA Moon Rover South Pole Landing Site** (2:44)
– After watching the videos, discuss the following to develop an understanding of the landing site:
  - Where will VIPER land on the moon?
  - What will VIPER be searching for?
  - Why are we interested in searching for these resources?

2. Divide students into groups of four. Each group will be one rover team consisting of one rover driver, one rover, one timer, and one official.
3. Create a course with painters' tape, waypoint/volatile samples/cutouts, and obstacles prior to beginning. It is suggested to create several identical courses for use in the main activity. (See examples provided in the side notes).

Procedure:(Optional) Pre- Activity: Rover Races

The Rover Driver will walk through the course first, counting the number of steps and listing the turns needed to guide the rover through the course. The driver will record the directions on a "Command Sheet". (e.g., 3 steps forward. Stop. 1 step left. Stop.)

1. The objects on the course are rock and volatile samples that can be collected if the Rover Driver has included this command in their directions. The command would be, "Volatile Retrieval Right" or "Waypoint Retrieval Left". At that command, the Rover participant bends down, still blindfolded, and picks up the object.
2. Once the Rover Drivers have recorded their directions on the "Command Sheet", the rover races can begin. The rovers (the blindfolded students) will line up at the starting line and run the course one at a time. The student is blindfolded to prevent the "rovers" from aiding the Rover Driver while executing the commands.
3. The Rover will proceed along the course by following the Rover Driver's verbal commands. The commands cannot be changed from the original commands the Rover Driver wrote down in Step 1.
4. The Timers will start their stopwatch as soon as the teacher says "start" and will record the time elapsed until their rover crosses the finish line. Their time should then be recorded on the "Official Record".
5. The Official will record any time either a foot of the Rover crosses outside of the track, or steps on an obstacle, as a "foot fault." For each "foot fault," add one second to their rover's final time. The Official will also record every rock sample collected and subtract five seconds from their rover's final time for each collected sample.
6. Upon completion, explain to students how NASA's Mission Control uses computer programs just like these to control their rovers, but in "computer languages."

Materials for Main Activity:

- Remote control rover/car or educational robot for each four-member team (See Appendix A for suggestions)
- Protractor
- Measuring devices (meter stick or tape measure) - two per team
- Cones, cutouts, or similar items for the 'waypoint' markers
- Student calibration and mission planning sheets
- Stopwatches
- Popsicle sticks
- Pencils
- Painter's tape to outline course and navigate
- Calculators (optional)

Preparation:

1. Create a course with painters' tape, waypoint/volatile samples/cutouts, and obstacles prior to beginning. It is suggested to create several identical courses for use in the main activity. (See examples provided in the side notes).
2. Choose two designated drivers (test driver and calibration driver) for each team. The drivers must be prevented from seeing the vehicle course while they are calibrating their rovers
3. Print one set of student data pages per team.

Procedure: Main Activity:

Now that the participants have a basic understanding of programming/coding, lets program an actual robot to visit waypoints on the Moon.

1. Referring to the student worksheets at the end of this lesson, the calibration driver (with the test driver

helping) will calibrate the remote vehicle as to:

a. Distance traveled in five seconds (three distance trials).

b. Time needed to turn in 45˚ increments, a full 360˚.

2. The rest of the team (course calibrators) will work on taking measurements of the course the vehicle will drive through and record their data on the course sheet. Ensure all teams are following the same path so times and accuracy can be compared. (Note: the same course design for each team, but multiple courses, could be set up all at once to speed up the team testing).
3. Have the course calibrating team measure the angle of turn needed to point the remote vehicle toward the next waypoint. (Note: The turns should be made in 45˚ intervals for easier measurement.)
4. Once the drivers and course calibrating team members have finished their tasks and recorded all necessary data, all team members can merge their data sets to create a mission plan scenario. Neither driver should be permitted to see the course the remote vehicle will be driving. This will be a "blind" test. The measured distance to each waypoint can be calculated with the speed and time necessary to achieve each waypoint destination. This should provide adequate driving time for the remote vehicle to travel to each waypoint destination. Time and coordinates should be given for each waypoint direction (i.e., 12 seconds straight. Stop. Left 3 seconds. Stop. 17 seconds straight. Stop. Right 3 seconds).
5. Once the data is calculated, the test driver will have the course calibration team members place the remote vehicle at the designated course starting line. The test driver (who is not in direct eye-contact with the vehicle) will drive the team vehicle according to the mission plan calculations taken from the calibration speed tests and course measurements. A team member can read out the commands and another member can time the remote vehicle's travel.
6. The calibration team members watching the test will measure the resulting movement of the remote vehicle and record the actual distance traveled by the remote vehicle against the pre-measured data.
7. After the actual driving results are compared with the precalculated results, determine the adjustments needed to drive the remote vehicle more accurately and repeat the test to see if progress can be improved.

