PLANETS

Worlds Apart
Engineering
Remote Sensing Devices

Engineering Pathway

Planetary Science Activities for Out-of-School Time • Grades 6–8

Contents

Welcome to Worlds Apart!

In This Unit

In this unit, learners think and work like scientists and engineers. They investigate and use real NASA data about Mars to select a scientifically interesting landing site and design remote sensing devices.

The unit is composed of a Science Pathway and an Engineering Pathway. In both pathways, learners have the opportunity to build their problem solving, teamwork, communication, and creative thinking skills. Specifically, the PLANETS units are designed to ensure that learners will

- engage in real-world activities that provide inclusive ways for all learners to connect to science and engineering.
- choose their path through open-ended challenges that have multiple solutions.
- engage in the habits of mind of engineers and inquiry practices of scientists.
- communicate and collaborate in innovative, active problem solving.

Getting to Know PLANETS

Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (PLANETS) is an interdisciplinary and cross-institutional partnership that integrates planetary science, education, technology, and engineering.

The Center for Science Teaching and Learning at Northern Arizona University (NAU), the U.S. Geological Survey (USGS) Astrogeology Science Center, the Museum of Science, Boston, and WestEd have partnered to develop, pilot, and research the impact of three curriculum units and related professional development resources **(http://planets-stem.org)** for grades 3–8.

The purpose of PLANETS is to increase public awareness and use of NASA resources by highlighting the relationship between science, technology, engineering, and mathematics in the context of planetary science in out-of-school time settings.

Note

Much of the information at the start of this guide is the same for the Science and Engineering Pathways. If you have already read the Science Pathway, you can read just **Learners Working and Thinking Like Engineers,** pg. v, and the **Engineering Pathway Storyline**, pgs. xxiii–xxvi, then skip to the **Engineering Pathway Vocabulary,** pg. 1, and read from there.

Worlds Apart *Unit Overview*

This guide contains the **Engineering Pathway**.

Remote sensing engineering is an interdisciplinary field that deals with the collection of data remotely, or from a distance. Remote sensing engineers use techniques from many fields, such as cartography, optics, civil engineering, software engineering, and computer science. It has a wide variety of applications, from creating models of cities or natural landscapes to helping scientists predict the effects of climate change to precisely tracking orbiting satellites. In this unit, learners engineer remote sensing devices and analyze remote sensing data from Mars to choose a landing site for a rover. The unit contains an Engineering Pathway and a Science Pathway.

DID YOU KNOW?

The latest NASA Mars rover, Perseverance, landed on Mars in February of 2021. However, there have been three prior Mars rovers — Sojourner, Spirit, Opportunity, and Curiosity — starting as early as 1997. These rovers have differed in weight, speed they can travel, and type of instruments they contain based on the type of information they are designed to collect. For more information about these rovers see: spaceplace.nasa.gov/mars-rovers/

Engineering Pathway Overview: *Engineering Remote Sensing Devices*

Remote sensing engineers at NASA design instruments to remotely observe Earth and other planetary bodies by recording characteristics of objects at a distance, sometimes forming an image by gathering, focusing, and recording light. A camera, also called an imager, is a classic example of a remote-sensing instrument.

Learners in the Engineering Pathway (this guide) are part of a team on a fictional NASA mission. They engineer remote sensing devices to gather and visualize information about the surface of Mars. The data they collect will help the scientists meet their scientific goals, such as choosing a landing site that is best suited for gathering data on the geological features of the landscape and looking for evidence of water.

The Engineering Pathway Storyline that more fully articulates the progression of activities can be found on pgs. xxiii–xxvi.

DID YOU KNOW?

Mars has familiar landforms similar to Earth such as river valleys, deltas, and alluvial fans. However, some additional familiar surface features, like volcanoes and canyons, are extremely large on Mars. Mars is home to the largest volcano in the solar system, Olympus Mons. It's three times taller than Earth's Mt. Everest. Also, a large canyon system on Mars, called Valles Marineris, is long enough to stretch from California to New York and is about 10 times the size of Earth's Grand Canyon! These features are examples of the importance of selecting viable landing sites for remote sensing rovers from NASA.

Science Pathway Overview: *Remote Sensing of Mars*

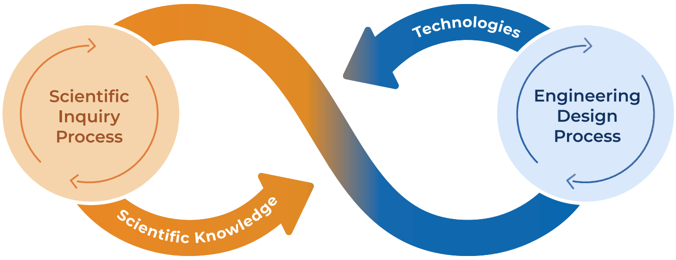
Planetary scientists often use the technologies developed by remote sensing engineers to further their understanding of the planets, satellites, and smaller bodies in the solar system. Engaging in the study of other planets provides scientific insight into the origins of features on Earth.

Learners in the Science Pathway participate in a fictional NASA mission to choose a landing site for a Mars rover. Learners engage with and interpret Mars data captured during actual NASA missions. In these activities, learners explore how scientists use remote sensing techniques to explore the surface of Mars in search of ideal landing sites for rovers. They learn about topography and mineral identification using light, and combine multiple data sets to choose a safe and scientifically interesting landing site for a Mars rover. Ensuring a viable landing site allows scientists to understand habitable environments on Mars and how the planet has changed over geologic time.

The Science Pathway Storyline that more fully articulates the progression of activities can be found on pgs. xxiii–xxvi of the Science Educator Guide.

Connecting Across Science & Engineering

Science and engineering depend on one another. Engineers leverage their scientific knowledge to effectively and efficiently develop new technologies. Scientists rely on a wealth of technologies that have been developed by engineers to advance understanding of the natural world—and their understanding, in turn, helps engineers develop additional technologies.



Scientific inquiry and engineering design require similar skills and practices, such as utilizing critical thinking skills, bringing a lens of curiosity, taking a systems approach, and tapping into creativity to answer questions and solve problems. Neither process follows a set path but both typically rely on similar tools, such as developing models, using mathematics and statistics, and computers. However, scientists primarily focus on understanding natural phenomena through an inquiry-based process, while engineers apply their knowledge, including scientific knowledge, to design and build practical solutions to help solve real-world problems.

The PLANETS curriculum provides equitable opportunities to engage learners in the habits of mind of engineers and the thinking practices of scientists can increase engagement and catalyze STEM identity and confidence for *all* learners. Learning activities that engage learners in the habits of mind and thinking practices of engineers and scientists also fuel development in the 21st Century learning skills of critical thinking, creativity, collaboration, and communication. For more insight into how these skills develop as learners engage in an engineering design process, see the PLANETS educator resource on Developing 21st Century Skills.

Learners Working & Thinking Like Engineers

Engineering Design Process

Engineers use structured processes to design technologies to solve problems. Although the particular steps vary, these processes share many elements, including an investigation of criteria and constraints, the generation of various ideas, and the design, testing, and iterative improvement of a technology. These are Engineering Design Processes, or EDPs.

Many communities and cultures have similar structured processes, from Indigenous medicine wheels to community farming processes. For Grades 6–8, the Museum of Science uses an seven-phase EDP. This EDP and a similar six-step EDP process from NASA are shown below. Optional questions throughout the PLANETS learning activities promote discussion about EDP, and you have the option to have learners build their own EDP or share one from their community.

Examples of Engineering Design Processes

© Museum of Science

Adapted from NASA's BEST Engineering Design Process

Habits of Mind

Habits of mind describe practices engineers use, such as persisting through failure, constructing models, and communicating ideas. The Museum of Science has articulated 19 Habits of Mind, as shown in the table below, that give insight into the type of thinking learners should be engaging in during the hands-on activities.
As learners use these Habits of Mind, they draw on their scientific content knowledge of natural phenomena to inform their choices.

FEEL	THINK	DO
Collaborate effectively	Apply math knowledge to problem solving	Communicate effectively
Persist and learn from failure	Apply science knowledge to problem solving	Construct models and simulations
See themselves as problem solvers	Consider problems in context	Decompose problems
Weigh the implications of solutions	Consider tradeoffs between criteria and constraints	Innovate processes, methods, and designs
	Envision multiple solutions	Investigate features and uses of tools
	Make evidence-based decisions	Investigate properties and uses of materials
	Use abstraction to create efficient solutions	Use computers to solve problems
	Use systems thinking	

Navigating the Unit

For additional resources, please see the [Worlds Apart Unit Website]

Considerations for Using the Worlds Apart Unit

- The following pathways present suggested orders in which to teach the activities. However, you can adapt the order of activities as appropriate for your learners and setting. (For example, you can alternate between pathways.)
- If you have time, it is beneficial for learners to engage in both the Engineering Pathway and then the Science Pathway. Learners do not need to repeat the context-setting or Activity 1.
- It is not necessary for learners to complete the Science Pathway activities to participate in the Engineering Pathway.

CONTEXT-SETTING ACTIVITY: *Ready, S.E.T., Go!*
Learners investigate remote sensing. As scientists, they decide what they want to learn about a planetary body. As engineers, they choose which instruments to put on a spacecraft for that investigation.

ACTIVITY 1: *Sharing Experiences*
Learners share experiences with and stories about technology.

Science Pathway

ACTIVITY 2: *Introducing Landforms*
Learners explore how different landforms are formed by wind and water.

ACTIVITY 3: *Exploring Landforms on Mars*
Learners examine images of landforms on Mars and Earth to find evidence of past water.

ACTIVITY 4: *Introducing Topography*
Learners build three dimensional models of topographic maps and then turn them into two-dimensional maps.

ACTIVITY 5: *Exploring Topography on Mars*
Learners interpret topographic maps of Mars to identify safe and interesting landing sites.

ACTIVITY 6: *Introducing Spectroscopy*
Learners learn to interpret the spectra of reflected light from various objects.

ACTIVITY 7: *Using Spectroscopy to Understand Mars*
Learners interpret spectra to identify water-based minerals at potential Mars landing sites.

ACTIVITY 8: *Choosing a Landing Site and Preparing for Science Share-Out*
Learners combine multiple data sets to choose a safe and scientifically interesting landing site for a Mars rover. They then prepare to share their findings with the whole group and invited guests.

ACTIVITY 9: *Using Spectroscopy to Understand Mars*
Learners share their recommendations for the safest and most scientifically interesting Mars rover landing site.

Engineering Pathway

ACTIVTY 2: *Investigating Light*
Learners investigate how light travels and how mirrors can redirect it to gather data from a dist

ACTIVTY 3: *Portable Light Redirection*
Learners design light redirection systems to gather data from a distance.

ACTIVTY 4: *Finding Minerals*
Learners work to distinguish between minerals using sight and/or sound.

ACTIVTY 5: *Finding the Shape of Land*
Learners engineer a model of a LiDAR technology to capture the shape and height of a landscape (topography).

ACTIVTY 6: *Creating a Remote Sensing Device*
Learners work in groups to plan, create, and test remote sensing technologies that use the different technologies from the previous activities to gather data from a distance.

ACTIVITY 7: *Improving a Remote Sensing Device*
Learners improve their remote sensing devices by making them easier to use, more compact, or better able to gather high-quality data.

ACTIVITY 8: *Preparing for the Engineering Share-Out*
Learners plan to share their designs at an Engineering Share-Out.

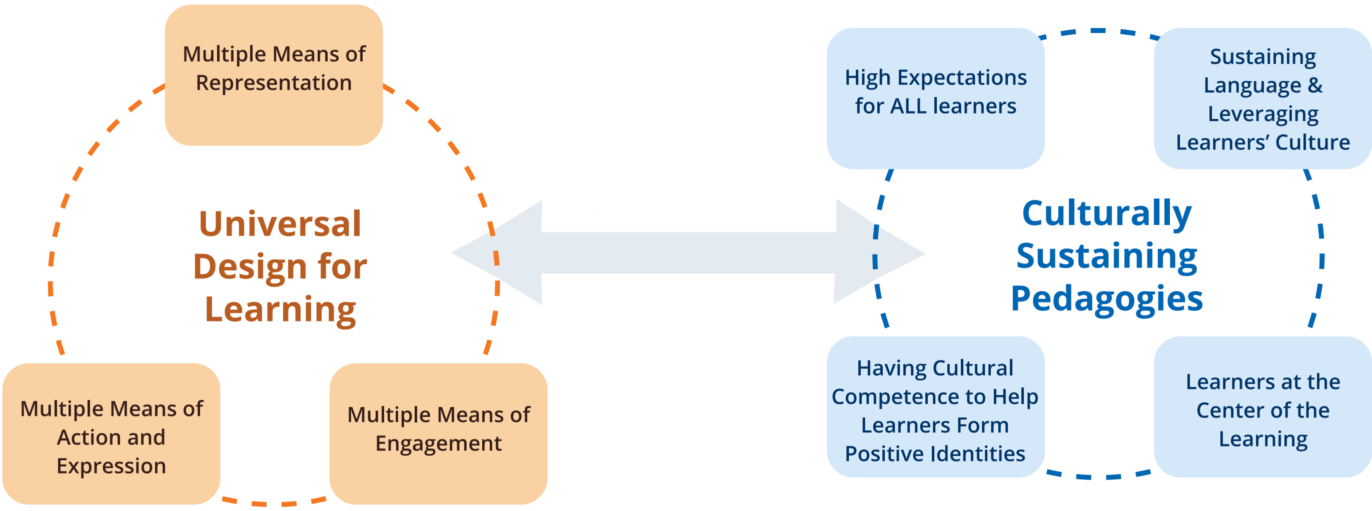
ACTIVITY 9: *Engineering Share-Out*
Learners recommend a remote sensing technology to be sent on a spacecraft.

Educator Resources to Support Learning

An Inclusive and Equitable Approach for STEM Learning

The Worlds Apart unit has been designed with an explicit focus on promoting STEM learning for all, and particularly Indigenous learners, emergent multilingual learners, and learners experiencing differing physical and/or sensory abilities. The Universal Design for Learning (UDL) and culturally sustaining pedagogies (CSP) conceptual frameworks informed the instructional design of this unit. This purposeful design supports all learners by reducing as many barriers as possible and incorporating planning for variability in learner strengths, needs, and interests.

These principles include the following:



Creating Inclusive & Collaborative Learning Environments

To create an inclusive learning environment, educators need to approach their learners with an asset-based mindset. Each learner possesses assets that contribute to the development and maintenance of that person's identity. Assets can be intellectual, physical, or social skills and personal strengths or qualities. A few ideas for cultivating inclusive and cooperative learning environments include the following:

Practices and Strategies for Inclusive Learning Environments

- Facilitate inclusive and cooperative learning environments.
- Build relationships with learners and their communities for learning partnerships.
- Build rapport to establish an emotional connection.
- Affirm the personhood of each learner by appreciating all aspects that they bring into a learning space and creating accessible and inclusive learning spaces.
- Design learning experiences that are authentic and relevant to the contexts of learners.
- Incorporate multisensory instruction.
- Provide options for multiple forms of expression to demonstrate understanding.
- Model and support self-advocacy.

Designing Instruction to Reach Diverse Learners

The strategies outlined below appear in this unit to support three groups of learners:

Multilingual learners: Youth who speak languages other than English at home and are in the process of becoming fluent speakers of English.

Indigenous learners: Youth who descend from the original, culturally distinct ethnic peoples of a land.

Learners with diverse abilities: Youth who experience differing physical abilities: (a) physical traits that affect mobility and/or dexterity; (b) sensory abilities that affect sight; and (c) sensory abilities that affect hearing.

DID YOU KNOW?

Some of these strategies, initially designed and highlighted below for specific learners, have shown potential benefits for all learners.

These strategies have been adapted from the *PLANETS Practical Guide for Inclusive and Engaging STEM Learning: Promoting Inclusion and Engagement in STEM Learning: A Practical Guide for Out-of-School-Time Professionals.*

The icons shown on the following pages appear throughout this guide in tips that are especially relevant for each group of learners.

Strategies for Multilingual Learners

Want to learn more about how PLANETS activities support Multilingual Learners? Please watch this educator support video.

Encourage translanguaging: learners using all the languages they know and making connections between those languages.

Why is this important?

Translanguaging signals to multilingual learners that their languages, culture, and experiences are valued and enrich learning.

It empowers learners to participate and can increase their comprehension and engagement.

Note that not all words have exact counterparts in English.

Strategy in Action

Encourage learners to share key vocabulary in their home or preferred languages. You can capture terms visually.

Note that some learners, including many Indigenous ones, communicate through gestures instead of speech.

Connections to the PLANETS Practical Guide

See Promising Instructional Practices, section 3: "Encourage Translanguaging and Storytelling" on pg. 20 of the **Practical Guide**.

Provide multiple means of accessing language.

Why is this important?

Providing learners enough support and tools (e.g., images, videos, diagrams with headings) to understand texts on their own empowers them to independently make sense of content without compromising the complexity of language.

Instead of simplifying language, amplify speech and text with supports and offer assistance to help learners grasp concepts effectively.

Strategy in Action

Actively listen and capture learners' ideas and use of vocabulary and language during partner, small-group, or whole-group discussions using written words, diagrams and pictures.
In PLANETS, this strategy is called the *Our Ideas Poster.*

Use icons and images to anchor language.

Connections to the PLANETS Practical Guide

See Promising Practices for Program Design, section 1, "Welcoming Learning Environments" on pg. 13 of the **Practical Guide**.

Teach vocabulary in context.

Why is this important?

Exposing learners to vocabulary and concepts together and not separately helps learners make sense of key concepts and ideas.

Strategy in Action

Learners engage in activities and then use their experiences to make sense of vocabulary.

Connections to the PLANETS Practical Guide

See Promising Practices for Program Design, section 1, "Features of Culturally and Linguistically Accessible and Welcoming Learning Environments" on pg. 13 of the **Practical Guide**.

Provide multiple means of expressing ideas.

Why is this important?

Multiple forms of expression, such as spoken, visual, and written, help learners share their understanding of science and engineering, make sense of concepts, and clarify their ideas.

Offering space to use different levels of formality (e.g., casual language from home vs. academic language from school) helps learners make sense of ideas.

Strategy in Action

Share-outs during group activities encourage multiple means of expression. Learners can share in diverse ways (e.g., posters, graphs, writing, drawings, audio, gestures, or videos).

Rather than "correcting" learners' speech, help them connect less-formal and more-formal words with similar meanings.

Connections to the PLANETS Practical Guide

See Promising Curriculum Design Elements, section 3, "Provide options for multiple forms of expression to demonstrate understanding" on pg. 28 of the Practical Guide.

Use strategic grouping.

Why is this important?

Conversations among peers who share languages (e.g., pairs, small groups, or whole-group share-out) provide a safe environment for learners to participate and gain comfort and confidence while testing out ideas. Educators can then build on the ideas expressed in whole-group discussions.

Strategy in Action

Activities engage learners in peer-to-peer conversations and sense-making discussions, including in pairs, small groups, and the whole group, depending on the needs of the learners.

Connections to the PLANETS Practical Guide

See Promising Instructional Practices, section 1, "Facilitate inclusive and cooperative learning environments" on p. 16 of the Practical Guide.

Prioritize precise name pronunciation and understanding.

Why is this important?

Names are important in culture and personal identity. Pronouncing names correctly shows respect for individuals and their culture. (Because different languages use different sounds, it can take practice to pronounce names correctly.)

This approach is particularly beneficial for multilingual learners but creates an inclusive environment for all learners.

Strategy in Action

When meeting new learners, educators are encouraged to ask about, practice, and model pronouncing learners' names correctly.

Connections to the PLANETS Practical Guide

See Promising Practices for Program Design, section 1, "Features of Culturally and Linguistically Accessible and Welcoming Learning Environments" on pg. 13 of the Practical Guide.

Strategies for Indigenous Learners

Want to learn more about how PLANETS activities support Indigenous Learners? Please watch this [educator support video.]

Encourage narratives.

Why is this important?

Indigenous communities have strong narrative traditions. These traditions serve as vital conduits of cultural heritage, transmitting knowledge, values, and history across generations. Through oral narratives, these communities forge a profound connection to their ancestral roots, fostering a sense of identity.

Relating narratives lets learners receive stories and tell their own. Narratives can be spoken, written, in song, or in pictures.

Strategy in Action

Make time for learner narratives that connect their learning to existing knowledge, stories, and culture. The "Building Community and Family Connections" section on p. xvi offers extension activities to engage community and family.

Take time to understand how stories are told in a particular community. Rhetorical style and the expected parts of a narrative vary between groups.

Connections to the PLANETS Practical Guide

See Promising Instructional Practices, section 3: "Encourage Translanguaging and Storytelling" on pg. 20 of the **Practical Guide**.

Use strategic grouping.

Why is this important?

Collaborative decision-making is more effective than individual spotlights in some Indigenous cultures. Small-group rather than large-group work enhances communication for Indigenous learners.

Thoughtful talk is often valued over spontaneous contributions, and delayed engagement may signify politeness rather than disinterest or shyness.

Strategy in Action

Group work is built into each activity. Grouping suggestions provide a comfortable group setting for Indigenous learners and others, such as grouping learners in even numbers to avoid a single designated leader.

Connections to the PLANETS Practical Guide

See Promising Instructional Practices, section 1, "Facilitate inclusive and cooperative learning environments" on pg. 16 of the **Practical Guide**.

Prioritize precise name pronunciation and understanding.

