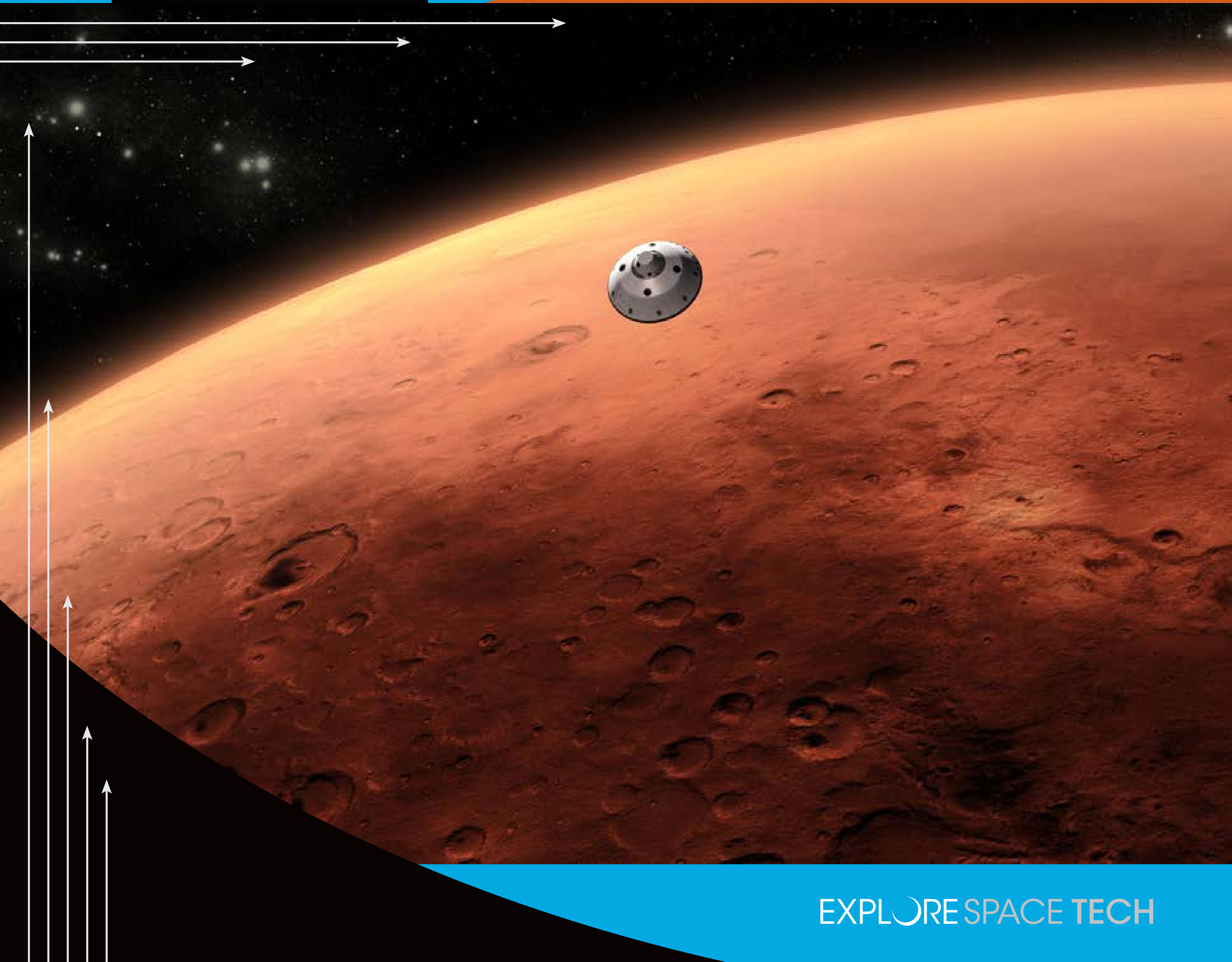
National Aeronautics and
Space Administration