Extensions:

- Explore additional VIPER resources:
  - **Latest news on VIPER from NASA**
  - **Check out this NASA Collection of Computer Science Activities**
- Allow teams to redesign and improve their strategy for both human and rover challenges, have students perform the simulation in different roles.
- Visualize, explore, and analyze the surface of the Moon using real data returned from a growing fleet of spacecraft using **NASA's Moon Trek**
- Tune into a NASA Downlink or **apply for a downlink experience** just like the students experienced with Callie and the other astronauts from the Moon in the 2nd Issue of First Woman.

Moon Rover Books a Ride to the Moon

Hunt for Water on the Moon

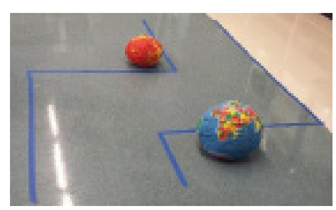
Latest News on Viper From NASA

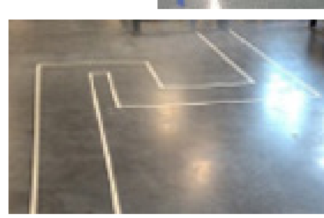
Computer Science Activities

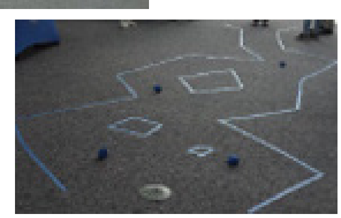
NASA's Moon Trek

Apply for a Downlink Experience

Rover Course Examples:







Team Name:

Calibration Tests:

Using a stopwatch and measuring tool, record the time or distance of the remote vehicle during the following tests. Make sure that all measurements are taken the same way each time and from the same starting place to insure they are accurate. Mark the starting place with a piece of masking tape.

Calibration	Distance or Time
How far did the remote vehicle travel in 5 seconds?	Distance trial #1 = meters
How far did the remote vehicle travel in 5 seconds?	Distance trial #2 = meters
How far did the remote vehicle travel in 5 seconds?	Distance trial #3 = meters
Add the three distances together and divide by 3 (the number of distance trials) to get the average distance the remote vehicle traveled in 5 seconds)	Average distance traveled = meters
Divide the average distance (answer in the box above) by 5 seconds to get the distance per second	Distance per second = meters
	Time needed to turn 45° = seconds Time needed to turn 90° = seconds Time needed to turn 180° = seconds Time needed to turn 270° = seconds Time needed to turn 360° = seconds Time needed to come to a full stop = seconds
Other remote vehicle test data: What else do you want to know? Invent your own test.	My test is:

Team Name:

Student Name:

Directions:

Using your data from the remote vehicle calibration tests and the measurements made by the calibration team, design a mission plan that will get your remote vehicle to each of the targets (waypoints) on the driving course. Use the average speed (meter/second) and the measured course distances (meters) to plan how long your rover will run in each direction to reach each waypoint. Also, figure out how many degrees the rover must turn (how many seconds it takes to turn the right distance from the calibration tests) to go to the next waypoint. List your moves on this sheet.

Remote Vehicle Mission Plan

1. Distance to waypoint #1 =________meters
   Remote vehicle time to waypoint #1 =________seconds
2. Turn ________degrees for next waypoint
   Remote vehicle time to turn ________degrees =________seconds
3. Distance to waypoint #2 =________meters
   Remote vehicle time to waypoint #2 =________seconds
4. Turn ________degrees for next waypoint
   Remote vehicle time to tum ________degrees = ________seconds
5. Distance to waypoint #3 =________meters
   Remote vehicle time to waypoint #3 =________seconds
6. Turn ________degrees for next waypoint
   Remote vehicle time to turn ________degrees =________seconds
7. Distance to waypoint #4 ________meters
   Remote vehicle time to waypoint #4 =________seconds
8. Turn ________degrees for next waypoint
   Remote vehicle time to turn ________degrees = ________seconds
9. Distance to waypoint #5 = ________meters
   Remote vehicle time to waypoint #5 = ________seconds
10. Turn ________degrees for next waypoint
    Remote vehicle time to turn ________degrees = ________seconds
11. Distance to waypoint #6 = ________meters
    Remote vehicle time to waypoint #6 =________seconds

Team Name:

Student Name:

Student Course Calibration and Actual Results of Remote Vehicle Tests

Directions: Fill in the chart with the data your team collected:

1. Record the waypoint measurements taken along the course before the remote vehicle driving test.
2. Record the actual data collected as the remote vehicle runs the course. Were there any differences between the two measurements? If so, record the difference (in feet, inches, meters, or centimeters) in the "Difference in Results" box.

Actual Measurements at Waypoint	Actual Distance Traveled by Remote Vehicle	Difference in Results
Waypoint #1 Measurement:		
Waypoint #2 Measurement:		
Waypoint #3 Measurement:		
Waypoint #4 Measurement:		
Waypoint #5 Measurement:		
Waypoint #6 Measurement:		

Challenge Questions:

- Did your actual test results differ from the calculated distance results? If so, how and why?
- What were the differences in operating the remote vehicle this way (not being able to see the course the rover was navigating) versus just driving the remote vehicle the regular way?
- What changes could you have made to get better results?
- What do you think the hardest challenge would be while driving a remote vehicle on another planet?