Why is this important?

Names are important in culture and personal identity. Pronouncing names correctly shows respect for individuals and their culture. (Because different languages use different sounds, it can take practice to pronounce names correctly.)

Note that Indigenous learners may want to share other information, such as their connections to tribes and locations.

Strategy in Action

When meeting new learners, educators are encouraged to ask about, practice, and model pronouncing learners' names correctly.

Connections to the PLANETS Practical Guide

See Promising Practices for Program Design, section 1, "Features of Culturally and Linguistically Accessible and Welcoming Learning Environments" on pg. 13 of the **Practical Guide**.

Design authentic and relevant learning experiences.

Why is this important?

Learners are most engaged when what they are learning is connected to their lives and communities. Providing a relevant cultural context helps to drive this engagement.

Strategy in Action

Spend time in learners' community and make connections with local knowledge keepers.

Learn about the cultural approaches of the community regarding competition and collaboration, communication styles, and systems of observation.

Connections to the PLANETS Practical Guide

See Promising Curriculum Design Elements, section 1, "Design learning experiences that are authentic and relevant to the contexts of learners" on pg. 23 of the **Practical Guide**.

Strategies for Learners with Diverse Abilities

Want to learn more about how PLANETS activities support Learners with Diverse Abilities? Please watch this educator support video.

Ask learners what they need.

Why is this important?

The needs of learners with diverse sensory and physical abilities vary. Learners and caregivers, being the most knowledgeable about their capabilities, provide valuable insights. Educators should emphasize learners' strengths and rely on them to guide facilitation of activities.

Strategy in Action

Ask learners directly about their needs prior to beginning an activity. This guide gives some ideas to consider when offering learners options.

Learn about etiquette for working with **blind learners**, etiquette for working with **D/deaf learners**, or etiquette for working with **wheelchair users**.

Connections to the PLANETS Practical Guide

See Promising Practices for Program Design, section 1, "Create safe, accessible, and welcoming learning environments" on pg. 11 of the **Practical Guide**.

Incorporate multisensory activities.

Why is this important?

Visual representations can be particularly beneficial for learners who are deaf or hard-of-hearing. Visual science and engineering models are powerful tools to illustrate observations, processes, and connections.

Auditory modalities of instruction can facilitate access to learners who are blind or have low vision.

Tactile models and physical objects are beneficial for all learners but are particularly important for blind and low vision learners.

Strategy in Action

Learners are given diverse means to participate in activities. For instance, spectrographic information is presented both visually and aurally so that all learners can access it.

Allow blind and low-vision learners to explore pre-made models ahead of time and to join the educator during demonstrations to follow the educator's movements.

Connections to the PLANETS Practical Guide

See Promising Curriculum Design Elements, section 2, "Incorporate multisensory instruction" on pg. 26 of the **Practical Guide**.

Use strategic grouping.

Why is this important?

For blind and low vision learners, although a note-taking role may be a preferred option, provide learners with the flexibility and opportunity to choose from a variety of roles, fostering exploration and skill development.

For deaf and hard-of-hearing learners, group work can be challenging due to elevated noise levels. Engage learners in smaller groups, move groups to quieter spaces, and encourage learners to speak clearly so everyone can follow the conversation.

Strategy in Action

Educators are provided with guidance on **surfacing learners' diverse abilities** through activities.

It's essential to ask individual learners about their preferences and needs, as learners with diverse abilities have widely varying preferences.

Connections to the PLANETS Practical Guide

See Promising Practices for Program Design, section 1, "Create safe, accessible, and welcoming learning environments" on pg. 11 of the **Practical Guide**.

Building Community and Family Connections

Strong relationships are key to learner success. Building community and family connections with learners encompasses having ongoing and meaningful two-way interactions between educators and families and/or other communities of supportive adults. It also involves creating a learning environment within OST (Out-of-School Time) programs that is familial, supportive, and empowering. OST programs with strong learning environments and communities recognize the assets that learners bring and allow learners to express themselves, making them feel comfortable engaging in STEM content. Family connections set the stage for social-emotional learning in the unit via

- **Relevance—**Family connections allow learners to draw connections between NASA science and engineering and the science and engineering in their daily lives and communities. This type of connection allows learners to bring their own funds of knowledge to the activities.
- **Belonging—**When learners see how their cultures and families use science and engineering principles, they feel that they belong in STEM.
- **Cultural responsiveness—**Family connections allow for relevant aspects of learners' cultures to enter or ground the learning in ways that the educator may not have been aware of. Learners' cultural knowledge can play an important scaffolding role in learning science and engineering while simultaneously sustaining that cultural knowledge for the next generation.

What does building community and connections look like in action?

A few examples of how to purposefully develop these relationships with learners and their families include the following:

- **Use a variety of communication methods.**
- **Acknowledge challenges to family and community engagement.**
- **Invite families to engage in and design STEM learning activities.**

Consider using some of the following ways to build family connections during this unit based on your capacity and/or your learners' ability to include family members:

- Add an activity in which you invite families to be guest speakers.
(Families can also work with you to find guest speakers from the community.)
- A Level Up! tip at the end of each activity invites learners to discuss a particular question with their families. (You can also suggest family activities to spark conversation around a particular topic.) Learners can share what they discussed at the start of the next activity.
- Invite families to the Engineering and Science Share-Outs at the end of each pathway to not only share in celebration of their learners' accomplishments but also to provide their knowledge (cultural or otherwise) about the engineering or science discussed and used in the pathway.

Instructional Support Tips for Learning

Within each activity across the Worlds Apart unit, several strategic tips are provided as opportunities for additional instructional support. These tips are guided by the following PLANETS core design principles:

- Support Thinking
- Teaching Tips
- Connecting Across Activities
- Support Learner Differences
- Level Up

The table below provides guidance on the purpose and use of each of the tips found within the activities.

Instructional Support Tip: **Support Thinking** 	**Purpose:** Provides ideas for educators to productively support learners' thinking, such as • suggestions of targeted language to use with learners to increase social emotional supports. • things to emphasize during student collaboration. • language that explicitly helps students to realize they are working, thinking, and looking like engineers or scientists (metacognitive and representation/identity/ confidence in STEM). • additional resources that may enhance student engagement/thinking about the current instructions of the activity (e.g., videos, audio).
Instructional Support Tip: **Teaching Tip** 	**Purpose:** Provides additional recommendations for educators with regards to the mechanics of the activity, such as • modifying materials. • grouping and/or roles of learners during parts of the activity based on materials, timing, and engagement. • additional procedural tips to increase effectiveness of investigations and designs. • modifying timing of activities with different procedures.

Instructional Support Tip: Connecting Across Activities

Purpose:
Highlights ways that the activities connect within the pathways and across the disciplines of engineering and science.

Instructional Support Tip: Support Learner Differences

Purpose:
Provides just-in-time supports during the activity that help educators ensure they are meeting the needs of all STEM learners—especially Indigenous learners, emergent multilingual learners, and learners experiencing differing physical and/or sensory abilities—such as

- ways to support multiple pathways for ensuring all learners can equitably engage in the activity.
- strategic peer grouping(s) to enhance engagement equity.
- additional challenges or ways to increase the learning rigor for learners who are ready.
- additional resources that increase equity to ensure that all learners can engage effectively in the activity (e.g., videos, audio).

Unique icons are used in PLANETS activities to help educators quickly identify specific tips that may apply to their learners:

Multilingual learners

Indigenous learners

Learners with diverse abilities

Engaging all learners

Instructional Support Tip: Level Up

Purpose:
Provides supplemental guidance to educators facilitating activities, such as

- ways to make the activities more inclusive to all STEM learners.
- extensions to broaden both content and options provided within each activity. Note that time estimates for Level Up activities are provided separately from the main activity timing.

References

Elsayed, R., Clark, J. G., Daehler, K. R., & Bloom, N. E. (2022). *A practical guide for out-of-school-time professionals to promote inclusion and engagement in STEM learning*. PLANETS, Northern Arizona University and WestEd.

Inclusion Activities

At the beginning of each activity, you can lead an inclusion activity that is appropriate for your group. Below are some possible activities:

Story of Your Name

In pairs or small groups, have learners share their names and stories behind them. For example, what do they mean? Why were they given? Have learners share other important information about their identities, such as locations they are from and tribes or other groups they belong to.

Handshakes and High Fives

Play three rounds of this inclusion activity. Each round, have learners pair up and introduce themselves in some way (e.g., handshake, high five, elbow bump, dance, nod, codeword). Then ask a question and have them discuss it for one minute. Once learners have completed all three rounds, have them re-find their three partners in order and repeat the introduction for each.

Paper Toss

Give each learner a piece of paper and a writing utensil. Ask a question and have them write an answer on the paper (for example, What is your name? What do you do for fun?) Have learners crumple the papers and throw them around. Then have them uncrumple the papers and share the answers with the group.

Choose an Object

Lay out a set of objects, such as small figurines, playing cards, or craft supplies. Ask a question (for example, How is your day going? What is a strength you bring to the group?) and have each learner choose an object that represents their answer (for example, *I chose the owl because I am good at watching what is happening*). Have learners share their objects and answers in pairs or small groups.

Interviews

Have learners pair up and spend three minutes each interviewing each other, then have them share about their partners in a large group. Possible interview questions include the following:

- What is your favorite place to hang out that is not school or home?
- What are some things you are good at?
- What tools or machines do you know how to use?
- What languages do you speak at home?
- What is something you did this week with someone else?
- How do you like to express yourself?

Accessibility Check

Have learners go around a circle and share their names and access needs. Access needs are things they might need to fully participate and feel comfortable in an activity or space. They can be anything that helps people learn, communicate, move around, or feel safe and included. As needed, share first yourself and give some examples, such as “I need short breaks during long activities to stay focused,” “I need to refill my cup of water,” “I feel more comfortable lying on the floor,” or “I need pictures to help me understand what we are learning.” Learners can also say “I’m still thinking about my access needs” or “All my access needs are met, check.” Note that learners may not be comfortable sharing their needs until after several days of participation.

Design a NASA Mission Patch

NASA mission patches are special symbols that tell the story of each space mission. They use pictures, colors, and symbols to show the mission’s goals, who the astronauts are, and important parts of the crew’s lives. Have learners form groups of three, choose a mission name, choose a patch shape, and draw or write three things to include on their patch. Patches can include meaningful images, symbols, and colors. As needed, show examples from **NASA’s Human Spaceflight Mission Patches.**

Transition

Say:

Let’s talk about why we did this. Inclusion isn’t just a nice idea–it’s crucial for success, both here and in the real world. At NASA, every astronaut needs to know their team well. Why? Because in space, your crew is your lifeline. Similarly, in our group, everyone matters. We learn better when we understand each other. Knowing our teammates helps us work together and solve problems. By sharing parts of ourselves, we build trust and respect. This makes our “mission”—learning together—more fun and more effective. Remember, great teams are built on understanding and appreciating each person’s unique strengths.

Conclude by connecting the inclusion activity to what learners are doing next. For example, say:

You just made different partners. Now you are going to work with one of those partners to...

Intentional Grouping Strategies

Intentional Grouping can support learners in a variety of ways.

Group roles can play to learners' **diverse abilities and strengths**. For instance, a blind or low vision learner might be much more skilled at tactile or auditory tasks, and having a role that plays to this strength will elevate that learner and strengthen the group. Never assume which tasks learners will prefer, because they can feel othered and misunderstood. Give them the first choice of group roles.

Grouping learners with **similar spoken or signed languages** can help multilingual learners bounce ideas off each other in their native language before translating them for the whole group. This will also help learners decide what words to share in their native languages.

Grouping learners by **culture** can allow them to work through things in ways that are familiar and valued at home before sharing with the larger group. For instance, Indigenous learners might benefit from being grouped together and working by consensus rather than by having a leader. Or they may decide to communicate their final challenge on posters during a gallery walk, rather than by presenting publicly.

Similarly, if learners are grouped by **shared interests or hobbies**, they may start to interpret the learning in the context of what they know, which is fantastic! For example, "We mitigate hazards when biking all the time by slowing down, wearing helmets, and not biking when it's dark outside."

The number of learners in a group

Groups of 2: If students are sharing personal information or stories, working in pairs first gives learners an opportunity to hear other ideas and rehearse their own ideas before sharing with the whole group. Pairing up is especially helpful for multilingual learners.

Groups of 4: Use groups of four when learners would benefit from lots of perspectives or ideas.

Please note, *these activities are not designed for groups of five or more. A group of five would likely have an outlier with not enough to contribute.*

Engineering Pathway Storyline

Engineering Activities 2–5
Learners experience different technologies used in remote sensing so they are successful in the final design challenge.

Engineering Activities 6–9
Learners apply what they have learned in the prior activities about remote sensing as they design, test, and improve their own devices.

CONTEXT

CONTEXT SETTING ACTIVITY – *Ready, S.E.T., Go!*

ACTIVITY OVERVIEW
Learners design spacecraft to gather data about Mars. As scientists, they choose a mission. As engineers, they figure out which instruments to send on the mission.

Prep Snapshot

Prep Time: 60min

- Read unit
- Print Notebooks
- Cut out instruments.
- Make *Our Ideas* Poster

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection
- Critical Thinking

Habits of Mind
- Use a structured problem-solving process

Science Practices
- Planning and conducting investigations

Connecting Across Activities

Today, learners design spacecraft to gather data about Mars. As scientists, they choose a mission. As engineers, they figure out which instruments to send on the mission.

Next time, learners share experiences with, and stories about, technology.

1

ENGINEERING ACTIVITY 1 – *Technology Stories: Sharing Experiences*

ACTIVITY OVERVIEW
Learners share experiences with, and stories about, technology.

Prep Snapshot

Prep Time: 30 min

- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection
- Communication

Habits of Mind
- Communicate effectively

Connecting Across Activities

Last time, learners designed spacecraft to gather data about Mars. As scientists, they chose a mission. As engineers, they figured out which instruments to send on the mission.

Today, learners share experiences with, and stories about, technology.

Next time, learners investigate how light travels and how mirrors can redirect light to gather data from a distance.

2

ENGINEERING ACTIVITY 2 – *Lighten Up! Investigating Light*

ACTIVITY OVERVIEW

Learners investigate how light travels and how mirrors can redirect light to gather data from a distance.

Prep Snapshot

Prep Time: 30 min

- Set up Materials Table
- Set up sample obstacle course

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Critical Thinking

Habits of Mind

- Use systems thinking
- Investigate properties and uses of materials

Connecting Across Activities

Last time, learners shared experiences with, and stories about, technology.

Today, learners investigate how light travels and how mirrors can redirect light to gather data from a distance.

Next time, they will design portable light redirection systems. These systems are one technology they can use when designing their complete remote sensing technologies.

3

ENGINEERING ACTIVITY 3 – *Looking Beyond: Portable Light Redirection*

ACTIVITY OVERVIEW

Learners design portable light redirection systems to gather data from a distance.

Prep Snapshot

Prep Time: 30 min

- Create a sample light redirection system
- Create a tactile light redirection system model
- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Critical Thinking

Habits of Mind

- Use systems thinking
- Investigate properties and uses of materials

Connecting Across Activities

Last time, learners investigated how light travels and how mirrors can redirect light to gather data from a distance.

Today, they design portable light redirection systems. These systems are one technology they can use when designing their complete remote sensing technologies.

Next time, they will explore the properties of filters and scrapers to gather more data, specifically about minerals.

4

ENGINEERING ACTIVITY 4 – *Hide and Seek: Finding Minerals*

ACTIVITY OVERVIEW

Learners work to distinguish between minerals using sight and/or sound.

Prep Snapshot

Prep Time: 35 min

- Print and cut materials
- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Collaboration
- Communication
- Critical Thinking

Habits of Mind

- Innovate processes, methods, and designs
- Investigate properties and uses of materials

Connecting Across Activities

Last time, learners designed portable light redirection systems. These systems are one technology they can use when designing their complete remote sensing technologies.

Today, learners explore the use of filters and scrapers to gather more data, specifically about minerals. These tools are a second technology they can use when designing their complete remote sensing technologies.

Next time, they will design straw model LiDAR systems to gather data on a new subject: topography. These systems are a third technology they can use when designing their complete remote sensing technologies.

5

ENGINEERING ACTIVITY 5 – *Taking Shape: Finding the Shape of the Land*

ACTIVITY OVERVIEW

Learners engineer a model of a LiDAR technology to capture the shape and height of a landscape (topography).

Prep Snapshot

Prep Time: 30 min

- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Collaboration
- Creativity

Habits of Mind

- Construct models and simulations
- Investigate properties and uses of materials

Connecting Across Activities

Last time, learners explored the use of filters and scrapers to gather more data about minerals. These tools are a second technology they can use when designing their complete remote sensing technologies.

Today, learners design straw model LiDAR systems to gather data on topography. These systems are a third technology they can use when designing their complete remote sensing technologies.

Next time, they will combine tools and systems from previous Activities and use their engineering design process to design and test remote sensing devices.

6

ENGINEERING ACTIVITY 6 – *Put It Together: Creating a Remote Sensing Device*

ACTIVITY OVERVIEW

Learners work in groups to plan, create, and test remote sensing devices that use the different technologies from the previous activities to gather data from a distance.

Prep Snapshot

Prep time: 60 min

- If you have not yet done so, create model landscapes and (optional) Space Screens
- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Critical Thinking
- Collaboration

Habits of Mind

- Consider problems in context
- Weigh the implications of solutions

Connecting Across Activities

Last time, learners designed straw model LiDAR systems to gather data on topography. These systems are a third technology they can use when designing their complete remote sensing technologies.

Today, learners combine tools and systems from previous Activities and use their engineering design process to design and test remote sensing devices.

Next time, they will use what they learned from testing to improve their devices.

7

ENGINEERING ACTIVITY 7 – *The Final Test: Improving a Remote Sensing Device*

ACTIVITY OVERVIEW

Learners work in groups to plan, create, and test remote sensing devices that use the different technologies from the previous activities to gather data from a distance.

Prep Snapshot

Prep time: 35 min

- Copy Share-Out invitations
- Set up Space Screens
- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Critical Thinking
- Collaboration
- Creativity

Habits of Mind

- Make evidence-based decisions
- Persist and learn from failure

Connecting Across Activities

Last time, learners combined tools and systems from previous Activities and used their engineering design process to design and test remote sensing devices.

Today, learners use what they learned from testing to improve their devices.

Next time, they will plan to share their designs at an Engineering Share-Out.

8

ENGINEERING ACTIVITY 8 – *Spread the Word: Preparing for the Engineering Share-Out*

ACTIVITY OVERVIEW

Learners recommend a remote sensing device to be sent on a spacecraft.

Prep Snapshot

Prep Time: 40 min

- Set up Space Screens
- Set up Materials Table

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Collaboration
- Communication

Habits of Mind

- See themselves as problem solvers
- Make evidence-based decisions

Connecting Across Activities

Last time, learners used what they learned from testing to improve their devices..

Today, learners plan to share their designs at an Engineering Share-Out.

Next time, they will meet with community members at the Engineering Share-Out to have conversations about their designs and remote sensing.

9

ENGINEERING ACTIVITY 9 – *Sum It Up: Engineering Share-Out*

ACTIVITY OVERVIEW

Learners present their recommendations about remote sensing devices.

Prep Snapshot

Prep Time: 40 min

- Set up Space Screens
- Set up Materials Table
- Invite community members

* See *Materials & Preparation* for more information

Skills, Habits, Practices

21st Century Skills Connection

- Collaboration
- Communication

Habits of Mind

- See themselves as problem solvers
- Make evidence-based decisions

Connecting Across Activities

Last time, learners planned to share their designs at an Engineering Share-Out.

Today, learners have conversations about their designs and remote sensing.

Next time, learners experience the science of this topic in the PLANETS Worlds Apart Science Pathway (optional).

Engineering Pathway Vocabulary

This list is included to provide an overview of the content of this pathway. Note that you should not pre-teach it to learners before the activities–terms are introduced after learners have direct experience with the materials and processes to which those terms are connected.

Ready, S.E.T., Go!

- **Composition**: what a surface is made of
- **Constraints**: limits on a design
- **Criteria**: things a successful design needs to do or have
- **Fairing**: the part that sits on top of the rocket and protects a spacecraft during launch
- **Physical properties**: the shape and texture of a surface
- **Resolution**: the amount of detail in an image
- **Technology**: an object, system, or process designed by people to solve a problem

Engineering Activity 2

- **Habitable:** could once have supported some kind of life
- **Obstacle**: thing that might be in the way
- **Redirect**: to change the direction of
- **System**: a group of parts that work together

Engineering Activity 3

- **Filter**: a technology for blocking certain things and letting other things through
- **Remote**: far away or distant
- **Sensing:** collecting or becoming aware of information
- **Remote sensing:** collecting information at a distance

Engineering Activity 4

- **Mineral:** a naturally occurring crystal formed by geologic processes, with a specific chemical composition. Rocks are made of one or more types of crystal.

Engineering Activity 5

- **Bird's-eye view**: a perspective from above
- **LiDAR**: light detection and ranging, a technique using lasers to measure distance
- **Topographic map**: a representation of the shape of land in an area
- **Topography**: the shape of land in an area

Teaching Tip

No new vocabulary terms are introduced to learners in Engineering Activities 1 or 6–9.

Engineering Materials List

The quantities below are for one group of 24 learners. Follow this weblink to calculate the amount of materials you'll need for your number of learners.