Tech Logic
LESSON SERIES

You Can’t Take It All With You

GRADES K–5

ELEMENTARY
EDUCATOR GUIDE



EXPLORE SPACE TECH

CLASS TIME
2 × 50 min

GROUP SIZE
up to 4

Tech Logic
LESSON SERIES

You Can't Take It All With You

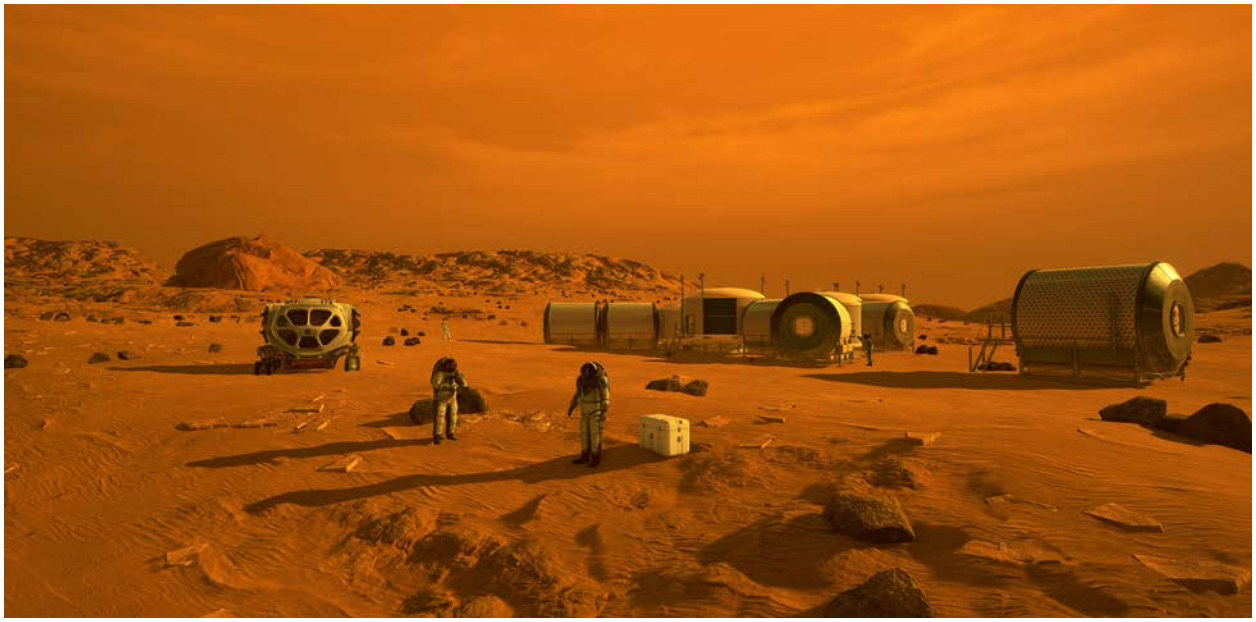
GRADES K–5

ELEMENTARY
EDUCATOR GUIDE

INTRODUCTION

When early settlers first arrived in North America, and eventually moved west, they had to utilize local resources to build settlements and survive. Likewise, NASA's Additive Construction with Mobile Emplacement project (ACME) is exploring how local, or **in situ**, resources can be used to build habitats and structures on other planets. NASA engineers and scientists are developing ways to prepare for human settlement on other planetary bodies, like the Moon and Mars, while limiting the amount of materials needed to be sent from Earth. One major challenge they face is determining the right combination of **regolith** and **binder** material needed to create structures that are ready and safe for astronauts off Earth.

To simulate the ACME project, students will become **materials engineers** by using sand, glue, and water to create "Martian" building bricks. Groups will then become **structural engineers** by designing and building a Martian structure with their bricks. Students can use a limited amount of "Earth-based materials" (wooden craft sticks and aluminum foil) to add strength and stability to their structure. The structure's protective abilities will be tested



by shining a light on the structure to check for leaks. Based on students' math abilities, they can calculate the square footage, perimeter, volume, or other aspects of their structure.