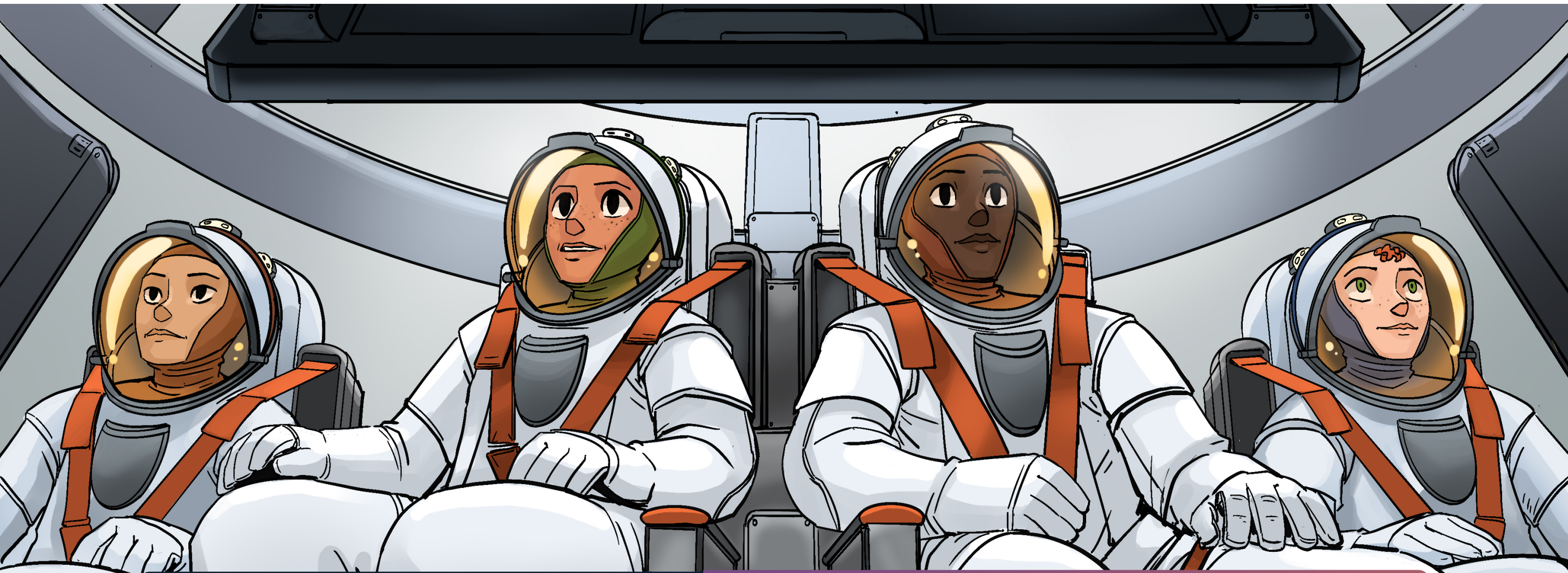
Appendix A

Do you have robots?

- Check to see if you can borrow Educational Robot Kits locally.
  - If your group is at a school, a school district may let you check out a classroom set of robots.
  - Non-school groups may find a community Makerspace that may have loaner sets of robots available. Try this link: **https://makerspaces.make.co/**
  - Check **libraries** for makerspaces.
- Write a grant to purchase your own classroom set of robots. Perform a web search “STEM grants” or “robotics STEM grants” to get started.

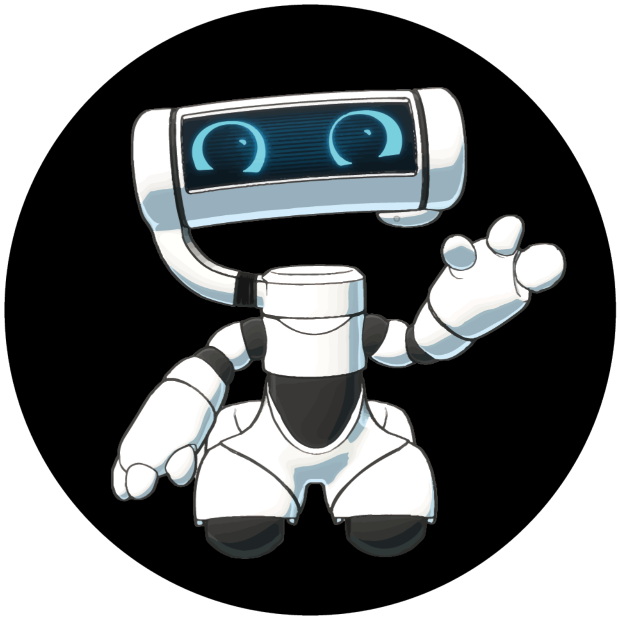
Possible Robots to use

- Remote controlled cars/trucks found at a dollar store
- SPHERO®
- EV3 robot kits
- Lego® Spike Prime kits.



Appendix B

Activity 4 waypoint cutouts



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