Non-Consumable Items

Quantity	Material
1	Engineering Design Process poster (PDF) (optional)
1 set	pattern blocks, 100 (optional)
1	utility knife
6	rulers
7	small boxes or stacked textbooks for obstacles in Activity 2
12 pairs	scissors
50	flat mirrors, approx. 2.5" × 3.5"
100	binder clips, medium, 5/8" capacity, 1 1/4" width
1+	pin screens (optional)
6	protractors (optional)

Consumable Items

Quantity	Material
1 pad	chart paper
1 bottle	white glue
4	shoeboxes with lids, 7" × 5" × 12"
4	tri-fold boards, 48" × 36"
6 packs	crayons, 8 assorted colors
6 packs	markers, 8 assorted colors
6	plates, paper, small
6 sheets	styrofoam, 12" × 12" × 1"
12 rolls	tape, masking
24 sheets	cellophane, blue
24 sheets	cellophane, red
24	Engineering Notebooks
45	cups, paper, 3 oz
50 sheets	craft foam
55	cups, paper, 8 oz
60 sheets	felt, 9" × 12"
75	manila folders
120	craft sticks
120 sheets	paper
120	rubber bands, 3" × 1/8"
140	pipe cleaners / fuzzy sticks
150	index cards
4000	straws, regular
4000+	straws, thin The thin straws used in this unit are commonly called coffee stirrers or cocktail straws and are typically 1/8" in diameter.

Engineering Advance Preparation

You can complete much of the preparation for the Engineering Activities ahead of time. Follow the steps below.

Educator Background

1. Read through the entire PLANETS Engineering Pathway Educator Guide Introduction, pgs. iii-xxvi, to learn more about the engineering content in this unit.
2. View the following video playlists:
   - How to prepare and teach with the materials
   - Background science and engineering content
   - How to support learner differences
3. Print and laminate any pages you want available for easy reference. (The Inclusion Activities, pgs. xx-xxi, Intentional Grouping Strategies, pg. xxii, and Pathway Storyline, pgs. xxiii-xvi, are especially useful.)
4. Consider printing all handouts at once from the Remote Sensing website page.
5. Print a copy of the Notebook for reference.
6. Reflect on the learners who will engage in the pathway and identify ways to create an inclusive and collaborative learning environment (pg. viii).
7. Read through the instructions for Model Landscape Assembly, pgs. 85-87 and Space Screen Assembly, pgs. 88-89. You can also watch a video about how to build the model landscapes. Then decide whether to use the Space Screens. This activity should be safe and inclusive. Use the Space Screens only if learners can reach through them safely. Make the choice that is best for your group but still allows all learners to gather data "remotely."

For the Whole Group

8. Invite staff, family, and community members to attend the Engineering Share-Out in Activity 9. Make copies of the Engineering Share-Out Invitation, pg. 96. Distribute this directly to caregivers and emphasize it is an opportunity for learners to celebrate and share what they have learned.
9. Prepare an *Our Ideas* poster by following the Prep & Setup Guide. Poster components and examples are provided for Ready, S.E.T. Go! (PDF) and for the rest of the Units (PDF). You can build your own poster with blank paper and markers if you don't have access to a printer.
10. If you are using mirrors for the first time, remove plastic film from them.
11. Create a sample light redirection system following the instructions in Create a Light Redirection System, pgs. 42-43. See the video on How to Build a Light Redirection System for additional support.
12. Bundle a handful of straws together using a rubber band and craft foam to demonstrate one way learners can keep the straws packed together in their model LiDAR device (see pg. 69).
13. Prepare the model landscapes, pgs. 85-87 and, if appropriate for your group, the Space Screens, pgs. 88-89. There should be two models each of Site A and Site B, one behind each Space Screen, so multiple groups can access them during testing. (If your group is small, you will need only one model of each site.)

14. To further support learners' understanding, it may be important to offer additional visual and audio support. Review the resources from the Activity Resources (weblink) and decide which you would like to have available.

For Each Group of Learners

15. Print 1 copy of each of the following handouts for each group of 4 learners:
    - Engineering Ready, S.E.T., Go! Visual Instructions Handout, p.18
    - Redirecting Light, pg. 36
    - Set Up an Obstacle Course, pg. 37
    - Investigating Light Constraints and Criteria, pg. 38
    - Create a Light Redirection System, pgs. 42-43
    - 4–5 Data Collection Grids, pgs. 62-63
    - Test Sites (both Blue and Red), pgs. 60-61. Print in color and cut along the lines to provide 4 blue quarter-sheets and 4 red quarter-sheets.
    - Pins and Pings, pg. 76

For Half the Groups

16. Print out Sound Model Directions, pg. 64, for half the groups and Light Model Directions, pg. 65, for half the groups.

17. Assemble the following materials into bags so that there are enough for half of the learners to have materials for Sound Exploration and half to have the materials for Light Exploration. If you have 24 learners, there should be three bags for sound exploration and three bags for light exploration.

Sound Exploration Materials

- 2 pieces of felt
- 2 pieces of craft foam
- 2 pieces of paper
- 2 craft sticks
- 2 large straws
- 2 small straws

Light Exploration Materials

- 4 blue test sites
- 4 red test sites
- 2 pieces of red cellophane
- 2 pieces of blue cellophane

Teaching Tips

- If Internet access may be a problem, consider downloading videos ahead of time. If it would benefit your learners, you can adjust the video playback speed. Note that video links may change over time; if a link does not work, try searching the title of the video.
- If you think learners will benefit from having more space in the Notebook, print one-sided or add sheets of blank paper as you make the Notebooks.

Support Learner Differences

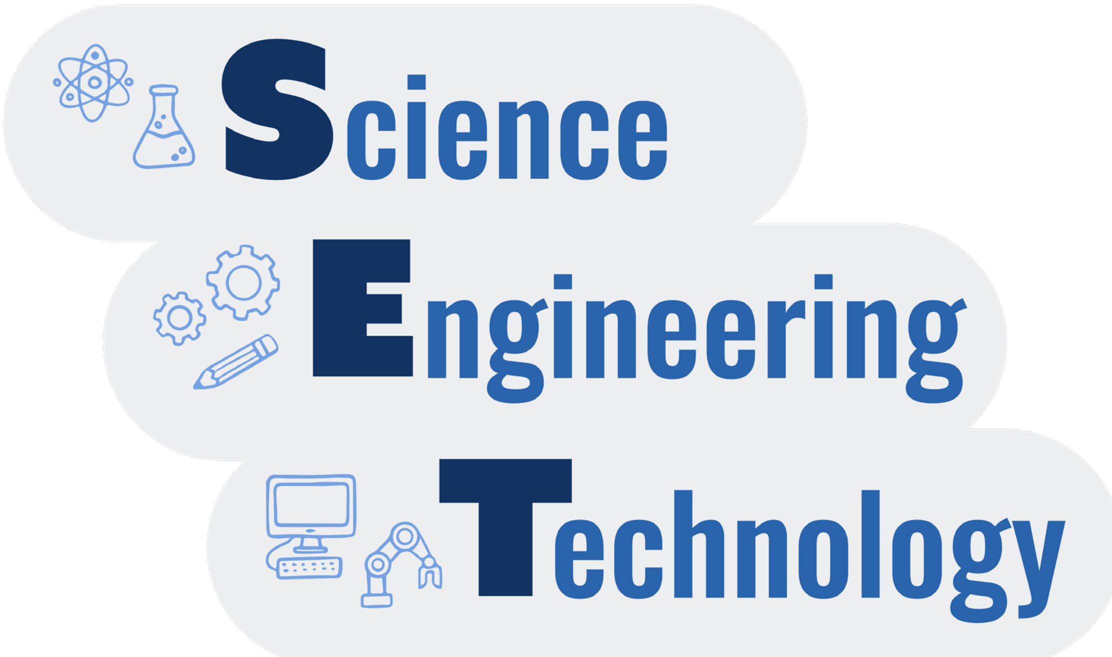
All videos in this unit include captions. As needed, these captions can be translated by online video platforms.

For Each Learner

18. Print and staple one Engineering Notebook (PDF) for each learner, in color if possible.

Educator Guide

Ready, S.E.T. (Science, Engineering, Technology), *Go!*



Educator Preview

Activity Snapshot

Learners design spacecraft to gather data about Mars. As scientists, they choose a mission. As engineers, they figure out which instruments to send.

Timing | 45 minutes

Get Ready & Team Up	10 min.
Plan & Create (S.E.T.)	25 min.
Reflect (Go!)	10 min.
Total	**45 min.**

Level Up Activities 5–30 min. each

Prep Snapshot*

Prep Time 60 min.

- Read unit.
- Print Notebooks.
- Cut out instruments.
- Make an *Our Ideas* poster.

**See Materials & Preparation for full info.*

21st Century Skills

Connection

- Critical Thinking

Habits of Mind

- Use a structured problem-solving process.

Science Practices

- Planning and Conducting Investigations

Guiding Questions

Which survey mission should we send to Mars?

What instruments does a spacecraft need for it?

Learners Will Do

As scientists, choose a type of mission. As engineers, choose and arrange instruments for that mission.

Learners Will Know

Scientists and engineers can work together to solve problems.

Connecting Across Activities

Ready, S.E.T., Go!	Activity 1: Sharing Experiences
Today, learners design spacecraft to gather data about Mars. As scientists, they choose a mission. As engineers, they figure out which instruments to send on the mission.	**Next time**, learners share experiences with, and stories about, technology.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/62c6fd93

Materials and Preparation

Materials

For the educator

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF) Examples | Templates
  - index cards
  - markers
  - scissors
  - tape

For each group of 4–6

- Cutouts from Fairing and Instruments Sheets, pgs. 14-17
- Engineering Ready, S.E.T., Go! Visual Instructions Handout, p.18

For each learner

- Engineering Notebook (PDF)

Ready, S.E.T., Go! Materials Preparation (60 min.)

Ahead of Time

1. Read through the entire PLANETS Engineering Pathway Educator Guide to learn more about the engineering content in this unit.
2. Read the Educator Background (weblink) for context about the science and engineering in the unit.
3. Print and staple one *Engineering Notebook* for each learner, in color if possible. As needed, prepare to share the Notebook digitally.
4. Print a copy of the Notebook for your own reference throughout the pathway.
5. Prepare an *Our Ideas* poster by following the online Prep & Setup Guide - Examples (PDF). Add the Guiding Question "Which survey mission should we send to Mars? What instruments does a spacecraft need for it?" so learners can refer to it throughout the activity.

Teaching Tip

This activity is the same in both the Science and Engineering Pathways. If you have already taught it in one pathway, you do not need to teach it again.

This activity can stand alone as a brief single-session program.

Support Learner Differences

- The *Engineering Notebook* can be printed in large font and you can share a digital version that will work with screen readers. The Notebook is written in English, but you can translate the instructions into other languages ; see translation guidance in our Translatable Glossary (DOCX).
- If you think learners will benefit from having more space in the Notebook, print one-sided or add sheets of blank paper as you make the Notebooks.

Teaching Tip

You can begin the *Our Ideas* poster with several standard 23" × 32" pieces of chart paper. If you fill them up before the end of the pathway, add more pieces. See the weblink for *Our Ideas* Examples in the Prep & Setup Guide (PDF).

The *Our Ideas* posters capture students' authentic language and ideas as they emerge in real-time discussions. The posters are not meant to simply display and front-load vocabulary. The posters develop over time as the educator listens for and adds the language that learners use in the moment, thus validating their ideas, providing feedback and supporting sensemaking and language development.

Support Learner Differences

Different learners have different needs. Choose from the following tips to best support your learners:

- View the Translanguaging Video to support learners who speak multiple languages.
- For those with low vision: add tactile elements, such as three-dimensional representations and Braille. Prepare a shared digital document all learners can access, ensuring that it supports text-to-speech for your learners.
- Add learner questions to the *Our Ideas* poster to foster an interest-led approach.

6. Cut out one set of instruments from the Fairing and Instruments Sheets, pgs. 14-16 for each group of 4–6 learners. Cut around the edges of the instruments themselves, not around the edge of the rectangles.

7. Print one Instruments Key, pg. 17 for each group of 4–6 learners.

8. Print one Engineering Ready, S.E.T., Go! Visual Instructions Handout, pg. 18, for each group of 4–6 learners.

In Your Space

9. Place the *Our Ideas* poster in a location all learners can access. Make a plan to store it between activities.

Support Learner Differences

If it will support your learners, consider making the following modifications to each instrument:

1. Punch out the white circle to indicate the top center.

2. Attach dots to indicate the relevant levels of communication, weight, and power: one dot if the feature does not appear, two dots if it is a low value (e.g., low power, low weight), and three dots if it is a high value (e.g., high power, heavy).

3. Attach a Braille sticker over the instrument number to indicate that number (e.g., "S4").

4. Print an extra Instruments Key, pg. 17, cut out the information for that item, and tape it to the back of that instrument.

Consider also placing all the instruments for each group in a tub or other container.

Activity Guide

Get Ready & Team Up (10 min.)

1. Organize learners into groups of 4–6.
2. Say: **NASA wants to learn about Mars; one way they do that is by sending spacecraft to orbit the planet. Today, you are going to choose a mission to learn about Mars and design a spacecraft for it.** Share the Guiding Question with learners aloud and in writing *(using multiple languages as needed)*: **Which survey mission should we send to Mars? What instruments does a spacecraft need for it?**

Plan & Create (S.E.T.) (25 min.)

Science: Choose a Mission

3. Ask: **What kinds of things do you think we should learn about Mars?** *(What it is made of, what mountains and other features it has, how big it is, where there is water, where a rover could land.)* Give groups five minutes to discuss and record their ideas on the *Our Ideas* poster. Say: **We will keep recording ideas on this poster.**
4. Say: **You've listed many possible things to study on Mars. It is not possible to study them all at once, so you will have to choose one mission to design for.**
5. Give each learner an Engineering Notebook. Say: **This Notebook is a place to record your observations and ideas.**

Support Learner Differences

Check out the Intentional Grouping Strategies, pg. xxii.

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. If everyone knows each other's names, ask if anyone has a middle name or nickname you could learn to pronounce. Invite them to share about it.

For more strategies to engage learners, refer to Designing Instruction to Reach Diverse Learners, pg. xv.

Teaching Tip

Throughout this guide, information for you to say to students appears in **bold**. You can say the bold sentences exactly as they are written or paraphrase them.

Support Learner Differences

Recording learners' ideas using words, diagrams, and pictures on the *Our Ideas* poster or shared digital document throughout the activities allows them to refer to the poster to remember words and build on past ideas. You can refer to an "In-Use Example" in the online Prep & Setup Guide - Examples (PDF).

If you have learners who speak multiple languages, encourage them to share in their preferred languages.

6. Have learners turn to *Missions to Mars*, Engineering Notebook, pg. 2. Say: **NASA designs different missions for different purposes. This page describes two different kinds of missions to Mars. Decide as a group which one you want to complete.**
   - **A *global survey* is a long-term mission to explore and map a new planet or moon.**
   - **A *landing site* selection survey is a short-term mission to choose the best place to land a robot or human on the surface.**
7. Allow each group to discuss, choose one mission, and mark it on the Notebook page.
8. Say: **Now that you've chosen a mission, you need to figure out what the mission needs to succeed.**
9. Say: **Survey missions need to make images. Which mission do you think needs more detailed images? Which mission needs less detailed images?** *(A global survey needs less detail because it is observing the entire planet. A landing site selection survey needs more detail because it is observing specific smaller locations.)*
10. Say: **The amount of detail in an image is called its resolution. A global survey can have lower-resolution images; a landing site selection survey needs higher-resolution images.** Write the word *resolution* on the *Our Ideas* poster. You can have learners add translations, drawings, or related images to the poster as well. Have learners record the level of resolution their chosen mission needs in their Notebook.
11. Say: **Some missions need to know what the surface of a planet is made of, and some just need to know the planet's general shape and texture. Which do you think is needed for each mission?** *(A global survey needs to know about shape and texture, but not necessarily what the surface is made of, because nothing is landing on the surface. A landing site selection survey needs to know shape and texture as well as what the surface is made of, because that information is important when landing.)*
12. Say: **The shape and texture of a surface are called its *physical properties*. Knowing about these is required for all missions. What a surface is made of is called its *composition*. Knowing about this is required for a landing site selection survey and optional for a global survey.** Write the terms *physical properties* and *composition* on the *Our Ideas* poster. You can have learners add translations, drawings, or related images to the poster as well. Have learners record information their chosen mission needs in their Notebook.
13. Explain that things a successful design needs to do are its *criteria*. Learners have just listed criteria for each mission. Have learners write this word after its definition in the Notebook and add it to the *Our Ideas* poster.
14. Say: **Throughout history, people have figured out how to learn more about the world, from local plants and animals, to Earth, to other planets. Like these people, you have been using some of the same practices as scientists. Scientists do many other things that we did not have time to do today, such as analyzing data.** Write the word *scientist* on the *Our Ideas* poster. Have learners work together to come up with a description of scientists and record it on the poster. *(For example: Scientists often ask questions, test things out, make observations and measurements, and gather evidence to answer the questions.)* You can have learners add translations, drawings, or related images to the poster as well.

Engineering: Design a Spacecraft

15. Ask: **Now that you have chosen a mission and figured out its criteria, what do you think you should do next?** *(Figure out how to complete the mission, design a spacecraft to do it.)*

Support Thinking

To help learners understand what they will be doing during this activity, play the translatable video Remote Sensing Instructional Read Aloud.

16. Have learners discuss in their groups: **What kinds of things does a spacecraft need to work? What kinds of things does it need to study the surface of Mars?** *(A spacecraft needs a source of power and a way to communicate with Earth. It needs technologies like cameras and sensors to study the surface of Mars.)*
17. Hand out one set of *Fairing and Instruments Sheets* cutouts, one *Instruments Key*, and one *Engineering Ready, S.E.T., Go! Visual Instructions Handout*, to each group. Say: **You will design a spacecraft using these pieces of paper, which represent different instruments and parts of the spacecraft. This key explains what each instrument is.** Demonstrate how to use the key: for example, find the S1 instrument and look it up to determine it is the High Resolution Camera.
18. Ask: **What symbols are on these instruments? What do you think they mean?** *(The bars mean communication or signal. The weight means how much it weighs. The battery means power.)*
19. Have learners sort the instruments by how big they are. Ask: **What do you notice about the size of the instruments?** *(They are different sizes. Some are small, some are medium, and some are large.)* Say: **When NASA designs a spacecraft, they build it so it can fit on top of a rocket. The part that sits on top of the rocket and protects a spacecraft during launch is called the fairing. All the instruments need to fit inside the fairing and not overlap.** Have learners find the piece of paper that represents the fairing.
20. Have learners sort the instruments by how much power they need or how much power they give. Ask: **What is needed to power these instruments?** *(Different instruments need different amounts of power. Some power sources give more power than others.)* Say: **Your spacecraft must have as much power as whichever instrument needs the most power. For example, if you have an instrument that needs a full battery, you need a source that provides a full battery of power.**
21. Have learners sort the instruments by how much data volume they need or how much data volume they can communicate. Ask: **How much data volume do these instruments need to communicate?** *(Different instruments need to send different amounts of data. Some communications relays can send more data than others.)* Say: **Your spacecraft's communications relay must have a data signal that supports whichever instrument has the highest data signal needs. For example, if you have an instrument that needs more than two bars of signal, you need a relay that can transmit large data volumes.**
22. Explain that limits on a design are ***constraints***. Learners listed the constraints for their spacecraft. Have learners write this word after its definition in the Notebook and add it to the *Our Ideas* poster.
23. Say: **Now it is time to choose instruments for your spacecraft. You need to choose two types: instruments to help you learn about the planet for your mission (your criteria) and instruments to provide as much power and data volume as you need (your constraints).** Give groups 5 minutes to choose instruments.

Level Up!

Have learners sort the instruments by weight. Ask: **What do you notice about the weight of the instruments?** *(They have different weights. Some are light, some are moderate, and some are heavy.)* Set a limit for the maximum amount of weight on the spacecraft. (5 min.)

24. Say: **Now it is time to arrange the instruments inside your fairing. They must fit without overlapping and without going past the edge of the fairing.** Give groups 5 minutes to arrange the instruments.

Support Thinking

Help learners understand that this challenge does not have a single correct answer. Learners need to make trade-offs in what they include on their spacecraft.

25. Say: **Humans often need to learn about things that are far away. Throughout history, people have done this in many ways, from telescopes to spacecraft. Like these people, you have been using the practices of engineers.** Write the word *engineer* on the *Our Ideas* poster. Have learners come up with a description of engineers together and record it on the poster. *(For example: Engineers design things to solve problems.)* You can have learners add translations, drawings, or related images to the poster as well.
26. Say: **Scientists start with a question and work to answer it. Engineers start with a problem and work to solve it. The objects, systems, and processes engineers design to solve problems are *technology*; for example, the spacecraft you designed are technologies. Engineers often design technologies that help scientists answer their questions. They depend on each other.** Write the word *technology* on the *Our Ideas* poster. You can have learners add translations, drawings, or related images to the poster as well.

Reflect (Go!) (10 min.)

27. Have learners discuss the following questions in their small groups: **Where on Mars do you think it might be interesting to land your spacecraft? What would be useful to know about the place before it landed there?** Consider returning to learners' ideas at the start of the next activity.
28. Say: **You will be acting as engineers to help solve more problems in space. These problems will involve designing technologies to gather information from a distance. You will think about the phases you used to solve the problem of designing the spacecraft so you can use those phases again later with other problems.**

Level Up!