Materials Needed

- Student engineering log (1 per student)
- Play sand, of uniform consistency (approximately 2 cups per group)
- Mixed gravel (approximately 2 cups per group)
- Glue (approximately 1 cup per group)
- Water
- Bowls or cups (several per group)
- Mixing spoons (several per group)
- Ice cube trays, plastic, or silicon (2 per group)
- Petroleum jelly, cooking spray, or plastic wrap to line ice cube trays (optional)
- Wooden craft sticks (several per group)
- Aluminum foil (1 square foot per group)
- Tarp, newspapers, disposable table coverings, or other coverings for work area
- Graph paper (1 sheet per group)
- Writing utensils
- Strong light, such as a flashlight or higher intensity desk light
- Optional: Small human figurines to provide students a sense of scale
- Engagement Activity Cards (1 location card per group)
- Short stories of early American settlers and their use of local resources, which can be found here:
    - *http://www.americaslibrary.gov/about/welcome.html*
    - *https://americanhistory.si.edu/blog/2012/10/conestoga-wagons-and-the-american-frontier.html*
    - *https://learningenglish.voanews.com/a/american-history-series-settlers-rush-to-claim-western-land-90841054/115787.html*
    - *https://www.archives.gov/education/lessons/homestead-act*
    - *http://www.loc.gov/teachers/classroommaterials/presentationsandactivities/presentations/timeline/colonial/indians/*

Time Required

Approximately two 50-minute class periods, plus drying time for Martian bricks (overnight or over the weekend works best). Some bricks can be created ahead of time to shorten activity time. For this option, students can still create their own bricks, but would use the premade bricks for the build portion of the activity.

Engagement Activity: Early Explorers

To begin, ask students what they would need to pack if they went on a trip or vacation. Provide several scenarios that require the students to pack differently (such as staying in a hotel, camping in an RV, backpacking, etc.). Ask students how what they want to bring is different from what early American and western settlers packed.

Divide students into groups, preferably no more than four students per group. Provide each group with an Engagement Activity card (included in this Educator Guide). Each card includes a different location, which requires settlers to bring different supplies and utilize different local resources. Locations include:

- Fairbanks, Alaska (snowy and cold)
- Arizona desert (hot and dry, large rock formations)
- Pacific Northwest (rainy, heavily wooded)
- Rocky Mountains (rocky, mountainous terrain, pine forests)
- Caribbean Islands (warm island environment, rich vegetation)
- Virginia (rich farmland)

Groups will use the assigned location on their Engagement Activity cards to answer questions in their student engineering logs. Students will describe and draw a picture of their assigned territory and list the resources available and materials they would have needed to bring if they were early settlers. Students will then use the graph paper in their student engineering logs to design a small living habitat at their destination, using local resources. You can decide how large students need to make their habitat. You can make this a simple exercise or add more math requirements to this section to increase the complexity. For example, you can ask students to make a 10' × 10' habitat or you can provide a required square footage and allow students to choose specific dimensions.

Students will read stories about early American and western settlers and the materials they brought with them and the local resources they used. In their student engineering logs, students will answer questions based on their assigned reading.

Activity: Using Local Resources

Now that students have learned how previous settlers have used in situ resources, it is time to apply these concepts to space exploration. For this part of the activity, students will work in groups as materials engineers to create their own "Martian bricks." Students can build two different types of bricks: 1) bricks made of sand and glue; and 2) bricks made of sand, rocks, and glue (with water added if desired). The less glue used, the quicker the drying time.

Once bricks are completed and dry, students will use the bricks to build Martian structures intended to protect astronauts. In addition to their bricks, students can add a few materials representing items brought from Earth—wooden craft sticks and aluminum foil—in order to strengthen their structures and better protect their astronauts. As a design challenge, each structure must have one door and one window.

Once completed, students will shine a bright light onto their structures to test the structures' protective abilities. Students will look for any safety breaches where light penetrates the structure.

Note: *This activity is messy! It is advisable to cover tables with newspaper or tablecloths. Bags of sand and rocks can be stored in plastic tubs. A cleanup area is also helpful.*

Preparations

The following materials are needed for each group (recommended group size is up to four students):

- Sand
- Sand and rock mixture
- Glue
- Water (optional)
- Mixing bowls or cups
- Mixing spoons
- 2 lined ice cube trays (can be lined with plastic wrap or greased with petroleum jelly or cooking spray)
- 1 square foot of aluminum foil (for use when building Martian structure)
- Several wooden craft sticks (for use when building Martian structure; decide ahead of time how many sticks you will allow each group to use)
- Strong light source
- Student engineering logs (1 per student)
- Extra graph paper (for use when building Martian structure)
- Small human figurines (optional)

Task 1: Create Bricks for Your Structure

1. Students will mix together sand and glue in order to create a dough-like material. (As previously mentioned, the less glue used, the faster the drying time. Two parts sand to one part glue (2:1) is a good ratio to start with.)
2. Students will record how much sand and glue they used for the first batch of bricks in their student engineering logs.
3. After students record their mixture recipes, groups should spoon the mixture into each well of the first ice cube tray. Each well should be packed tightly in order to make the most compact bricks possible.