- Learners may believe that *technology* refers only to devices powered by electricity. Explain that anything designed by people to solve a problem is technology. Have learners identify non-electrical technologies around them. (10 min.)

  Have learners create portrayals–through drawing, acting, or some other method of their choice–of scientists and engineers working together to plan missions and design spacecraft. (30 min.)

- Instead of using the premade *Engineering Design Process*, you can have learners make their own. If you do so, skip Step 29 and refer to the Level Up! at the end of this section instead.

29. Have learners turn to Our *Engineering Design Process*, pg. 3 in their Notebooks. Say: **There are many different processes that engineers use to design things to solve problems. You will be using these seven phases as your *Engineering Design Process*: Frame, Investigate, Brainstorm, Plan, Create, Test, and Evaluate. Then you go through the cycle again, or Iterate, to improve your design.** Ask: **How did you use this *Engineering Design Process* when engineering a spacecraft?**

(We framed the problem of fitting instruments into the fairing, investigated the instruments' requirements, brainstormed ways they could fit, planned and created an arrangement, tested whether it would fit and evaluated the results, and iterated as necessary to find a better solution.)

30. Say: **Next time, we will think about what we already know about technology and why it is important.**

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for Activity 1.
   - Collect all paper cutouts. If possible, save them for reuse.
2. Have learners invite people from the community, including their families and friends to the Engineering Share-Out in Activity 9 (see pg. 103).
3. Plan ahead for Activity 1. See Activity 1 Preparation on pg. 20.
4. Take time to reflect on the following educator prompt. **How did you create connections between the science and engineering portions of the activity?**

Remote Sensing Additional Resources

QR code leads to resources available for this unit.

weblink: https://hov.to/248cf0d9

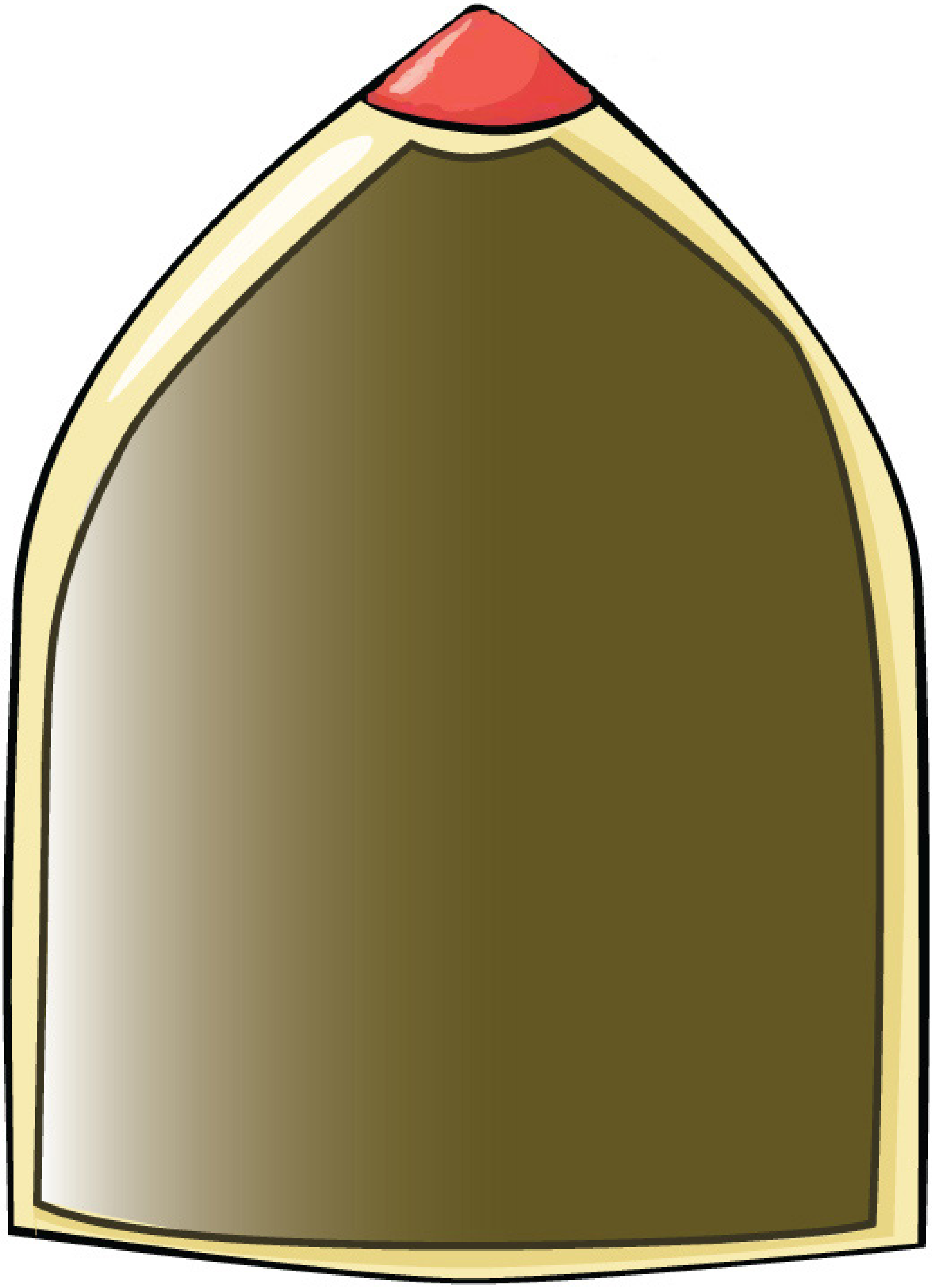
Level Up!

If time permits, have learners create their own engineering design processes:

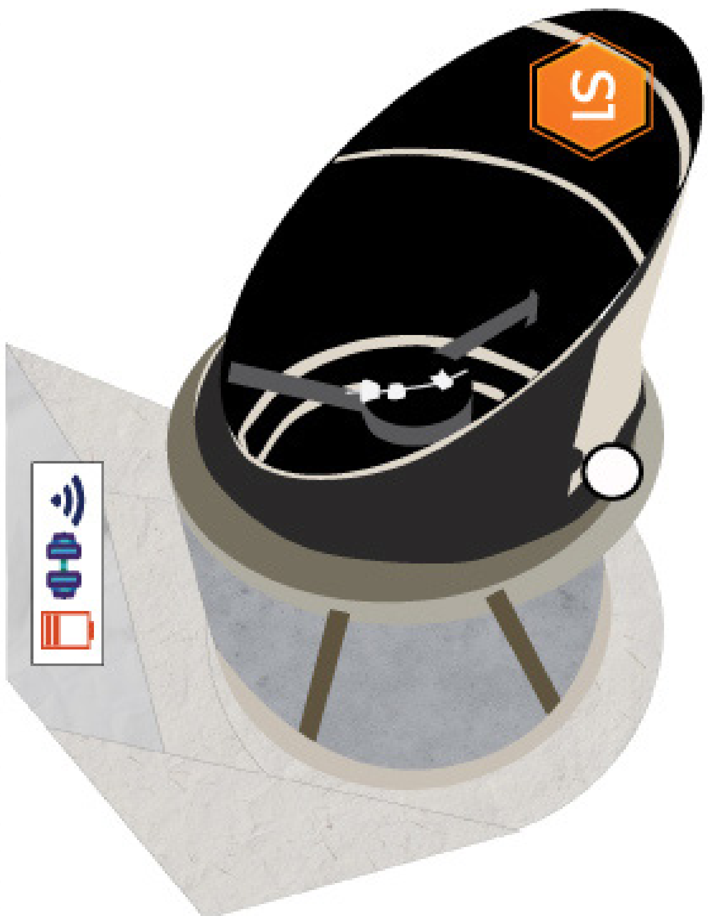
- Give each group index cards, markers, and one set of Phase Cards (PDF). Explain that they should choose the phases they used to design a spacecraft. They can choose some or all of the Phase Cards, and they can write or draw their own cards (one phase per card). They should put the phases in the order they used them. (Note that the options shown on the phase cards are intentionally different from the phases of the EDP in the Engineering Notebook, tto avoid implying that the EDP in the Notebook is the "correct" answer.)
- When writing their own phases, learners may describe specific actions, such as "We folded the index cards." Through discussion, encourage learners to come up with terms to describe each phase of the process more generally, such as "We talked about it" and "We tested the materials." If learners speak multiple languages, encourage them to discuss in their preferred languages.
- Give groups copies of the *Engineering Design Process Example* for inspiration.
- Gather the group and compare processes. Organize all the cards in groups on a poster to create a whole-group engineering design process of between three and ten phases. *(For example: ask, imagine, plan, create, test, improve.)* Save this *Engineering Design Process* poster for use in future adventures.
- Say: **You have just designed a set of phases like the ones engineers use to solve problems: an engineering design process.**

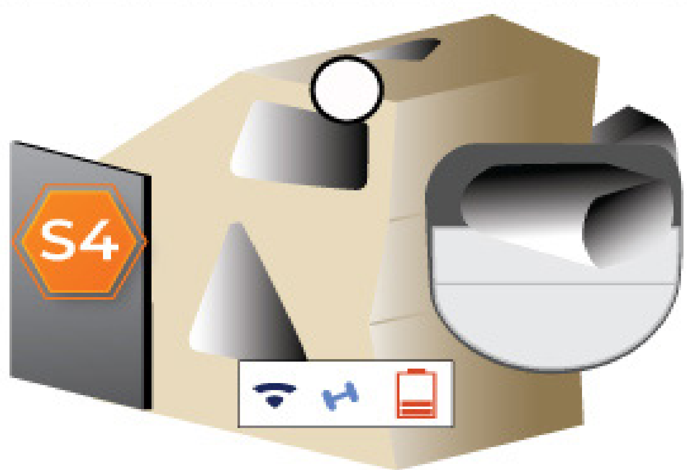
Watch this video about plans for sending humans to the Moon during the Artemis missions. How We Are Going to the Moon - 4K. Discuss how spacecraft must be designed differently if they are carrying robots versus if they are carrying humans. (15 min.)

Fairing Handout



Instruments Sheet Handout – 1





Instruments Sheet Handout – 1

Instruments Key Handout

S1

Science Instrument 1:
High Resolution Camera
Can take 3D images of the surface and can take scientific measurements, which makes it great for making different kinds of maps.
high signal, heavy weight, low energy

S2

Science Instrument 2:
Low Resolution Camera
Can take good images of the surface, but has more limited scientific measurements.
low signal, light weight, low energy

S3

Science Instrument 3:
High Resolution Spectral Imager
Can take images of the surface and can take high resolution scientific measurements.
high signal, heavy weight, high energy

S4

Science Instrument 4:
Medium Resolution Spectral Imager
Takes good scientific measurements, but with reduced detail.
low signal, light weight, low energy

S5

Science Instrument 5:
Magnetometer
Measures the magnetic field of the planetary body.
low signal, light weight, low energy

S6

Science Instrument 6:
Thermal
Measures the temperatures of the surface, which can be used to figure out the grain size and where rocks are.
low signal, light weight, high energy

S7

Science Instrument 7:
Radar Instrument
Detects below the surface, showing us buried rocks, ice, and caverns.
low signal, light weight, high energy

C1

Comms Instrument 1:
High-Volume Communications Relay
Can transmit large data volumes.
light weight

C2

Comms Instrument 2:
Low-Volume Communications Relay
Can transmit small data volumes.
light weight

PS1

Power Source 1:
High Power Source
Can last for a long-duration mission.
heavy weight

PS2

Power Source 2:
Low Power Source
Can last for a short mission.
light weight

S8

Science Instrument 8:
Gamma Ray Spectrometer
Detects gamma rays on the surface, showing where different elements may be located.
low signal, light weight, low energy

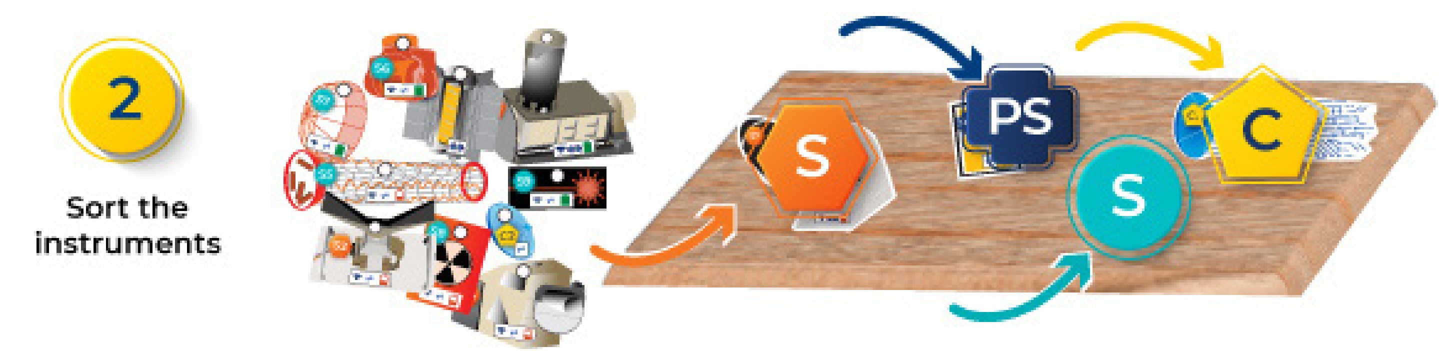
S9

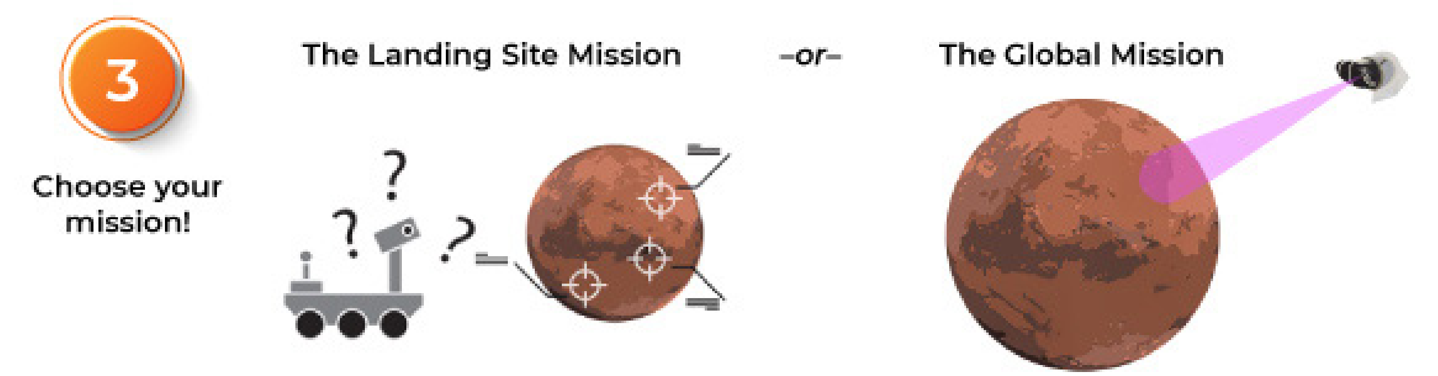
Science Instrument 9: LiDAR
"Light Detection and Ranging" instruments can measure distances using light, which helps to understand the shape of the surface.
low signal, light weight, high energy

Last Updated
033125 tmsr

Engineering Ready, S.E.T., Go! Visual Instructions Handout

Prep for your Mission to Mars





Once you decide, you are on your way!

Engineering Activity 1: Technology Stories: Sharing Experiences

Educator Preview

Activity Snapshot

Learners share experiences with, and stories about, technology.

Timing | 45 minutes

Get Ready & Team Up	10 min.
Storytelling	25 min.
Reflect	10 min.
Total	**45 min.**

Level Up Activities 5–60 min. each

Prep Snapshot*

Prep Time 30 min.

Set up a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection

- Communication

Habits of Mind

- Communicate effectively.

Guiding Question

Why is technology important?

Learners Will Do

Share a story or experience about technology.

Learners Will Know

Humans design technologies to solve problems they have identified.

Connecting Across Activities

Ready, S.E.T., Go!	Activity 1: Sharing Experiences	Activity 2: Investigating Light
Last time, learners designed spacecraft to gather data about Mars. As scientists, they chose a mission. As engineers, they figured out which instruments to send on the mission.	**Today**, learners share experiences with, and stories about, technology.	**Next time**, learners investigate how light travels and how mirrors can redirect light to gather data from a distance.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https:///hov.to/f03b2141

Materials and Preparation

Materials

For the educator

- *Our Ideas* poster (on paper or a shared digital document) in Prep & Setup Guide (PDF) Examples | Templates
  - index cards
  - markers
  - scissors
  - tape

For the Materials Table

- drawing supplies (such as pencils, crayons, markers)
- building supplies your site has access to (such as clay, Legos®, beads, natural materials).

For each learner

- Engineering Notebook (PDF)

Activity 1 Materials Preparation (30 min.)

Ahead of Time

1. If you did not do so before the Ready, S.E.T., Go activity, prepare an *Our Ideas* poster by following the Prep & Setup Guide - Examples (PDF). Add the Guiding Question "Why is technology important?" so learners can refer to it throughout the activity.

Teaching Tip

This activity is the same in both the Science and Engineering Pathways. If you have already taught it in one pathway, you do not need to teach it again.

2. Learn about local industries and traditions, reasons why they are important in local communities and cultures, and their history in your area. This information will help you understand learners' stories, and you can use it to provide examples and prompt learners' thinking.
3. Learn about or reflect on the storytelling styles of learners' communities. Think about the kinds of stories learners might tell and how you can structure the activity to support them.

In Your Space

4. Place the *Our Ideas* poster in a location all learners can access. Make a plan to store it between activities.

5. Set up a Materials Table with the materials listed in the Materials section.

6. Optional: Set the mood for the activity by playing music.

Get Ready & Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(As scientists, we chose a kind of mission to send to Mars. As engineers, we designed a spacecraft to complete that mission.)*

2. Say: **Our ultimate goal is to design technologies to use on a spacecraft to learn about Mars. To start figuring this out, we're going to share what we know about why technology is important. Remember that a technology is anything designed by people to solve a problem.** Share the Guiding Question with learners aloud and in writing *(using multiple languages as needed)*: **Why is technology important?**

3. Organize learners into groups of four.

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on pgs. xx-xxi). This tip is repeated because you may have new learners joining you in this and future sessions. Whenever you have new learners, repeat this strategy.

For more strategies to engage learners, refer to Designing Instruction to Reach Diverse Learners, pg. xv.

If you have learners who speak multiple languages, consider pairing learners with the same preferred language so they can share with each other in that language. Check out Intentional Grouping Strategies, pg. xxii.

If you have learners who speak multiple languages, have them discuss words for "technology" in their preferred languages and notice similarities between languages. If you can, provide an example from a language you know. Take time to learn learners' words and use them throughout the activities.

Storytelling (25 min.)

4. Say: **We all have stories. They can be stories we've heard from other people, stories we've watched or read about, or stories about things we have experienced ourselves. We experience stories every day in conversations, art, traditional craft, and online videos. Today, we're going to share stories about technologies or tools that made a big difference in our lives. These stories could be about technologies you use at home, technologies in history, what it means to use technology responsibly, and how technology affects different people in different ways.**
5. Have learners turn to My Technology Story, pg. 5, in the Engineering Notebook (PDF). Say: **To start, you will have 15 minutes to think about a story to tell that shows how a technology or tool has made a big difference in your life. Create some art that tells your story. You can write it down or write a poem, draw it, record it on a device, create a performance about it, or build something to demonstrate it. Note that there are drawing and building materials on the Materials Table.** During this time, check in with each group. If learners are struggling, consider sharing your own short story about technology to spark ideas.
6. After 15 minutes, say: **Now, everyone in your group will take a few minutes to share their stories. If your story is long, you can choose one or two minutes of it to share so there is time for everyone.**
7. Allow learners to share their stories for 10 minutes. Remind them to switch so that everyone has time to share. Visit each group and listen to learners' perspectives on technology.

Reflect (10 min.)

8. Say: **Thank you for sharing your stories. They gave us great reasons why technology is important.** Point out common themes you noticed among stories. Emphasize how technologies allow people to do things they could not do otherwise. Ask: **Is there anything else you want to share to answer the Guiding Question?** Revisit the Guiding Question: **Why is technology important?**

Support Thinking

Learners may want to make up their own stories. Bear in mind that the goal of the activity is to identify why technology is important to learners and communities they belong to, which made-up stories may or may not do.

Support Learner Differences

It is possible that stories about the use and effects of technology may bring up trauma. If you notice this, ask the learner privately what they might need at that moment. If they do not know, you can offer some ideas from the Arizona Adverse Childhood Experiences Consortium Resource Library.

In this activity, you will need to strike a balance between allowing learners to share complete stories and ensuring there is enough time for everyone to share. Different cultures have different conventions for storytelling, which may involve very long stories with many parts, the significance of which is not immediately apparent. Consider the best way to approach time management, which may involve dedicating multiple sessions to this activity.

You can use storytelling as an opportunity for learners to practice social skills such as taking turns and showing respect for other people's experiences.

9. Have learners record answers to the Guiding Question near it on the *Our Ideas* poster. You can
   - have each group designate a member to record responses on the *Our Ideas* poster.
   - have each learner write or draw something on a (physical or digital) index card and add it to the *Our Ideas* poster.
10. Say: **Next time, we will think about how light can help us gather information from a distance.**

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for Activity 2.
   - If learners created objects related to their stories, save those objects for reference in future activities.
2. Plan for Engineering Activity 2. See the Activity 2 Preparation on pg. 26.
3. Take time to reflect on the following educator prompt. What strategies helped learners feel comfortable sharing stories?

Remote Sensing Additional Resources

QR code leads to resources available for this unit.

weblink: https://hov.to/248cf0d9

Support Learner Differences

As needed, allow learners to choose other methods of sharing their ideas, such as audio recordings. Have them write the filename of each record on an index card and put the index cards on the *Our Ideas* poster. They will serve as placeholders. When necessary, you can ask, **"Who has the idea named X?"** and have the learner in question share the record.

Support Thinking

Learners may bring up ideas that will be relevant in future activities, such as technology that can gather information from far away. As appropriate, note that the group will return to these ideas.

Level Up!

- Refer to the Engineering Design Process poster (PDF). Ask: **What phases of the *Engineering Design Process* did you use today?** *(We investigated reasons why technology is important.)* (5 min.)
- Check out some great examples of the more than 2,000 NASA spin-off technologies that enrich our lives thanks to space exploration. (5 min.)
- Tell learners, if anyone asks them what they did today, they can tell them "We shared stories about why technology is important." (5 min.)

Educator Guide

Engineering Activity 2: Lighten Up! Investigating Light

Educator Preview

Activity Snapshot
Learners investigate how light travels and how mirrors can redirect light to gather data from a distance.

Timing | 45 minutes

Get Ready and Team Up	10 min.
Investigate Light	25 min.
Reflect	10 min.
Total	**45 min.**

Level Up Activities 5 min. each

Prep Snapshot*

Prep Time 30 min.

Set up sample obstacle course and Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection
- Critical Thinking

Habits of Mind
- Use systems thinking.
- Investigate properties and uses of materials.

Guiding Question
How can we redirect light to gather data from a distance?

Learners Will Do
Evaluate the properties of light and decide how to place mirrors to redirect its path.

Learners Will Know
Mirrors can change the direction of light.

Connecting Across Activities

Activity 1: Sharing Experiences	Activity 2: Investigating Light	Activity 3: Redirecting Light
Last time, learners shared experiences with, and stories about, technology.	**Today**, learners investigate how light travels and how mirrors can redirect light to gather data from a distance.	**Next time**, they will design portable light redirection systems. These systems are one technology they can use when designing their complete remote sensing technologies.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/955d7e8b

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document) in Prep & Setup Guide (PDF)
  Examples | Templates
  - index cards
  - markers
  - scissors
  - tape
- 1 box or other obstacle, 7" × 5" × 3" (approx. 18 cm × 13 cm × 8 cm) or larger
- 1 index card

For each group of four

- Redirecting Light Handout, pg. 36
- Set Up an Obstacle Course Handout, pg. 37
- Investigating Light Constraints and Criteria Handout, pg. 38
- 1 box, small, or other obstacle
- 1 fuzzy stick
- 1 index card
- 6 mirrors (distributed later)
- 6 binder clips, medium (distributed later)
- 1 pack of crayons or markers
- 1 pair of scissors
- 5–10 straws
- 1 protractor (for measuring angles, optional)
- 1 roll of tape, masking

For each learner

- Engineering Notebook (PDF)

Teaching Tip

Save straws for reuse in Engineering Activity 5.

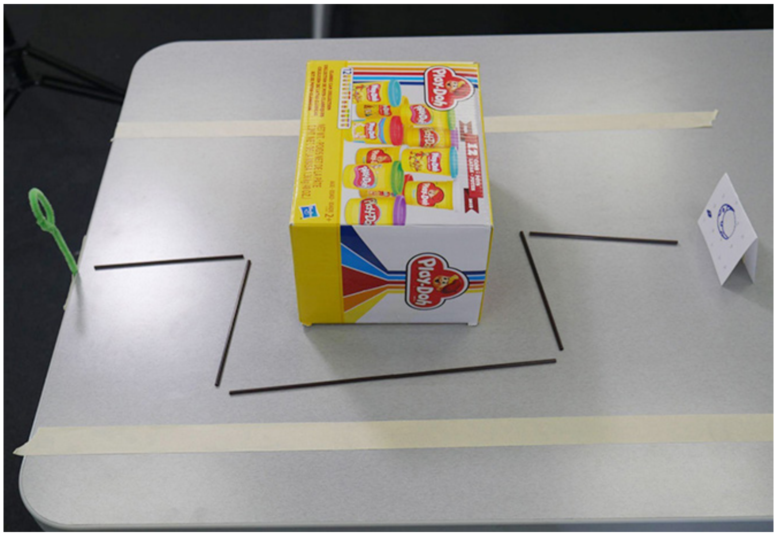
Activity 2 Materials Preparation (30 min.)

Ahead of Time

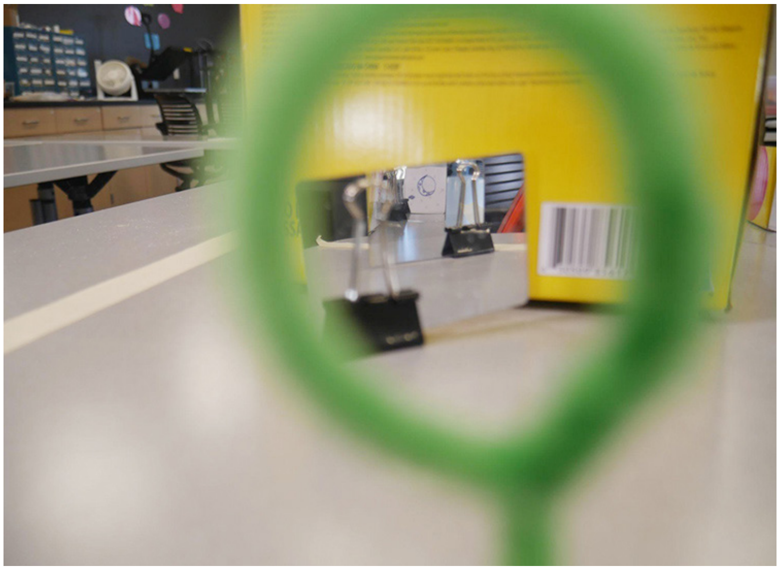
1. Print out one copy of Redirecting Light, pg. 36, and one copy of Investigating Light Constraints and Criteria, pg. 38, per group.
2. If you are using mirrors for the first time, remove plastic film from them.

In Your Space

3. If you did not do so before the Ready, S.E.T., Go activity, prepare to build on the *Our Ideas* poster by following the *Prep & Setup Guide*. Add the Guiding Question "How can we redirect light to gather data from a distance?" so learners can refer to it throughout the activity.
4. Set up a sample obstacle course according to Obstacle Course Setup, pg. 37. Ensure it will be in an area that all learners can access safely.



Obstacle Course



View through eyepiece of Obstacle Course

5. Create a Materials Table with the materials listed above as For each group of four. Do not include mirrors and binder clips. These will be distributed later.

Preparation for Engineering Activities 6–9 (60 min.)

The final design challenge for this unit requires the educator to prepare a multi-part model so learners can test their remote sensing devices. Read Activity 6 Materials Preparation, pg. 80 and decide whether to use the Space Screens with learners. **Then consider preparing the following models in parts or set aside at least an hour to assemble them in one session.**

- Model Landscapes for Site A (2 copies) and Site B (2 copies)
- Optional: Space Screens that prevent learners from looking at the model landscapes on the opposite side and represent the distance between the Earth and other planets

The complete instruction for building Site A and B, pgs. 85-87 and the Space Screens, pg. 88-89 are outlined in this guide, and a video that shows the process of how to build a model landscape is available. Since remote sensing engineers cannot see the surface of a planet up close, it is important that learners use only the remote sensing devices they create to gather information about each site and that they do not look at the models directly. Keep the model landscapes covered when not in use until groups complete their tests in Activity 9.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** (*We told stories about why technology is important, which helped us understand why it's important to think carefully about designing technology.)* Draw learners' attention to their work on the *Our Ideas* poster about how technology makes a difference in their lives.

2. Say: **NASA wants to send a rover to Mars to see if liquid water was once there. If it was, Mars might have been able to support some form of life–in other words, it might have been habitable. As engineers, our ultimate goal is to help the scientists at NASA by answering the big question "How can we gather information about Mars from far away?"** Write the question in a prominent spot on the top of the *Our Ideas* poster.

3. Ask: **What smaller questions will we need to answer in order to answer this question?** Allow learners to think of questions in pairs, then share them with the whole group. Record their questions on the *Our Ideas* poster in related categories. Possible sets of questions include the following:
   - **Light:** How can we view the surface? How can we see Mars up close?
   - **Water:** Was there water on Mars? How can we tell if there was water on Mars? How can we learn about the surface?
   - **Land:** How can we figure out where to land a rover? What are the landforms on Mars? How can we learn about the physical properties of the surface?

4. Point out questions about light and say: **Today, we'll be investigating our questions about using technology to view Mars up close. Images or pictures need light.** Share the Guiding Question or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **How can we redirect light to gather data from a distance?**

5. Organize learners into groups of four.

Support Learner Differences

If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).

Teaching Tip

Each activity in this pathway has a suggested Guiding Question. As much as possible, replace these questions with similar ones from the list of questions learners have thought of. Using learners' questions will increase their engagement. There will likely be questions you do not answer in the pathway. When you can, mention these questions and have learners think about ways to answer them in the future.

Learners might ask questions about Mars and not the technologies they will design. That is okay. Each subsequent activity will answer questions related to each of the three categories above, but because they are engineers, they will focus on technologies needed to answer that question. For example, the first two activities answer questions related to viewing the surface of Mars. In order for scientists to answer the question "What does Mars look like?", engineers need to answer the question "How can we view Mars from a distance?"

Investigate Light (25 min.)

6. Have each group discuss: **What are technologies that redirect light and use it to gather data from a distance?** *(Mirrors, telescopes, cameras.)* Have learners record their ideas on the *Our Ideas* poster.

7. Distribute one copy of *Redirecting Light* to each group and the Engineering Notebook to each learner. Invite learners to refer to *Redirecting Light* to find out how technologies such as telescopes use mirrors to change the way light travels. Say: **Engineers often use technologies like the ones you talked about to gather data from a distance.**

8. Gather learners around the sample obstacle course you prepared (see *Obstacle Course Setup*). Say: **Instruments on spacecraft must fit in small spaces and work around things that might be in the way inside the spacecraft, called *obstacles*. You will use a model to practice working within spacecraft size limits and to understand how light is redirected to see around obstacles.**

9. Demonstrate as you say: **At your tables, each group will build a model like this one. The tape boundaries represent the size limits of the spacecraft. You will draw an image on a folded index card and place the card within the tape boundaries so it can be seen through the eyepiece. You will place a box between the eyepiece and the index card. It will block the view of the image from the eyepiece. It will be an obstacle. Straws represent the path of light. Because light has to reflect from an image and reach a person's eye for it to be seen, your goal is to create a path through the course with the fewest straws possible, beginning at the index card, going around the obstacle, and ending at the eyepiece.**

Support Learner Differences

Group learners with different abilities and strengths in a way they can all contribute. Check out the Intentional Grouping Strategies, pg. xxii.

As needed, allow learners to feel the obstacle course in order to become familiar with it. Also consider arranging your space to make room for accessibility devices. See our video on Supporting Learners with Diverse Physical Abilities.

Support Thinking

Demonstrate an obstacle by placing someone or something in a doorway and explaining that there is something in the way, or an **obstacle**, to getting into or out of the room. Ask learners if they can think of other examples of obstacles.

Level Up!

Tell learners that there are lots of different kinds of telescopes, such as the James Webb Space Telescope, which includes 18 six-sided mirrors that unfolded into a giant curved mirror after the telescope was launched into space. Cameras such as the Context Camera and High Resolution Imaging Experiment (HiRISE) onboard Mars Reconnaissance Orbiter use a complex system of mirrors to capture images in space. Explore more resources as an educator on our Quick Links and More Resources webpage, or have learners explore more on the Remote Sensing Learners website. (10 min.)

10. Distribute one copy of *Set Up an Obstacle Course, page 37* and one copy of *Investigating Light Constraints and Criteria*, pg. 38, to each group. Read through with learners and answer any questions. Have a volunteer from each group collect materials. Do not include mirrors and binder clips yet.

11. Give groups a few minutes to build their obstacle courses and begin to place the straws. Ask: **Can you create a path from the image to the eyepiece using straws? What do you notice about the path?** *(The path can't go in one straight line to get around the obstacle; it needs to turn a corner. The shortest path has the fewest turns. The path is made up of straight lines, not curves.)* **How did you decide where the path needed to change direction?** *(We reached a barrier. We recognized that we had gone far enough to be able to change direction and not touch the obstacle.)* Say: **Light travels in a straight line, just like the straws in the obstacle course.**

12. Grab a few mirrors. As needed, pass them around so learners can feel them. Say: **In a minute, you will get some mirrors like these.** Ask: **What happens when light hits a mirror?** *(It changes direction. It is reflected.)* **What is the source of light for these mirrors?** *(The Sun, lights in the room.)*

13. Demonstrate as you say: **Next, place mirrors to redirect the path of light so the drawing can be seen from the eyepiece, even though it is hidden behind the obstacle. Use the binder clips to hold up the mirrors. Keep the straws in place to guide you.** Pass out six mirrors and binder clips per group. Allow learners time to place the mirrors and try to see the drawing through the eyepiece.

14. As learners work, ask: **How are you using what you learned from the straws to place your mirrors?** *(We need to make light travel in a straight path. We are placing mirrors where the straws meet because that is where the light needs to change direction.)* **How is placing mirrors different from placing straws?** *(The angle of the straws didn't matter, but the angle of the mirrors does.)* **What advice would you give to other groups?** *(It helps to move the mirrors a little bit at a time. Make sure the mirrors are secure in their stands.)*

15. Invite learners to draw their solutions on Obstacle Course Diagram in their Engineering Notebooks. If there is time, allow groups to provide advice to each other.

Support Learner Differences

As needed, provide groups with a tub or other container to hold their materials.

Support Thinking

To access learners' prior knowledge, provide an image of a mirror at a corner in a hallway or show one in your own space. Ask learners why they think the mirror is there. Have them consider how this idea might help them place the mirrors in the obstacle course.

Level Up!

If learners finish quickly, challenge them to use fewer mirrors or to set the mirrors so that the image isn't reversed. (5 min.)

16. After groups finish, say: **You have made a technology that redirects light to gather data remotely. Ask: What parts did your technology have?** (Mirrors and an eyepiece.) Say: **Your technologies contain parts that work together. A term for a group of parts that work together is system. In what way is your technology a system?** (The mirrors and eyepiece work together to redirect light to a person.) **Remote sensing technologies are often systems with multiple parts. For example, a spacecraft on the Moon facing away from Earth can send signals to a satellite, which then sends the signals to Earth.** Write the word system on the *Our Ideas* poster. You can have learners add translations, drawings, or related images to the poster as well.

Reflect (10 min.)

17. Revisit the Guiding Question on the *Our Ideas* poster: **How can we redirect light to gather data from a distance?** *(We can redirect light using systems of angled mirrors.)* Remind learners of the terms *obstacle* and *system*.

18. Say: **Turn to a neighbor and discuss: What are places in your daily lives where people use mirrors to redirect light?** *(Examining people's mouths at the dentist, rearview mirrors in cars, etc.)* Have learners record their ideas on the *Our Ideas* poster. Consider returning to learners' ideas at the start of the next activity.

19. Say: **Good job working as engineers today! Next time, you'll use what you've learned to make a technology that both redirects light and is easily carried.**

Support Thinking

- Show the video Using Light to See Around Obstacles to help learners understand how systems of mirrors are used in technologies.
- When introducing questions that require learners to extend their thinking and formulate new ideas, invite them to share ideas with a partner or small group before sharing with the whole group.

Support Learner Differences

As needed, allow learners to choose other methods of sharing their ideas, such as audio recordings or Braille. Post index cards with filenames on them so the record can be referenced later.

Level Up!

- Refer to the Engineering Design Process poster (PDF). Ask: **What phases of the *Engineering Design Process* did you use today?** (The Investigate phase. We investigated how light moves and gets reflected.)
- NASA uses special mirrors called retroreflectors to precisely locate places on the Moon. Read more about them: How NASA Uses Simple Technology to Track Lunar Missions - NASA. (5 min.)

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for Activity 3.
   - Save or throw away obstacle course materials. Save mirrors for Activity 3 and straws for Activity 5.
2. Plan ahead for Engineering Activity 3. See Activity 3 Materials Preparation on pg. 40.
3. Take time to reflect on the following educator prompt: How did you create connections between the straw part and the mirror part of this activity?

Remote Sensing Additional Resources

QR code leads to resources available for this unit.

weblink: https://hov.to/248cf0d9

Engineering Activity 2

Obstacle Course Setup

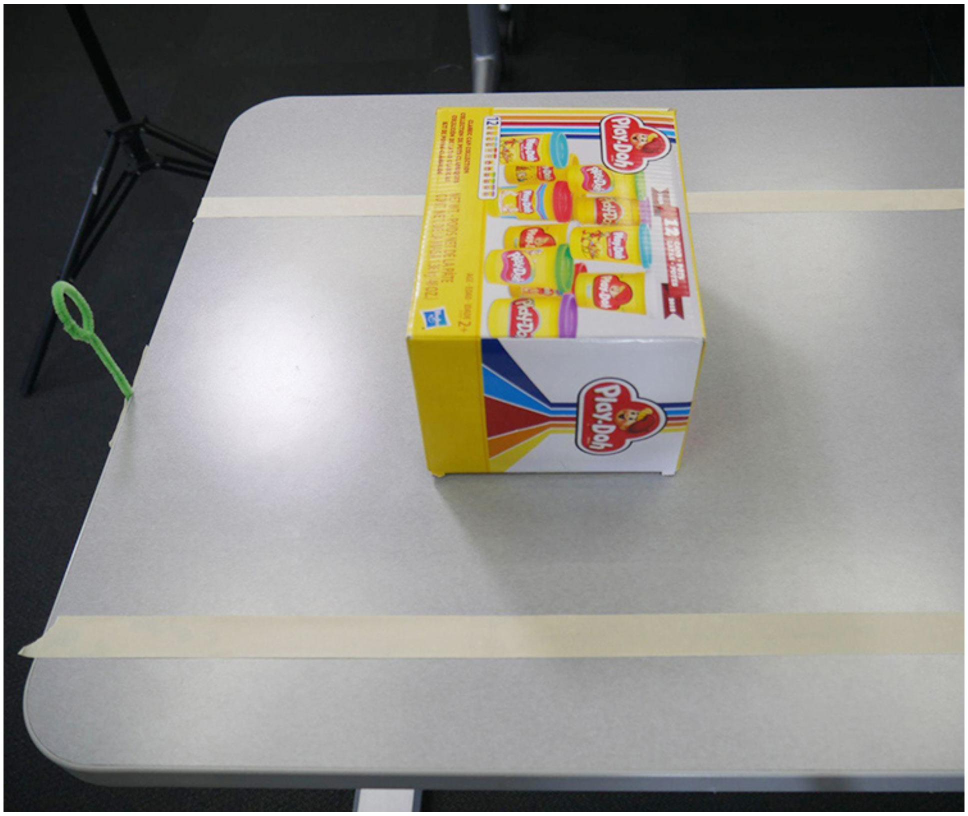
These instructions explain how to build a sample obstacle course for use in Step 3 of the "Investigate Light" section.

Materials for setup:

- index card
- obstacle
- fuzzy stick
- tape

Make an Eyepiece

1. Take a fuzzy stick and twist a loop about 1 inch in diameter, curling the fuzzy stick around itself to close the loop.
2. Bend the excess back.
3. Tape the eyepiece to the edge of a table.

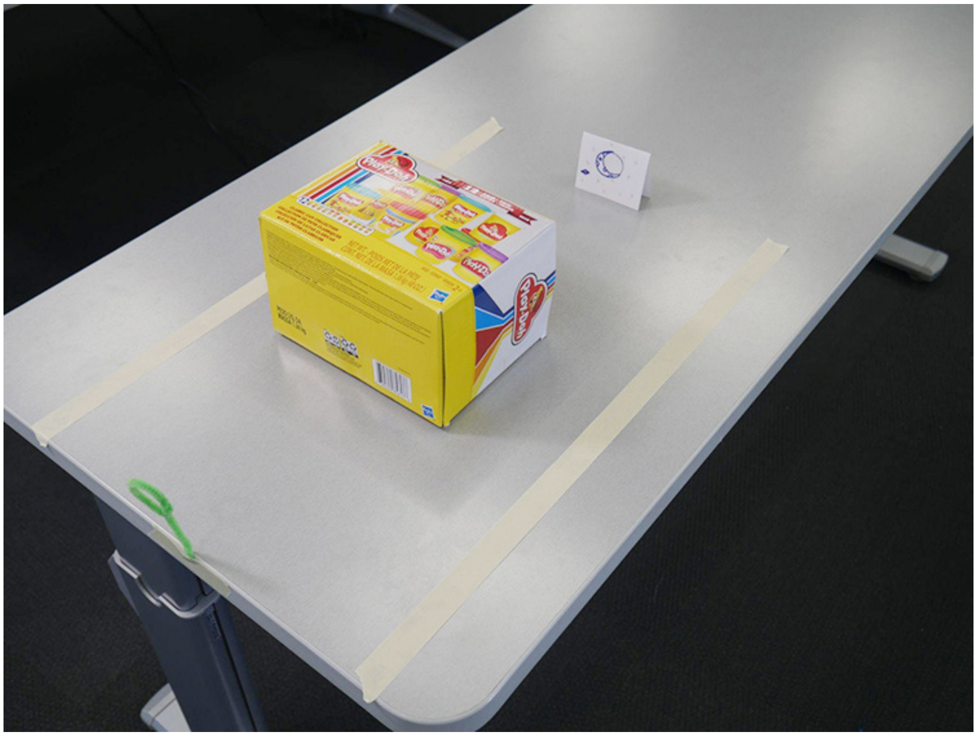


Obstacle Course Set Up

4. Fold an index card in half so it stands upright. Make a drawing learners will try to see using the mirrors. Make it asymmetrical so learners can tell if it is reversed.