4. Groups will set their ice cube trays aside and allow the bricks to dry.
5. Students will create a second batch of bricks, this time using both sand and gravel. Glue or a mixture of glue and water will be used to bind the sand and gravel mixture together.

6. Again, students should record how much of each material is used for the second set of bricks in their student engineering logs.
7. Again, set the ice cube trays aside and allow the bricks to dry.
8. Students will describe their process, including the equipment they used (cups, spoons, bowls, etc.), in their student engineering logs.

NOTE: *Most bricks will take at least 24 hours to dry. It is sometimes helpful to remove sand bricks from the trays when they are partially dry. It can also be helpful to set trays in direct sunlight—warmer environments can help speed up the process. However, be careful not to remove the bricks too early or they may fall apart.*

9. Have students record their observations as the bricks dry in their student engineering logs.
10. Once dry, carefully remove bricks from the ice cube trays (adults may want to help with this, some bricks may be a bit fragile). Groups will analyze the results of the building process and record their findings in the student engineering logs. The analysis can range from simple observation to more quantitative data, such as density.

Task 2: Design and Build Your Shelter

1. To begin, students will work with their groups to design a Martian structure using the bricks they created. Groups will decide on any additional materials they want to use, such as aluminum foil and/or wooden craft sticks, and how these materials will be used. Groups should carefully design their structures to ensure as little light leaks inside as possible. As a design challenge, the structures should have one door and one window. Students will record their materials and draw their structure design in their student engineering logs. Before building begins, have students submit their design to you for approval. Approval will be noted by signing in the space designated in the student engineering logs.
2. Students will work with their groups to construct their Martian structures. No additional glue or other adhesives should be used. If desired, groups can build

their structure on a piece of graph paper, which will allow students to easily calculate the perimeter, square footage, etc.

Task 3: Test Your Shelter

1. Students will shine a bright light on their structures to test for any leaks. Adjustments can be made accordingly before the structure is tested again. Students should record all of their findings in their student engineering logs. Action figures or mini-figures can be used for scale, if desired.
2. If the finished structure is on top of graph paper, as suggested previously in this guide, students can trace the base of their structure and record measurements on the graph paper. If students will be calculating volume, they should measure the height of their structures as well. All measurements should be recorded in the student engineering logs.
3. Groups can share their results with their classmates, as a presentation, tour of each group's shelter, etc. An evaluation rubric is included at the end of this guide, if desired.

Explain

Throughout history, explorers and settlers traveling long distances or for long periods of time could not take everything they needed with them. Instead, they had to rely on local resources in addition to what they carried. Using local, or in situ, resources allows explorers to carry less with them, which reduces weight and costs. This also allows explorers to better adapt to their new surroundings. NASA is looking at ways to use in situ resources when humans travel into space.

Every kilogram of material sent into space requires lots of fuel, takes up valuable cargo space, and usually needs to be replaced by more materials created and prepared on Earth. Once materials arrive in space, astronauts need to unpack and manage these materials. This is why reusability is crucial on the International Space Station and any other off-Earth location. Currently, astronauts on the space station use many Earth-based resources that need to be continuously replenished. Once used, the waste generated from these materials is packaged into a nonreusable cargo vessel and jettisoned from the space station to burn up in the atmosphere.

The space station does have some capabilities to generate and recycle its own products. Water is collected and recycled using two different water recovery systems. In 2010, a Sabatier system was delivered to the space station, which takes "waste" hydrogen and carbon dioxide and produces water. The **Sabatier process**, developed by French chemist Paul Sebatier in the early 1900s, had previously been used in commercial and military applications, but its use in space travel has further reduced astronauts' dependence on deliveries from Earth. This helps pave the way for farther space exploration as well as settlement on planets and moons that may not have a ready supply of water.

For missions to other planetary bodies, such as the Moon and Mars, NASA will need to send even more materials into space. Therefore, more astronauts will be needed to handle these materials. Saving travel time is also an important factor when sending items to space. For example, if astronauts are living and working on Mars, it will take at least 6 months to get a spacecraft there from Earth—astronauts might not be able to wait that long!

NASA's Space Technology Mission Directorate (STMD) and others are working on ways to address these challenges. STMD is developing technologies that allow NASA to use materials more efficiently and effectively, including using in situ resources on other planetary bodies. STMD is also exploring how to use and manipulate materials autonomously, reducing the manpower needed. Imagine a few astronauts traveling to Mars, setting up a system that can start building structures and other foundational parts of a settlement autonomously, and overseeing this system remotely as it prepares for future astronauts to arrive. This is what NASA is working on.

Currently, there is a 3D printer on the space station, which allows astronauts to print materials—such as tools—when needed. The first tool printed aboard the space station was a ratchet wrench in 2014. The wrench was designed on Earth and delivered to the space station as a file, ready for astronauts to print. You can find the wrench file, along with other NASA 3D models, here: *https://nasa3d.arc.nasa.gov/*.

STMD is taking 3D printing, also referred to as **additive manufacturing**, to new levels by creating larger printers for new uses. This includes developing techniques that utilize in situ resources, such as Martian regolith, lunar regolith or Earth-based soils, to 2D or 3D print roads, landing pads, building structures, radiation shelters, and other objects off Earth. For Earth-based projects, islands such as Hawaii can reduce building costs by manufacturing buildings and other structural needs using in situ resources instead of shipping materials to remote locations.

STMD's Additive Construction with Mobile Emplacement project has several goals, including investigating regolith and binder mixtures, demonstrating additive manufacturing for construction, analyzing materials for additive construction on other planets, and providing the first steps for using additive manufacturing in deep space missions.

Differentiation Ideas

- Ask students to calculate square footage, perimeter, and/or the volume of their Martian structure.
- Give students limited design parameters—provide students with limited square footage, perimeter, and/or volume requirements as design constraints.
- Strength test individual bricks and/or completed structures. This can be done by adding items to the top of bricks/structures, blowing a fan at the bricks/structures, subjecting the bricks/structures to a heat lamp, etc.
- For students who may need more support with constructing a building or have motor control issues, prebuilt blocks such as LEGO bricks or other blocks can be used, since they are sturdier and of a more uniform size.

Glossary

In Situ Resources: The collection, processing, storing, and use of materials encountered in the course of human or robotic space exploration that replace materials that would otherwise be brought from Earth.

Regolith: Loose rock, dust, and sometimes soil that is found on top of the solid rock on a planet, moon, or other planetary body.

Binder: Any material or substance that is used to hold other materials together.

Materials Engineer: An engineer who uses and improves existing materials and develops new materials.

Structural Engineer: An engineer who focuses on the design and construction of structures (bridges, buildings, dams, etc.).

Sabatier Process: A process whereby hydrogen and carbon dioxide, under high temperatures and pressures in the presence of a nickel catalyst, produces methane and water.

Additive Manufacturing: Also known as 3D printing, additive manufacturing builds a structure by adding material to a structure, layer by layer, until it is complete.

Evaluation Rubric

	0–1 point	2–3 points	4–5 points	Total Points Earned
Early Settler Habitat	Early settler habitat was missing and/or did not follow location specifications.	Early settler habitat matched location specifications but was inaccurate and/or incomplete.	Early settler habitat matched location specifications and accurately accounted for location needs.	/5
Shelter Design	Students either did not design a shelter or did not follow any design parameters.	Students designed a shelter but did not follow all design parameters.	Students successfully designed a shelter, following all design parameters.	/5
Mathematical Calculations	Mathematical calculations were missing.	Mathematical calculations were incorrect or not completed according to directions.	Mathematical calculations were completed according to directions and were correct.	/5
Shelter Construction and Evaluation	The shelter was not completed and/or the evaluation was missing or incomplete.	Students built their structure and completed their evaluation. However, their shelter was not constructed according to design parameters and/or some of their evaluation was incomplete.	Students successfully built their structure according to design parameters and completed all evaluation steps.	/5
Shelter Improvement Plan	Shelter improvement plan was missing or incomplete.	Shelter improvement plan was included but did not address all required components needed for improvement.	Shelter improvement plan was complete and included all required components.	/5

Engagement Activity Cards

Fairbanks, Alaska

You and your team of explorers are traveling to Fairbanks, Alaska. What do you know about this area? Take a look at the map below and see if you might be able to predict what the weather is like.