5. Place an obstacle, such as a box or stacked books, between the eyepiece and drawing. The obstacle should be about 8" (21 cm) from the drawing and 8" (21 cm) from the eyepiece.

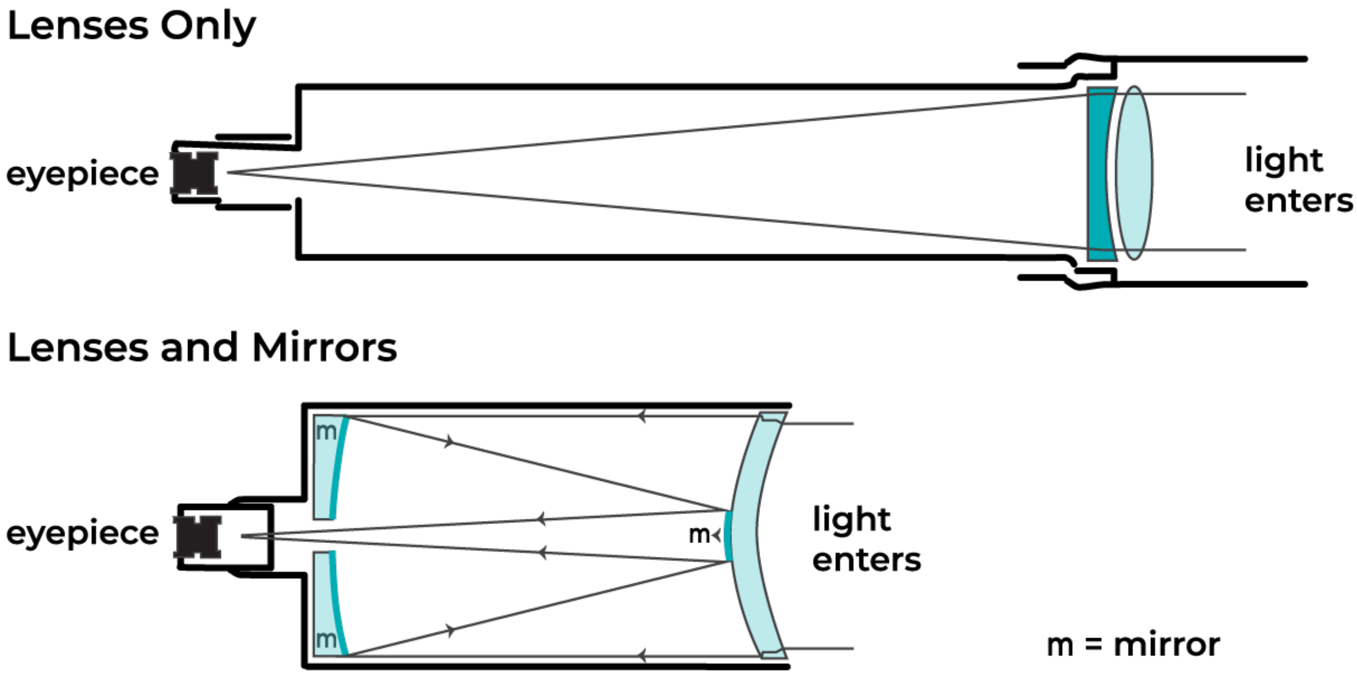
6. Use masking tape to make boundary lines around the obstacle course.



Obstacle Course Set Up - Alternate View

Redirecting Light

Lots of technologies use mirrors to change the way light travels from an object to your eye. See if you can trace the path of light in the technologies below!



Comparing Telescopes with and without Mirrors

A telescope is an example of a technology that collects and focuses light to capture information about faraway objects. Large telescopes often use mirrors to redirect light so that they don't have to be extremely long. The Hubble and James Webb Space Telescopes are reflecting telescopes used to study deep space. The HiRISE (High Resolution Imaging Science Experiment) telescope orbiting Mars is also a reflecting telescope. It can take detailed pictures of the planet's surface.

Set Up an Obstacle Course

1 Make eyepiece.

fuzzy stick

shape fuzzy stick to make eyepiece

tape to table edge

2

index card with drawing

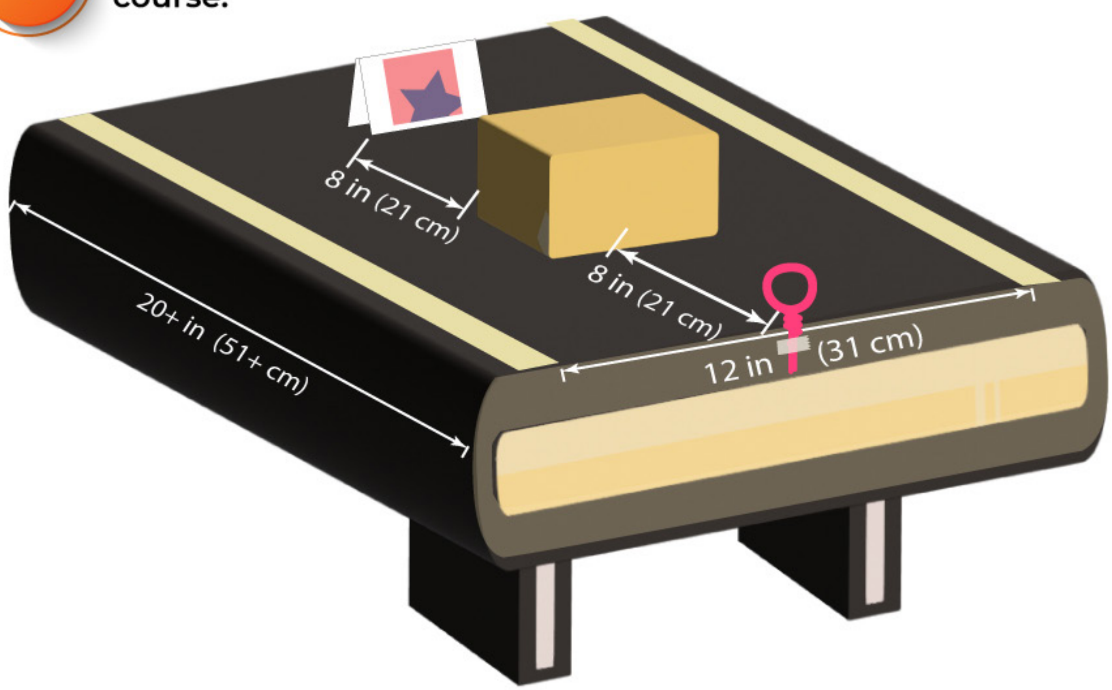
+

box to be the obstacle

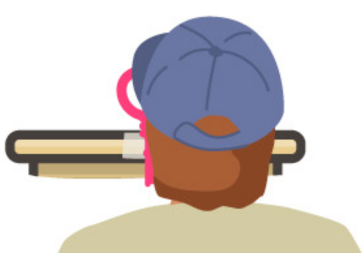
+

masking tape

3 Set up course.



4 Look through eyepiece.



Investigating Light Constraints and Criteria

Build your obstacle course.

- The course must be about 20 inches (51 cm) long.
- The tape must be 12 inches (31 cm) apart.
- Place an obstacle between the eyepiece and the drawing, about 8 inches (21 cm) away from the eyepiece.
- Place the index card drawing about 8 inches (21 cm) away from the obstacle.

Direct light through your obstacle course.

Create a path through your obstacle course with the fewest number of straws to model the path of light from the index card, around the obstacle, to the eyepiece. Every straw must always be in contact with other straws. If a straw is cut into pieces, each piece counts as a straw.

✗ Straws cannot touch the obstacle.

✓ Straws must lay flat on the table.

✓ Straws must stay within the tape boundaries.

✓ You may use more tape to keep straws in place on the table or to connect to each other.

Draw your solution to the obstacle course on the diagram in your Engineering Notebook (PDF), pg. 7.

Educator Guide

Engineering Activity 3: Looking Beyond: Portable Light Redirection

Educator Preview

Activity Snapshot
Learners design portable light redirection systems to gather data from a distance.

Timing | 45 minutes

Get Ready and Team Up	10 min.
Create a Light Redirection System	25 min.
Reflect	10 min.
Total	**45 min.**

Level Up Activities 5 min. each

Prep Snapshot*

Prep Time 30 min.

- Create a sample light redirection system.
- Create a tactile light redirection system model.
- Set up a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection
- Critical Thinking

Habits of Mind
- Use systems thinking.
- Investigate properties and uses of materials.

Guiding Question
How can we use a system to redirect light to gather data from a distance?

Learners Will Do
Design portable mirror systems and use the systems to see around obstacles.

Learners Will Know
Engineers can combine technologies into a system.

Connecting Across Activities

Activity 2: Investigating Light	Activity 3: Redirecting Light	Activity 4: Finding Minerals
Last time, learners investigated how light travels and how mirrors can redirect light to gather data from a distance.	**Today**, they design portable light redirection systems. These systems are one technology they can use when designing their complete remote sensing technologies.	**Next time,** they will explore the properties of filters and scrapers to gather more data, specifically about minerals.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/9cf7a44c

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF)
  Examples | Templates
- sample portable light redirection system
- Tactile light redirection system model, pg. 47

For each pair

- Create a Light Redirection System, pg. 42
- 1 folder, manila
- 2 mirrors
- 1 pair of scissors
- 1 roll of tape, masking

For each learner

- Engineering Notebook (PDF)

Activity 3 Materials Preparation (30 min.)

Ahead of Time

1. Review the "In-Use Example" in the Prep & Setup Guide (PDF) to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. Print out one copy of Create a Light Redirection System Handout, pgs. 45-46, per group.
3. Create a sample portable light redirection system following the instructions on *Create a Light Redirection System*, pgs. 42-43. See the video How to Build a Light Redirection System for additional support.
4. Create one or more Tactile Light Redirection System models, pg. 47, to support learner understanding of the portable light redirection systems they will create.

In Your Space

5. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.
6. Create a Materials Table with the materials listed above as *For each pair*.
7. Place the tactile light redirection system model at a station for learners to access.

Preparation for Engineering Activities 6–9 (60 min.)

The final design challenge for this unit requires the educator to prepare a multi-part model so learners can test their remote sensing devices. Read Activity 6 Materials Preparation on pg. 80 and decide whether to use the Space Screens with learners. **Then consider preparing the following models in parts, or set aside at least an hour to assemble them in one session.**

- Model Landscapes for Site A (2 copies) and Site B (2 copies)
- Optional: Space Screens that prevent learners from looking at the model landscapes on the opposite side and represent the distance between the Earth and other planets

The complete instructions for building Site A and B, pgs. 85-87 and the Space Screens, pg. 88-89 are outlined in this guide, and a video that shows the process of how to build a model landscape is available. Since remote sensing engineers cannot see the surface of a planet up close, it is important that learners use only the remote sensing devices they create to gather information about each site and that they do not look at the models directly. Keep the model landscapes covered when not in use until groups complete their tests in Activity 9.

Supporting Learner Differences

Learners will leave this activity with a tool to hold mirrors they can use in Activities 6–9 for viewing sites obscured by space screens. Learners with little to no vision might not find this activity engaging. Consider making it a group activity, encouraging blind/low vision learners to feel and help predict the angles, but have sighted peers perform the actual construction of the redirection systems. Allow blind/low vision learners extra time to explore the sample portable light redirection system.

Cutting and folding the manila folders can be tricky, even with demonstration. Consider pre-folding the manila folders and marking where to cut and/or showing them the video How to Build a Light Redirection System.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We used straws and mirrors to investigate how light travels. We learned light moves in a straight line and we can use a system of mirrors to redirect its path to answer "How can we redirect light to gather data from a distance?")* Draw learners' attention to their work on the *Our Ideas* poster about light and mirrors.
2. Say: **Our challenge is to figure out how to gather information about Mars from far away.**
3. Say: **Today, we'll continue answering questions about how we gather information from a distance. We know now that the technologies we are designing will be systems–in other words, they will have multiple parts.** Modify the previous Guiding Question to create the new Guiding Question or a similar new question from the *Our Ideas* poster with learners aloud and in writing *(using multiple languages as needed)*: **How can we <u>use a system to</u> redirect light to gather data from a distance?**
4. Organize learners into pairs.

Support Learner Differences

If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).

Create a Light Redirection System (25 min.)

5. Give each pair a copy of Create a Light Redirection System, pgs. 45-46. Say: **You will work in pairs and use these instructions to create a system of mirrors to get light where you need it to be in a compact space. This system should be easy to move.**
6. Draw learners' attention to the tactile light redirection system model. Say: **Here is a model that you can feel. It demonstrates how light will move through the system you make**.
7. Give learners about 20 minutes to build their light redirection systems. As they work, circulate to each group and ask one or more of the following questions: **How is this technology working as a remote sensing device?** *(The mirrors redirect light from objects in the room to a person's eye, so that person can gather information from a distance.)* **Why must the mirrors be placed in this way?** *(The mirrors need to be at certain angles for the light to be reflected in the right direction.)*

Support Thinking

To help learners follow the process, you can demonstrate each step for the whole group before having pairs complete it and/or show the video How to Build a Light Redirection System.

Support Learner Differences

As needed, provide groups with a tub or other container to hold their materials. Give them time to explore the materials before they begin working.

8. Say: **Spacecraft rely on remote sensing technologies to gather information. Take five minutes to practice gathering information through your remote sensing technologies. Test your systems to search for items in the room.** Allow learners about 5 minutes to gather information.

9. Say: **These systems are easy to move around. Another word for this is portable. How are these portable systems an improvement from the mirrors on the table?** *(They can be used in many places.)* Write the word *portable* on the *Our Ideas* poster. You can have learners add translations, drawings, or related images to the poster as well.

Reflect (10 min.)

10. Say: **How did you use what you learned about the way light travels to redirect the light around obstacles?** *(We made sure that light could get through our system by traveling in straight lines because that is how light travels, etc.)*

11. Revisit the Guiding Question on the *Our Ideas* poster. Ask: **How can we use a system to redirect light to gather data from a distance?** *(Accept all responses that learners can support by referring to their light redirection systems.)* Remind learners of the terms portable and remote sensing.

12. Ask: **What questions do you still/now have?** *(How might we collect other types of data besides visual data?, etc.).* Record any new ideas.

13. Say: **Engineers call what you have been doing–gathering data from a distance–remote sensing. They call technologies to gather that data, like the ones you designed today, remote sensing technologies.** Write these terms on the *Our Ideas* poster.

14. Invite learners to turn and talk to a partner about the question, **How might someone use remote sensing technologies in everyday life?** *(Using mirrors on roads to see around corners to prevent collisions, aerial images, etc.).* Have them record ideas on the *Our Ideas* poster. Consider returning to learners' ideas at the start of the next activity.

15. Say: **Good job working as engineers today! The images our light redirection systems can collect will provide only some information about Mars for the scientists. Next time, you will learn about a way to gather evidence of water on Mars. Later you will combine your light redirection systems with other technologies to gather even more types of information.**

Support Thinking

Help learners understand the concept of remote sensing technologies by showing the videos Remote Sensing and How Light Is Used in Remote Sensing.

Level Up!

- Have learners explore the inside of their light redirection systems by dropping a small ball in one end and noticing what they see, hear, or feel as it travels through the system and comes out the other end. (5 min.)
- Refer to the *Engineering Design Process* poster. Ask: **What phases of the** *Engineering Design Process* **did you use today?** *(Frame and Investigate. Learners may also describe how they iterated on their first mirror setup to create a connected light redirection system.)* (5 min.)

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for Activity 4.
   - Save pairs' light redirection systems for use in Activity 4.

2. Plan ahead for Engineering Activity 4. See Activity 4 Materials Preparation on pg. 50.

3. Take time to reflect on the following educator prompt: How did you activate learners' knowledge about light from Activity 2?

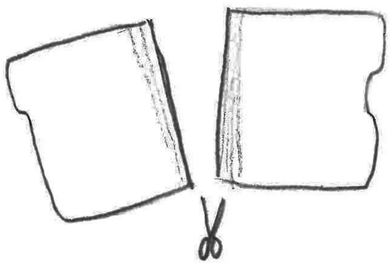
Remote Sensing Additional Resources

QR code leads to resources available for this unit.

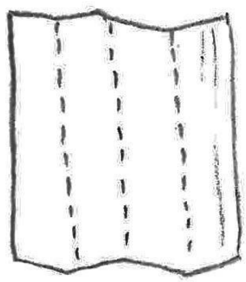
weblink: https://hov.to/248cf0d9

Create a Light Redirection System

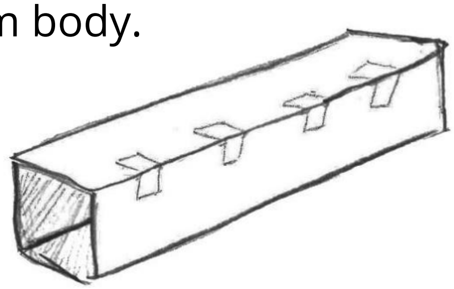
1. Cut the manila folder in half to get two sheets. Put one half aside.



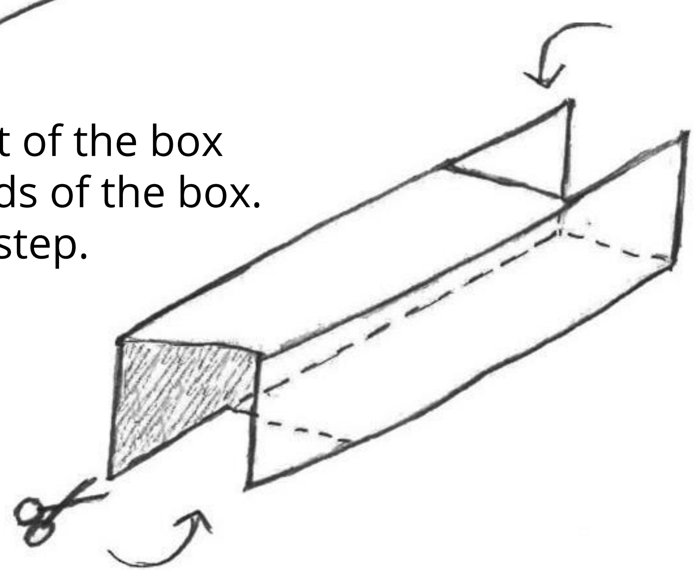
2. Cut the tabs off the manila folder sheets.
3. Fold one manila sheet in half longways, then fold it in half longways a second time. Unfold the manila sheet.



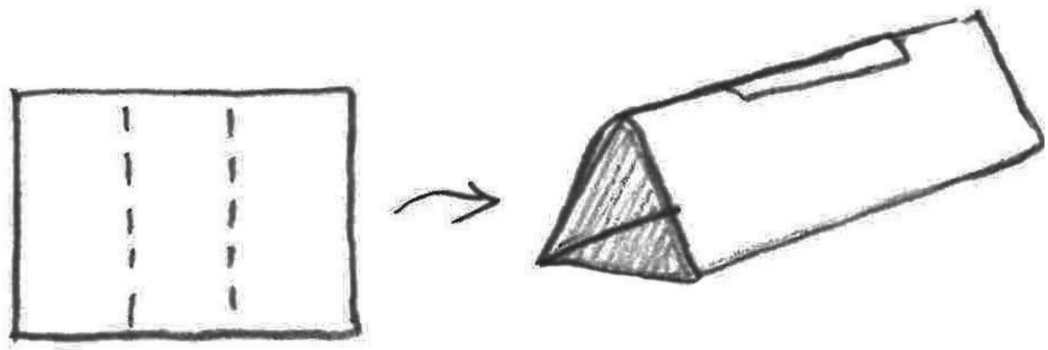
4. Fold the manila sheet into a box shape and tape it closed to make the light redirection system body.



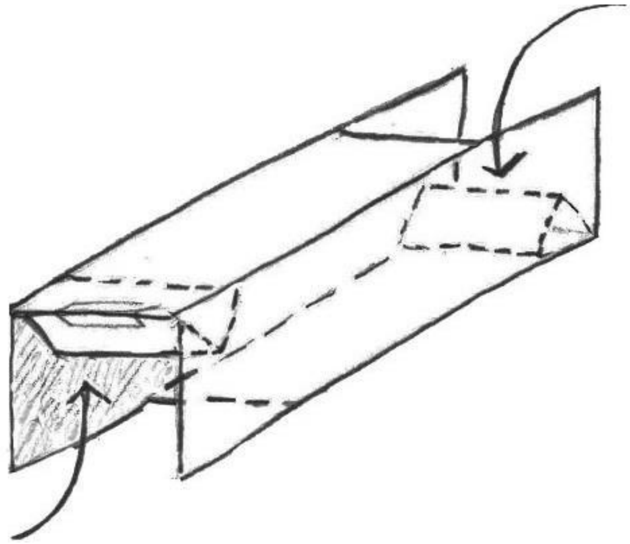
5. Cut two mirror-sized rectangles out of the box on opposite sides and opposite ends of the box. Save these rectangles for the next step.