Fairbanks, Alaska is often colder than many other places in the United States. There are some streams and rivers in this area. It is classified as subarctic, which means it has long winters and short, warm summers. Fairbanks is considered the coldest city in the United States, with temperatures that are often –40 degrees F (–40 degrees C) in the winter. Each year, Fairbanks averages 65 inches of snow. When the weather is cold, the rivers and streams are frozen.

Arizona Desert

You and your team of explorers are traveling to the Arizona desert. What do you know about this area? Take a look at the map below and see if you might be able to predict what the weather is like.

The Arizona desert is hot and dry and has sand, dirt, and large rock formations. Many summer days reach over 125 degrees F (52 degrees C). However, at night, the temperature can drop by 70 degrees F (21 degrees C). There is very little rain, but watch out for dust storms. Some cacti live in the Arizona desert. You can find animals such as snakes, spiders, scorpions, and lizards there, as they are all equipped to survive the harsh conditions of the desert.

Engagement Activity Cards *(continued)*

Pacific Northwest

You and your team of explorers are traveling to the Pacific Northwest region of the United States. What do you know about this area? Take a look at the map below and see if you might be able to predict what the weather is like.

One of the first things explorers in the Pacific Northwestern region of the United States may notice is the heavy amount of rainfall. Unlike in drier climates, temperatures in this area do not change drastically over the course of the day or during the year. During the warmest month, temperatures are around 79 degrees F (26 degrees C) and cold temperatures are around 45 degrees F (7 degrees C) in winter. Because the weather is warm and rainy, large trees grow there. Over half the land is covered in forests. Lots of shrubs, flowers, and other plants also grow in the Pacific Northwest.

Rocky Mountains

You and your team of explorers are traveling to the Rocky Mountains. What do you know about this area? Take a look at the map below and see if you might be able to predict what the weather is like.

To live in the Rocky Mountains, you must survive in a high elevation. Many mountain peaks in this region are more than 14,000 feet high. Rocky terrain, dense pine forests, and cooler temperatures are typical in the Rocky Mountains, located in the middle of the United States. Lightning storms with lots of rain are common in the summertime. Some higher areas have snow for more than 6 months every year. There are many lakes and streams, along with large fields of grasses and wildflowers. Bears, mountain lions, and other predators live in the Rocky Mountains.

Engagement Activity Cards *(continued)*

Bahamas

You and your team of explorers are traveling to the islands of the Bahamas. What do you know about this area? Take a look at the map below and see if you might be able to predict what the weather is like.

Many islands make up the Bahamas. The temperature most days is between 70–80 degrees F (21–26 degrees C), all year round. Since the islands are surrounded by water, the weather is humid. During the summer, people who live in the Bahamas can expect around 44 inches of rain and need to watch out for hurricanes during hurricane season. Hardwood forests, shrubs, and low trees populate the islands. The coasts are very rocky. Because of the steady, warm temperatures, many different animals live there, too, including iguanas, flamingos, bats, and frogs.

Virginia

You and your team of explorers are traveling to the state of Virginia. What do you know about this area? Take a look at the map below and see if you might be able to predict what the weather is like.

Virginia is known for its nutrient-rich soils and farmland. The state has four distinct seasons, including a warm, humid summer and plenty of rain all year, which makes Virginia a good place to grow crops and raise livestock. Lakes and rivers are found in Virginia. Winters often see snowfall, while summers can reach around 100 degrees F (38 degrees C). Large deciduous trees grow in Virginia. Abundant wildlife allows for hunting deer, rabbits, and many other animals.

Standards

NGSS

1. Scientific and Engineering Practices *(K–5)*
    a. Asking questions and defining problems
    b. Developing and using models
    c. Planning and carrying out investigations
    d. Analyzing and interpreting data
    e. Using mathematics and computational thinking
    f. Constructing explanations and designing solutions
    g. Obtaining, evaluating, and communicating information
2. Crosscutting Concepts *(K–5)*
    a. Cause and effect: mechanism and explanation
    b. Scale, proportion, and quantity
    c. Systems and system models
    d. Structure and function
3. Disciplinary Core Ideas
    a. Physical Sciences
        i. PS1: Matter and its interactions *(2-PS1-2, 5-PS1-3)*
        ii. PS3: Energy *(K-PS3-2)*
    b. Life Sciences
        i. LS2: Ecosystems: Interactions, energy, and dynamics *(K-LS1-1)*
    c. Earth and Space Sciences
        i. ESS1: Earth's place in the universe
        ii. ESS2: Earth's systems *(K-ESS2-2, 3-ESS2-2)*
        iii. ESS3: Earth and human activity *(K-ESS3-1, 3-ESS3-1)*
    d. Engineering, Technology, and Applications of Science
    e. ETS1: Engineering design *(K–2-ETS1-1, 3–5-ETS1)*
    f. ETS2: Links among engineering, technology, science, and society *(K–5)*

Common Core

CCSS-ELA/Literacy

SL.K.3 Ask and answer questions in order to seek help, get information, or clarify something that is not understood. *(K-ESS3-2)*

SL.K.5 Add drawings or other visual displays to descriptions as desired to provide additional detail. *(K-ESS3-1)*

RI.2.3 Describe the connection between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text. *(2-PS1-4)*

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). *(2-PS1-1), (2-PS1-2), (2-PS1-3)*

W.2.8 Recall information from experiences or gather information from provided sources to answer a question. *(K-2-ETS1-1), (K-2-ETS1-3)*

W.3.7 Conduct short research projects that build knowledge about a topic. *(3-ESS3-1)*

W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. *(5-PS1-2), (5-PS1-3), (5-PS1-4), (3-5-ETS1-1), (3-5-ETS1-3)*

CCSSM

MP.2 Reason abstractly and quantitatively. *(K-ESS3-1), (2-PS1-2), (3-ESS2-1), (3-ESS2-2), (3-ESS3-1), (5-PS1-1), (5-PS1-2), (5-PS1-3), (3-5-ETS1-1), (3-5-ETS1-2), (3-5-ETS1-3)*

MP.4 Model with mathematics. *(K-ESS2-1), (2-PS1-1), (2-PS1-2), (K-2 ETS-1), (3-ESS2-1), (3-ESS2-2), (5-PS1-1), (5-PS1-2), (5-PS1-3), (3-5-ETS1-1), (3-5-ETS1-2), (3-5-ETS1-3)*

MP.5 Use appropriate tools strategically. *(2-PS1-2), (3-ESS2-1), (3-ESS3-1), (5-PS1-2), (5-PS1-3), (3-5-ETS1-1), (3-5-ETS1-2), (3-5-ETS1-3)*

5.MD.C.3 Recognize volume as an attribute of solid figures and understand concepts of volume measurement. *(5-PS1-1)*

5.MD.C.4 Measure volumes by counting unit cubes, using cubic cm, cubic in, cubic ft, and improvised units. *(5-PS1-1)*

Resources

http://www.nasa.gov/spacetech

http://homeandcity.nasa.gov

https://www.nasa.gov/mission_pages/station/research/benefits/water_in_space

https://www.nasa.gov/sites/default/files/atoms/files/fs_acme_factsheet_150910.pdf

https://techport.nasa.gov/view/17558

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160013562.pdf

https://www.bradley.edu/challenge/

https://www.cia.gov/library/publications/the-world-factbook/graphics/ref_maps/political/jpg/north_america.jpg

About This Lesson

Author

April Lanotte
Wings Over the Rockies Air & Space Museum
Denver, CO

In collaboration with the

Space Technology Mission Directorate
National Aeronautics and Space Administration
Washington, DC