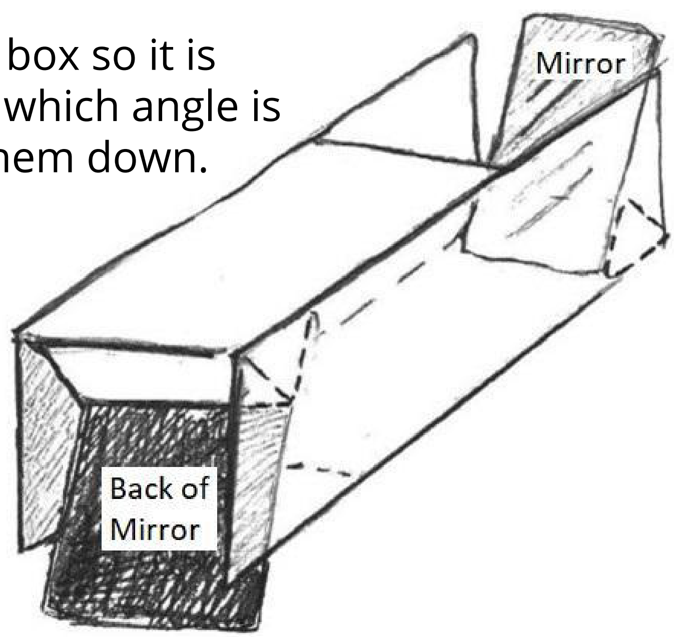
6. Fold and tape the rectangles into triangle shapes so they can be mirror stands.



7. Tape the triangles (mirror stands) inside the box at the long ends.



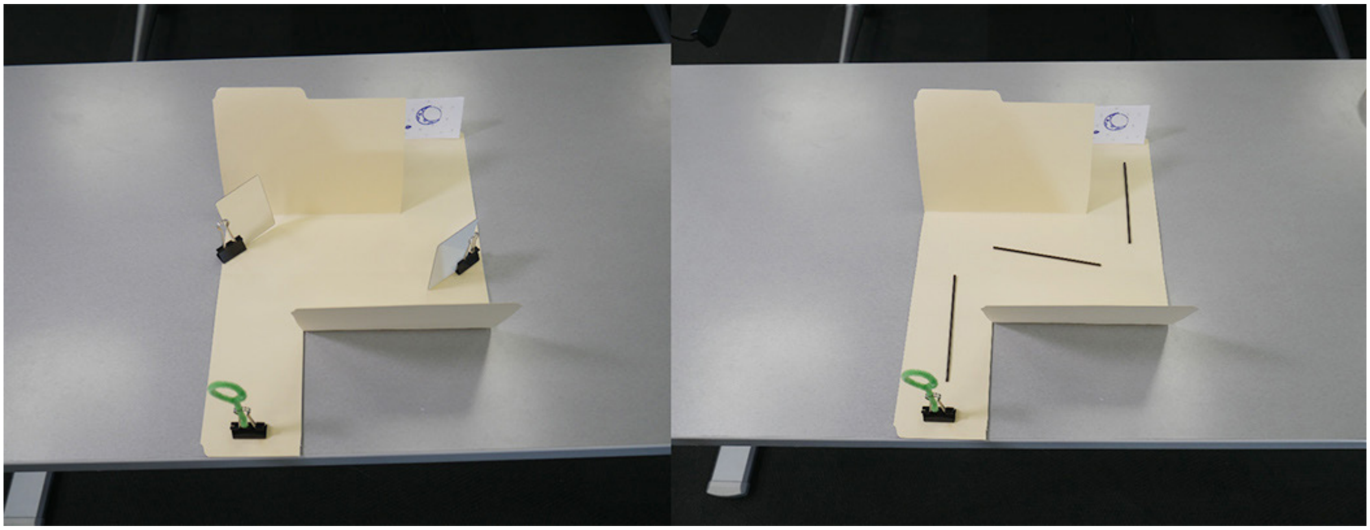
8. Position a mirror at each end of the box so it is resting against the triangle. Explore which angle is best for the mirrors before taping them down.



9. Test out your light redirection system!

Create a Tactile Light Redirection System Model

1. Cut the manila folder in half to get two sheets. Put one half aside.
2. Cut the tabs off the manila folder sheets.
3. Fold one manila folder sheet into thirds longways, then unfold it.
4. Make one cut from each outer long edge of the folder to the fold line. Position the cuts on opposite ends of the folder, each about 2" from the short edge.
5. Fold the large resulting flaps up. Keep the 2"-wide strips lying down. You now have the body of the tactile light redirection system model.
6. Attach two binder clips each to two mirrors and place them at opposite ends of the central third of the folder, oriented at 45° so they face both the central third and the 2"-wide strips.
7. To represent the path of light, tape coffee stirrers along the center of the 2"-wide strips and the central third of the folder. The coffee stirrers should connect at right angles at the mirrors.
8. Fold small pieces of paper or index cards to make triangular prisms. Attach a fuzzy stick loop to one. Place one at the end of each 2"-wide strip.



Tactile Light Redirection System Model

Educator Guide

Engineering Activity 4: Hide and Seek: Finding Minerals

Educator Preview

Activity Snapshot

Learners work to distinguish between minerals using sight and/or sound.

Timing | 45 minutes

Get Ready and Team Up	10 min.
Detect Minerals Remotely	25 min.
Reflect	10 min.
Total	**45 min.**

Level Up Activities 5–10 min. each

Prep Snapshot*

Prep Time 35 min.

- Print and cut materials.
- Set up a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection

- Collaboration
- Communication
- Critical Thinking

Habits of Mind

- Innovate processes, methods, and designs.
- Investigate properties and uses of materials.

Guiding Question

How can we learn what the surface of Mars is made of?

Learners Will Do

Use a system of cellophane and mirrors to identify hidden symbols. Use scrapers to identify textures.

Learners Will Know

Engineers can design technologies that enhance human senses.

Connecting Across Activities

Activity 3: Redirecting Light	Activity 4: Finding Minerals	Activity 5: Taking Shape
Last time, learners designed portable light redirection systems. These systems are one technology they can use when designing their complete remote sensing technologies.	**Today,** they explore the use of filters and scrapers to gather more data, specifically about minerals. These tools are a second technology they can use when designing their complete remote sensing technologies.	**Next time,** they will design straw model LiDAR systems to gather data on a new subject: topography. These systems are a third technology they can use when designing their complete remote sensing technologies.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/aca4805b

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF) Examples | Templates
- markers
- paper, chart
- 50 sheets of paper

For each group of four

(in the half of the class composing the Sound group)

- Sound Model Directions, pg. 64 and Image of Mars, p. 59
- 4+ Data Collection Grids
- 4 folders, manila
- 1 pair of scissors
- 1 roll of tape, masking
- bag containing the following items:
  - 2 quarter sheet pieces of felt
  - 2 quarter sheet pieces of foam, craft
  - 2 quarter sheet pieces of paper
  - 2 craft sticks
  - 2 large straws
  - 2 small straws

For each group of four

(in the half of the class composing the Light group)

- Light Model Directions, pg. 65 and Image of Mars, p. 59
- 4+ Data Collection Grids
- 4 folders, manila
- 1 pair of scissors
- 1 roll of tape, masking
- 1 portable light redirection system from Engineering Activity 3
- bag containing the following items:
  - 2 quarter-sheets of cellophane, blue
  - 2 quarter-sheets of cellophane, red
  - 4 quarter-sheet test sites, blue, cut from Test Site—Blue
  - 4 quarter-sheet test sites, red, cut from Test Site—Red
  - additional copies of the red and blue test sites for use in recording observations (optional)

For each learner

- Engineering Notebook (PDF)

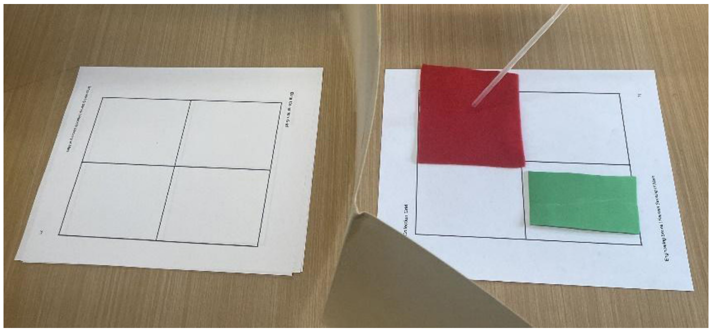
Activity 4 Materials Preparation (35 min.)

Ahead of Time

1. Review the "In-Use Example" in the in Prep & Setup Guide - Examples (PDF) to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. Find a large area in which to teach this activity so that learners are not confused by sounds from each other's groups. Alternatively, plan to allow learners to use devices to record and amplify sounds during the activity.
3. Print out Test Sites, pgs. 60-61, in color. Cut along the lines to provide 4 blue quarter-sheets and 4 red quarter-sheets to each group of four in the half of the class composing the Light group.
4. Print out 4–5 Data Collection Grids, pgs. 62-63, per group.
5. Print out Sound Model Directions, pg. 64, for half the groups and Light Model Directions, pg. 65, for half the groups.
6. Assemble the following materials into bags so that there are enough for half of the learners to have materials for Sound Exploration and half to have the materials for Light Exploration. If you have 24 learners, there should be three bags for Sound Exploration and three bags for Light Exploration.

Sound Exploration Materials

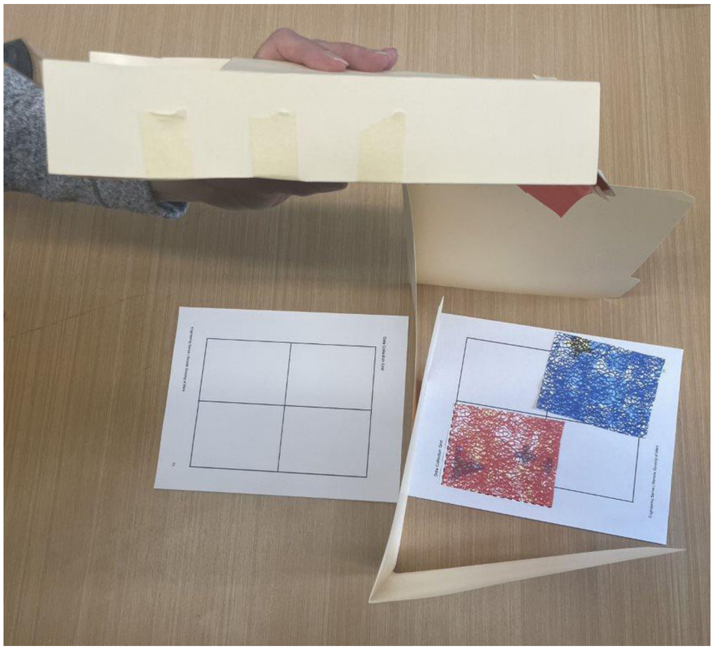
- 2 pieces of felt
- 2 pieces of craft foam
- 2 pieces of paper
- 2 craft sticks
- 2 large straws
- 2 small straws



Scraper test setup

Light Exploration Materials

- 4 blue test sites
- 4 red test sites
- 2 pieces of red cellophane
- 2 pieces of blue cellophane



Light filter test setup

In Your Space

7. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.
8. Prepare a Materials Table with the materials listed above.
9. Cut sheets of felt, paper, and craft foam into four pieces each to provide two quarter-sheets of each material to each group of four in the half of the class composing the Sound group.
10. Cut cellophane into half-sheets to provide two half-sheets to each group of four in the half of the class composing the Light group.

Support Learner Differences

- If it is helpful for learners, you can use full sheets from Test Sites, pgs. 84-85 rather than quarter-sheets. You can also provide each group with additional copies of the quarter-sheets for use in the "Detect Minerals Remotely" section.
- Instead of felt, foam, and paper, you can use other textured materials that are familiar or meaningful to learners. You can also give learners the opportunity to bring in materials to represent minerals. If you use different materials, use those same materials when building the model landscapes for Engineering Activity 6.

Preparation for Engineering Activities 6–9 (60 min.)

The final design challenge for this unit requires the educator to prepare a multi-part model so learners can test their remote sensing devices. Read Activity 6 Materials Preparation on pg. 80 and decide whether to use the Space Screens with learners. **Then consider preparing the following models in parts, or set aside at least an hour to assemble them in one session.**

- Model Landscapes for Site A (2 copies) and Site B (2 copies)
- Optional: Space Screens that prevent learners from looking at the model landscapes on the opposite side and represent the distance between the Earth and other planets

The complete instructions for building Site A and B, pgs. 85-87 and the Space Screens, pg. 88-89 are outlined in this guide, and a video that shows the process of assembly is available. Since remote sensing engineers cannot see the surface of a planet up close, it is important that learners use only the remote sensing devices they create to gather information about each site and that they do not look at the models directly. Keep the model landscapes covered when not in use until groups complete their tests Activity 9.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We designed portable light redirection systems and used them to gather data about objects to answer "How can we use a system to redirect light to gather data from a distance?")* As necessary, draw learners' attention to the *Our Ideas* poster and the term remote sensing.
2. Ask: **What is the problem we are trying to solve?** *(We are trying to figure out how to gather information about Mars from far away.)*
3. Organize learners into groups of four.

Support Learner Differences

If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).

Level Up!

Show the video Why Do Scientists Need to Measure Infrared Light? (5 min.)

Detect Minerals Remotely (25 min.)

Detecting Minerals Using Light and Sound (10 min.)

4. Distribute one copy of *Image of Mars* to each group. Say: **Cameras on spacecraft have captured images of Mars.** Invite teams to discuss this question and then share out: **What does this image tell us about Mars? What does it not tell us?** *(It tells us the planet is round, some areas on it are darker and some are lighter; it has some channels. It does not tell us what the planet is made of or what shape its surface is.)*
5. Say: **NASA is interested in finding out what planets are made of because this can tell them about a planet's history. The types of rocks and minerals on a planet can reveal whether it once had liquid water on it, which means it could have been habitable.** Point to the *Our Ideas* poster and questions this information will answer, such as "How can we learn where water used to be?"
6. Say: **By studying minerals on Earth, scientists know certain minerals reflect certain colors of visible and invisible light. They use this information to identify unknown minerals on other planets. Scientists need engineers like you to create technologies to distinguish between minerals.** Share the Guiding Question or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **How can we learn what the surface of Mars is made of?**
7. Say: **In the first investigation, half of you will explore minerals using sound, and the other half will explore minerals using sight.**

8. Hold up the materials for the Sound Model and demonstrate as you say: **In the Sound Model, felt, foam, and paper represent different minerals. If you feel these materials, you will notice they have different textures. Felt represents clay minerals, foam represents volcanic minerals, and paper represents sulfate minerals. You will investigate these materials by scraping them with craft sticks, large straws, and small straws. You will listen to the sounds they make and feel the vibrations to figure out which scrapers are best at identifying each type of mineral by sound and touch only.** Pass around the materials so learners have a chance to feel them.
9. Hold up the materials for the Light Model and demonstrate as you say: **In the Light Model, triangles, circles, and stars printed on *Mineral Test Site paper* will represent different kinds of minerals that might be found on Mars. Triangles represent clay minerals, circles represent volcanic minerals, and stars represent sulfate minerals. You will notice the shapes are difficult to see. You will use a technology called <u>cellophane</u>. You may recognize cellophane from gift baskets and your kitchen, but this kind is sturdier.** Demonstrate the process as you say: **Cellophane blocks some light but lets other light through, just like the light filters used on NASA spacecraft. Cellophane filters allow some colors to be seen more clearly. You will investigate which colors of cellophane filter the light to make the different shapes easier to see.**
10. Assign groups to either the Sound or the Light exploration and review the instructions on *Data Detection Investigation – Sound*, pgs. 8-9, or *Light*, pgs. 10-11, in their *Engineering Notebooks*. Answer any questions they have. Say: **You will share materials among your group but may work independently for this part of the activity. You have 10 minutes. Don't forget to record your observations in your Engineering Notebooks. You will have to share what you learn with the rest of the group.**
11. Invite one person from each group to gather the supplies and begin the investigation.

Teaching Tip

In this activity, half of learners participate in a sound investigation and half participate in a light investigation. Below are the instructions for both investigations. If you have time, switch groups so that everyone explores both sound and light.

Support Learner Differences

- The "Detect Minerals Using Light" portion of this activity is not accessible to all learners. Therefore, the "Detect Minerals Using Sound" portion presents data that are typically presented visually in tactile and auditory forms for learners to perceive with other senses. Make sure that learners don't misunderstand and think that minerals can actually be identified by scraping the surface of the planet!

  Some learners may find the sound of scraping materials irritating. Consider ways to provide choice to learners about the kinds of scrapers they use. If scraping does not work for learners, they may touch the materials directly instead.
- Encourage learners to use their preferred language as they record their observations.
- As needed, provide groups with a tub or other container to hold their materials.

12. As learners work on the Sound Model, circulate among groups and ask one or more of the following questions: **Which scraper materials are easiest to use? Sturdiest? Easiest to handle?** *(Learners may think that some materials are best in one category but not another.)* **Which scraper is best for identifying the differences between felt and paper? Paper and foam? Felt and foam?** *(Accept all responses that learners can support with observations.)*

13. Write "Scraper Investigation" on the *Our Ideas* poster and draw two columns beneath it–one titled "Texture" and the other titled "Scraper Material." Have learners record their findings in this chart.

14. As learners work on the Light Model, circulate among the groups and ask one or more of the following questions: **What changes do you observe when looking at the red test site through the red filter? Why?** *(Blue and green look darker. See Teaching Tip.)* **Do you see a difference if you fold the cellophane in half? In quarters?** *(The effect of the cellophane becomes stronger, making certain colors easier to see.)*

15. Write "Filter Investigation" on the *Our Ideas* poster and draw two columns beneath it–one titled "Color" and the other titled "Filter Material." Have learners record their findings in this chart.

Detecting Hidden Minerals (15 min.)

16. Get learners' attention and invite those who explored sound to find a partner who explored light.

17. Say: **Engineers sometimes combine remote sensing technologies in spacecraft. You will now use what you learned to combine technologies to gather hidden information about minerals by engineering remote sensing devices.** Point to learners' definition of *remote sensing* on the *Our Ideas* poster.

Teaching Tips

- The differences between sounds are slight. Have learners use their devices to record audio from the scrapers so they can play back the sound and increase its volume if necessary.
- A red filter helps blue or green symbols on a red and white background appear more visible by letting only red light through. This makes the red and white parts of the background look the same. Blue and green look dark through a red filter because the blue or green ink on the paper absorbs most of the red light, so very little is reflected.
- Learners can communicate what they find during this activity in multiple ways, such as drawing or placing duplicate materials on the grid or describing what they detect. Prepare additional red and blue test sites and *Data Collection Grids* to provide multiple options.

18. Grab a portable light redirection system from Activity 3, a *Data Collection Grid*, and two manila folders. Demonstrate as you say: **You will play a game that demonstrates how these technologies are used to gather information about minerals remotely. You will work in pairs. One player will be the Hider. The Hider will set up two manila holders to hide a *Data Collection Grid*. They will then put two pieces of felt, foam or paper OR two red or blue *Test Sites* on the grid in secret. The other player will be the Detector. They will use a scraper, a *Light Redirection System,* and cellophane to figure out what minerals are hidden and which boxes–A, B, C, or D–they are in.** As needed, allow learners to feel the demonstration setup.
19. Say: **The Detector will record what they find on their own *Data Collection Grid*. Afterward, they will check if they were correct. Then the players will switch roles and play again.**
20. Distribute two manila folders, a portable light redirection system from Engineering Activity 3, and two *Data Collection Grids* to each group.
21. While learners are working, circulate and ask: **What worked well to identify the hidden surfaces? What was challenging about detecting the sites?** *(Our system reversed the image, so we saw the sections in a different direction, etc.)* **How did you combine the filters with your detection systems so you could use them at the same time?** *(We taped cellophane to the mirrors, etc.)*
22. Have learners keep track of what they learn on *Data Detection Investigation* in their *Engineering Notebooks*.

Teaching Tips

- The manila folders are intended to block the view of the Detector. Allow learners to modify their scrapers and light redirection systems, but challenge them not to modify the manila folder barriers too much.
- If time permits, and learners are ready, allow them to create and test hidden surfaces using both the different materials and the red and blue test sites.

Reflect (10 min.)

23. Have a few volunteers share their experiences using the scrapers and filters with the group. Ask: **Would you be able to use scrapers to transmit sounds from Mars to Earth?** *(No, because you would have to touch the surface, so it's not remote sensing. No, because sound can't travel through space—it can exist only when there is something to vibrate.)*

24. Revisit the Guiding Question on the *Our Ideas* poster. Ask: **How can we learn what the surface of Mars is made of?** (*We can design/combine technologies like filters that use light to identify minerals*.) Remind learners of the term *filter*.

25. Say: **Today we used filters to let some light pass through but keep other light out. Turn and talk to a partner about how you might use filters, which let some things pass through, but keep other things out, in everyday life.** *(Polarized lenses in sunglasses, separating soil from rocks, photography, etc.).* Have learners record their ideas on the *Our Ideas* poster. Consider returning to learners' ideas at the start of the next activity.