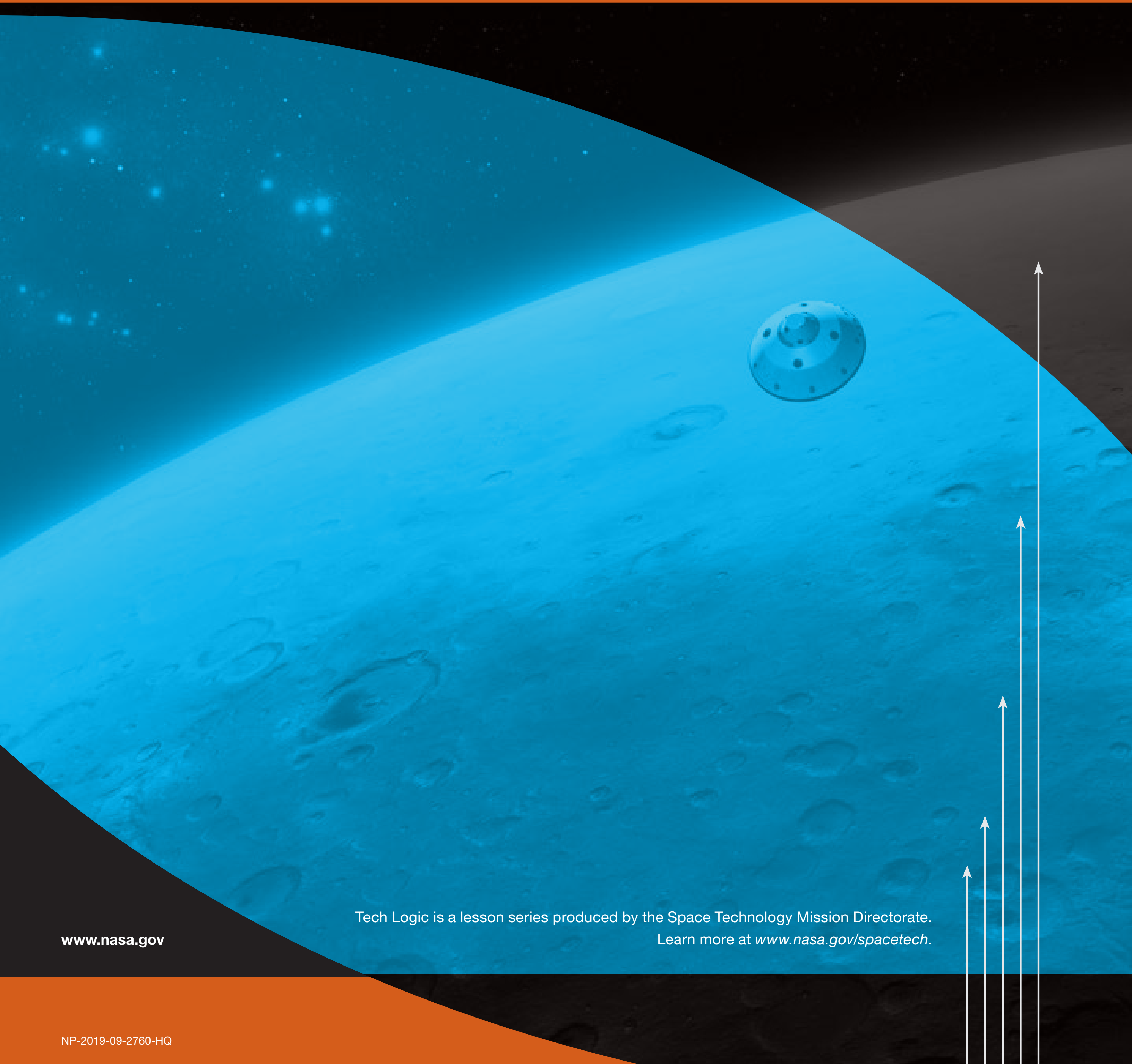
Acknowledgments

Special thanks to the Wings Over the Rockies Teacher Envoys for providing feedback, testing in classrooms, and editing this resource.

Image Credits

Cover: Mars Science Laboratory spacecraft approaching Mars—NASA. Page **1:** Illustration of Mars settlement—NASA. **3–5:** Experimental setup images—April Lanotte/NASA. **6:** 3D printed tool–Made in Space (*https://www.nasa.gov/sites/default/files/ratchet_pic1.jpeg*); **8–10:** Map of North America—*https://mapswire.com/north-america/physical-maps/*; Map of the United States— *https://www.cia.gov/library/publications/the-world-factbook/graphics/ref_maps/physical/jpg/united_states.jpg*. **Back cover:** Illustration of Mars settlement—NASA; Sand mixture in ice cube tray and student building a structure—April Lanotte/NASA; Contour Crafting Robot on the moon—Behnaz Farahi/NASA.

Published January 2020



Tech Logic is a lesson series produced by the Space Technology Mission Directorate.
Learn more at *www.nasa.gov/spacetech*.

www.nasa.gov

NP-2019-09-2760-HQ