26. Point to the *Our Ideas* poster and ask: **What questions do you still/now have?** (*How can we figure out where to land a rover? How can we learn about the physical properties of the surface?*). Record any new ideas.

Level Up!

Scientists use filters to identify minerals on Mars. Minerals absorb specific colors of visible or invisible light. By using a filter that lets through only that color of light, minerals appear darker in images and can be identified more easily. To help learners better understand the concept of mineral reflection at different wavelengths, you can share images and videos about spectroscopy from the Activity resources page. (5+ min.)

The Worlds Apart Science Pathway goes into more depth about how scientists use spectroscopy, a remote sensing technology, to identify minerals on other planetary bodies.

It is not possible to scrape the surface of Mars from a distance. However, scraping can be useful up close: for example, Mars rovers can use drills to learn about rock hardness. Check out the one on the Perseverance Mission in the article "Testing Rocks on Earth to Help NASA's Perseverance Work on Mars." (10 min.)

Support Thinking

Have learners consider what sound and light have in common. If necessary, explain that they are both waves. Studying the waves can provide information about where they came from.

27. Say: **Good job working as engineers today! Next time, you will learn about a remote sensing technology that uses lasers to gather information about the shape of the surface of Mars.**

Level Up!

Refer to the Engineering Design Process poster (PDF). Ask: **What phases of the *Engineering Design Process* did you use today?** *(Investigating how filters work; iterating filters to make information easier to collect.)* (5 min.)

After the Activity

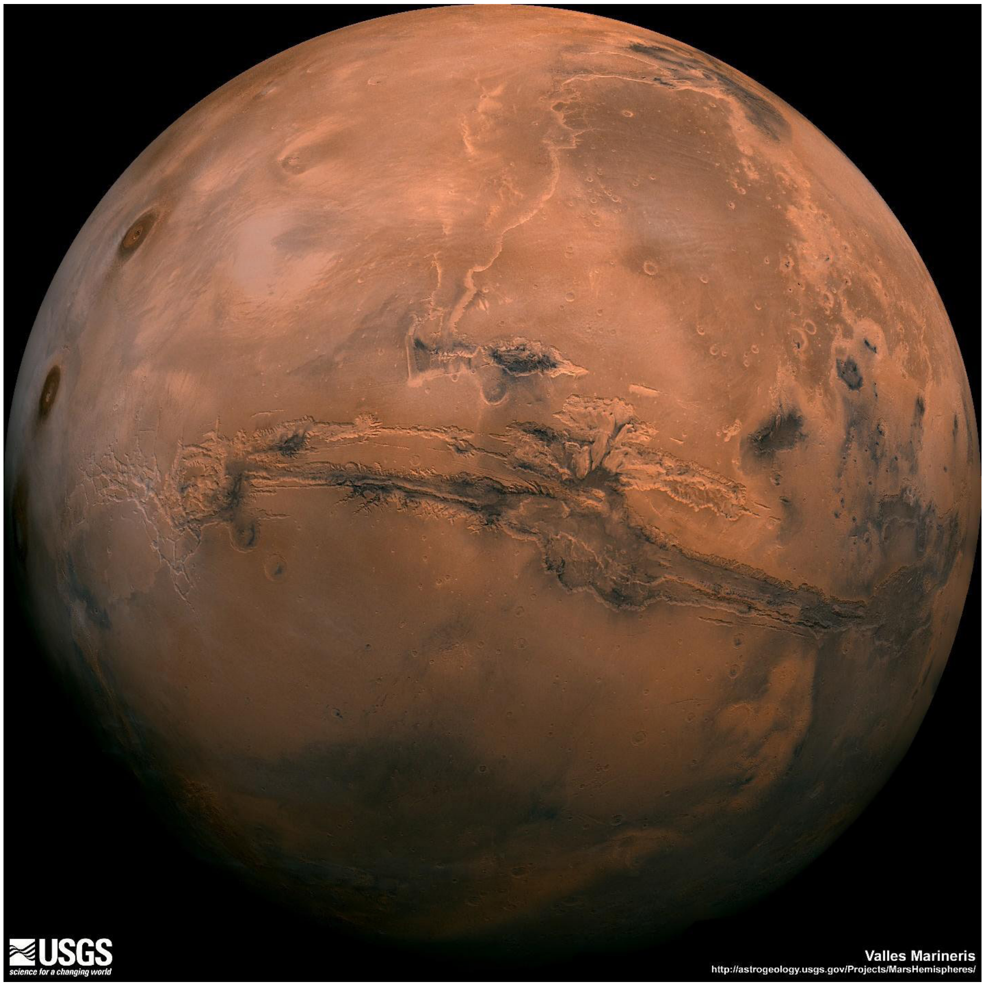
1. Clean up:
   - Keep the *Our Ideas* poster for use in Activity 5.
   - Collect and save the folders and *Data Collection Grids* for use in Activity 5.
   - Save pairs' scrapers and light redirection systems for use in Activity 6.
   - Collect and save the remaining materials for future use.
2. Plan ahead for Engineering Activity 5. See Activity 5 Materials Preparation on pg. 68.
3. Take time to reflect on the following educator prompt: **How did learners interpret the different sensory options (sight and hearing/touch)? What strategies might you use to support multisensory learning in future activities?**

Remote Sensing Additional Resources

QR code leads to resources available for this unit

weblink: https://hov.to/248cf0d9

Image of Mars

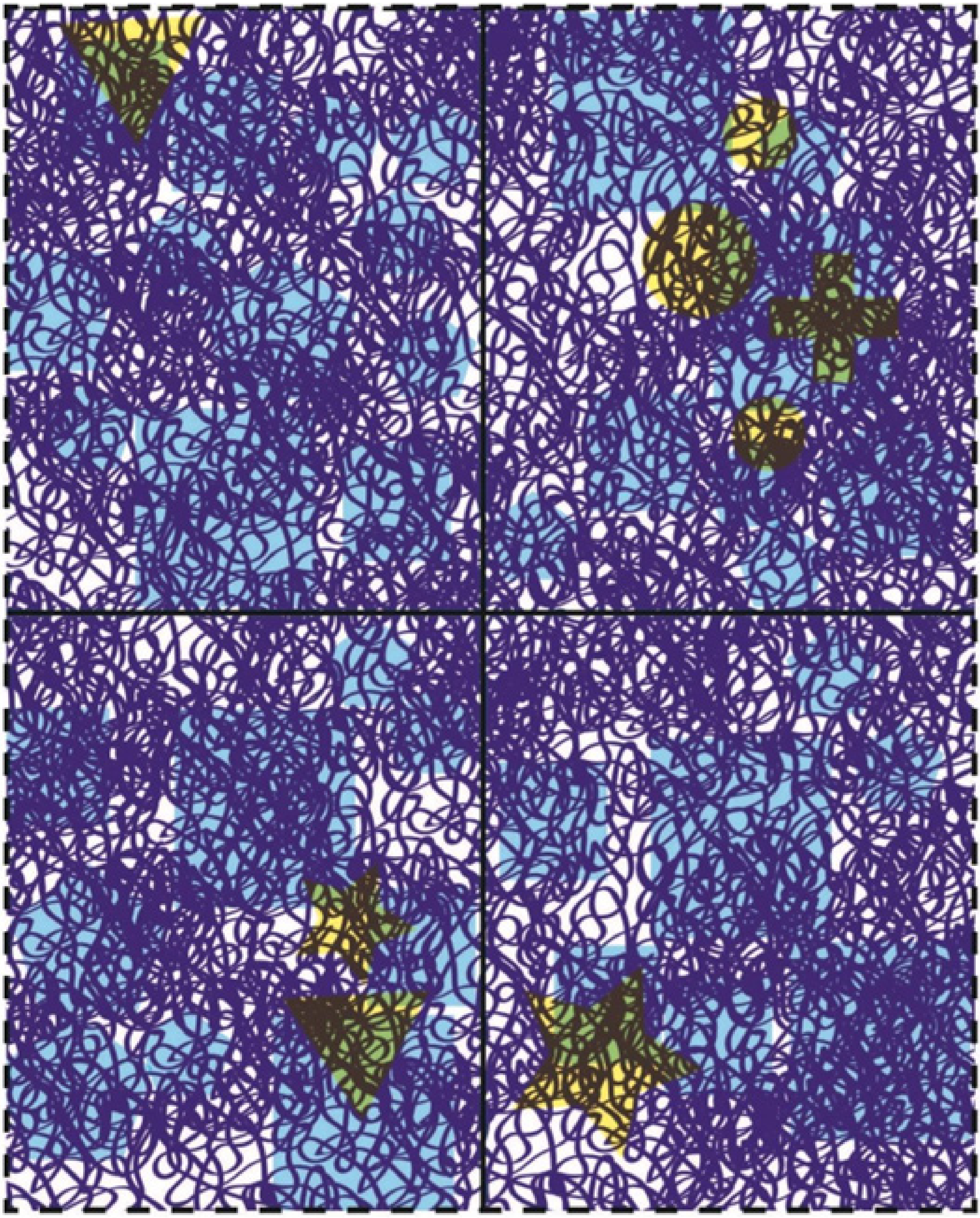


More to Explore

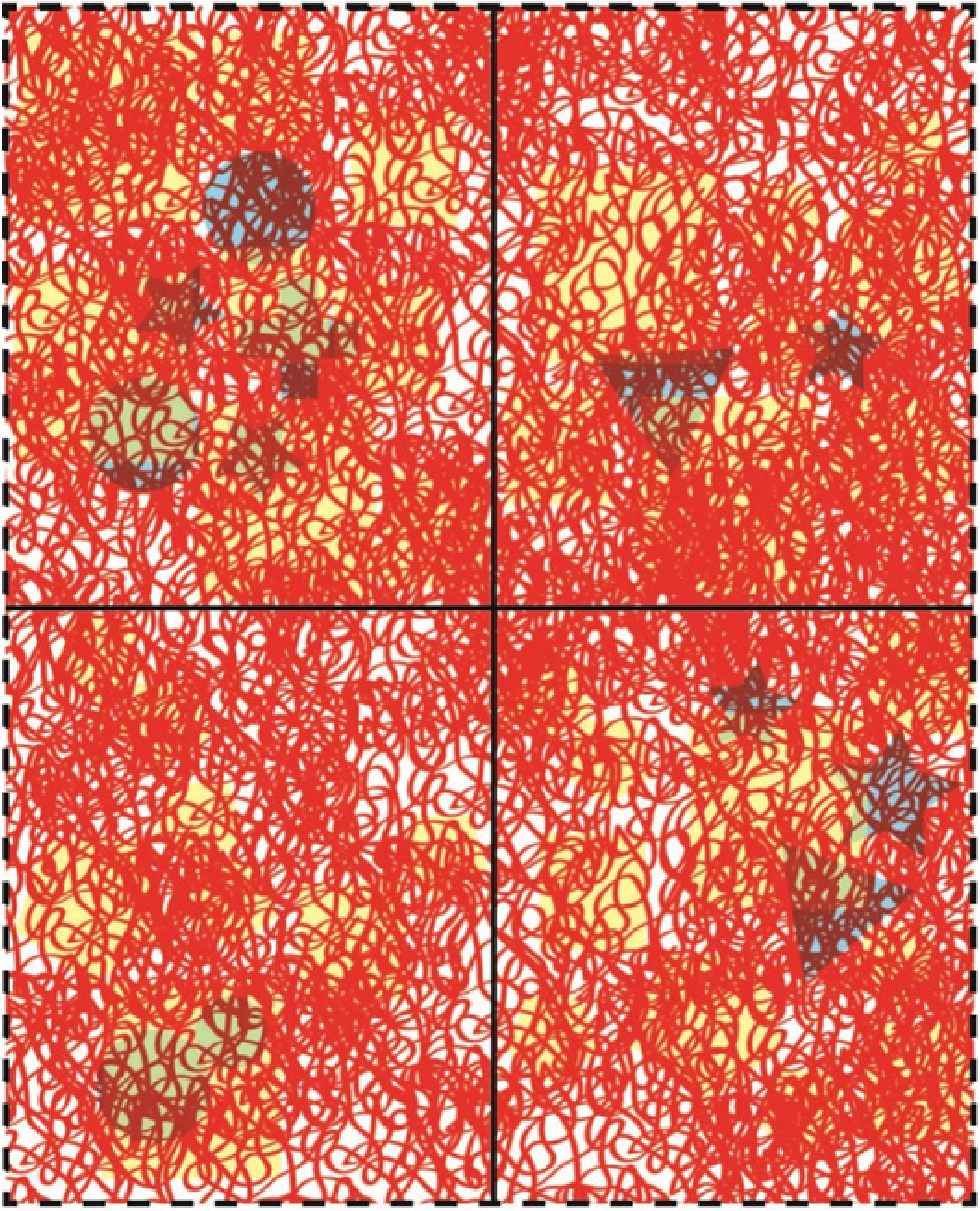
Find out more about NASA on the PLANETS website.

weblink: https://planets-stem.org/remote-sensing/rs-learners/

Test Site-Blue



Test Site-Red



Data Collection Grids

A	B
C	D

Data Collection Grids

A	B
C	D

Sound Model Directions

1. Lay out the materials: felt, paper, and foam.
2. Feel and scrape each material with a craft stick and different-sized straws.
3. Feel and listen to the differences as you scrape.
4. Think about these questions:
   - Which scraper materials are easiest to use?
   - Which scraper materials are sturdiest?
   - Which scraper materials are easiest to handle?
   - Which scraper is best for identifying the differences between felt and paper? Paper and foam? Felt and foam?
5. Record your observations in your Notebook.

Light Model Directions

1. Investigate how the colors on the red and blue test sites look in two ways:
   - with cellophane filters placed over them
   - without cellophane filters placed over them
2. Think about these questions:
   - What changes do you observe when looking at the red test site through the red filter? Why do you think that is?
   - Do you see a difference if you fold the cellophane in half? In quarters?
   - How could a filter help us detect minerals from a distance?
3. Record your observations in your Notebook.

Educator Guide

Engineering Activity 5: Taking Shape: Finding the Shape of the Land

Educator Preview

Activity Snapshot

Learners engineer a model of a LiDAR technology to capture the shape and height of a landscape (topography).

Timing | 45 minutes

Get Ready and Team Up	10 min.
Using LiDAR	25 min.
Reflect	10 min.
Total	**45 min.**

Level Up Activities 5–15 min. each

Prep Snapshot*

Prep Time 30 min.

Set up a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection

- Collaboration
- Creativity

Habits of Mind

- Construct models and simulations.
- Investigate properties and uses of materials.

Guiding Question

How can we learn about the shape of the surface of Mars?

Learners Will Do

Use a straw model to gather information about the shape of a surface.

Learners Will Know

Engineers often use models to represent the technologies or materials they are investigating and test their technologies in model conditions.

Connecting Across Activities

Activity 4: Finding Minerals	Activity 5: Taking Shape	Activity 6: Creating a Remote Sensing Device
Last time, learners explored the use of filters and scrapers to gather data about minerals. These tools are a second technology they can use when designing their complete remote sensing technologies.	**Today,** they design straw model LiDAR systems to gather data on topography. These systems are a third technology they can use when designing their complete remote sensing technologies.	**Next time,** they will combine tools and systems from previous Activities and use their engineering design process to design and test remote sensing devices.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/851cbb1e

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF) Examples | Templates
- towel or similar fabric object
- 1 set of 100 pattern blocks (optional)
- pin screens (optional)

For each learner

- Engineering Notebook (PDF)

For the Materials Table

- coffee stirrers
- rubber bands
- felt
- foam, craft

For each group of four

- Pins and Pings, pg. 76-77
- 2 folders, manila
- 1 ruler
- 1 pair of scissors
- 200 straws, regular size
- 1 sheet of foam, craft
- 1 rubber band
- 1 roll of tape, masking
- 4 cups, paper, 3 oz. (approx. 90 mL)
- 4+ Data Collection Grids, pgs. 62-63

Activity 5 Materials Preparation (30 min.)

Ahead of Time

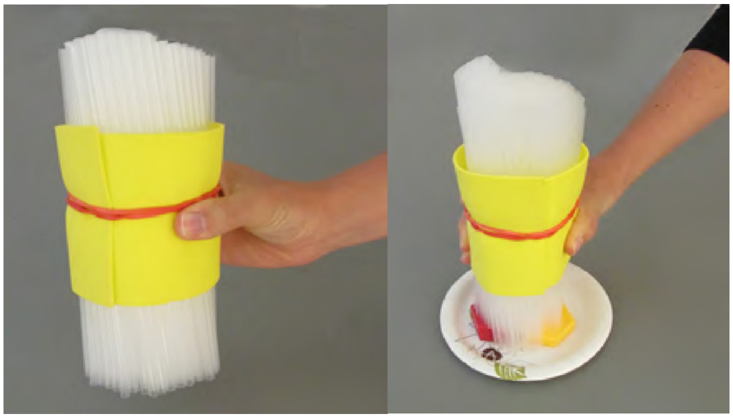
1. Review the "In-Use Example" in the Prep & Setup Guide - Examples (PDF) to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. Print one copy of Pins and Pings, pg. 76-77, per group.

Teaching Tip

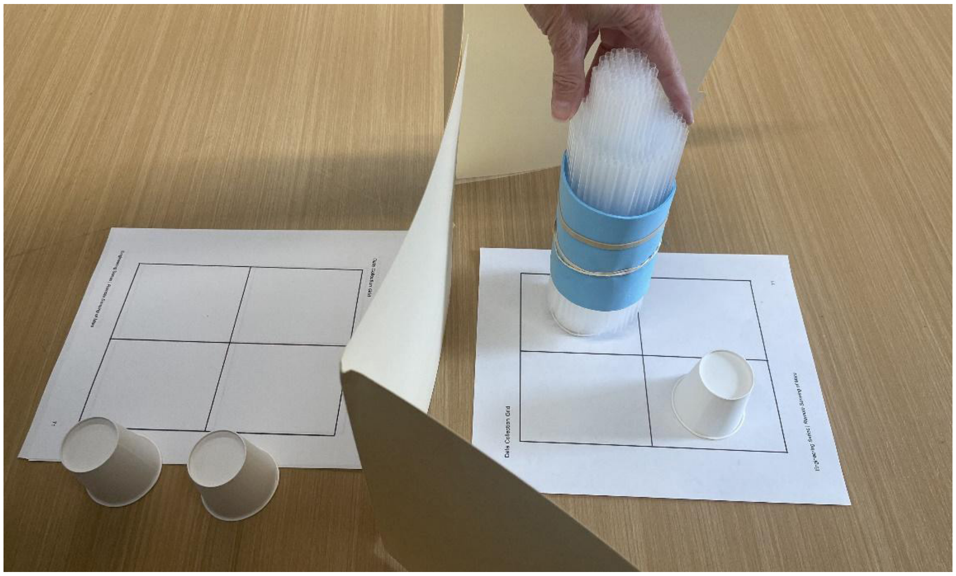
Put the materials for each group in a bag so learners can collect them quickly.

3. Print out 4–5 *Data Collection Grids* per group.

4. Bundle a handful of straws together using a rubber band and craft foam to demonstrate one way learners can keep the straws packed together in their model LiDAR device.



Model LiDAR Device



LiDAR test setup with cups

In Your Space

5. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.

6. Arrange all materials on the Materials Table.

Preparation for Engineering Activities 6–9 (60 min.)

The final design challenge for this unit requires the educator to prepare a multi-part model so learners can test their remote sensing devices. Read Activity 6 Materials Preparation on pg. 80 and decide whether to use the Space Screens with learners. **Then consider preparing the following models in parts, or set aside at least an hour to assemble them in one session.**

- Model Landscapes for Site A (2 copies) and Site B (2 copies)
- Optional: Space Screens that prevent learners from looking at the model landscapes on the opposite side and represent the distance between the Earth and other planets

The complete instructions for building Site A and B, pgs. 85-87 and the Space Screens, pgs. 88-89 are outlined in this guide, and a video that shows the process of how to build a model landscape is available. Since remote sensing engineers cannot see the surface of a planet up close, it is important that learners use only the remote sensing devices they create to gather information about each site and that they do not look at the models directly. Keep the model landscapes covered when not in use until groups complete their tests in Activity 9.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We used scrapers and filters to gather information about minerals to answer questions about what Mars is made of.)* Indicate the scraper and filter charts on the *Our Ideas* poster.

2. Ask: **What is the problem we are trying to solve?** *(We are trying to figure out how we can gather information about Mars from far away.)*

3. Draw learners' attention to the questions on the *Our Ideas* poster about physical properties of the surface, such as height and landforms. Say: **Today, you will think about how to measure the shape of a planet's surface. It will be useful for scientists to know about the shape of the surface, so they know if it will be possible to land a rover.** Share the Guiding Question with learners: **How can we learn about the shape of the surface of Mars?**

4. Organize learners into groups of four.

Support Learner Differences

If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).

Using LiDAR (25 min.)

Investigating Test Surfaces (10 min.)

5. Place the towel on the floor of the room and bunch it up so it has a variety of bumps and flat areas. Say: **Imagine this towel is a landscape. How would you describe the parts of the landscape?** *(Hills, mountains, valleys, plains, mesas.)* Allow learners to discuss in their groups.

   If needed, allow learners to feel the towel.

6. Say: **The shape of land in an area is called that area's *topography*. You will be investigating the topography of Mars.** Write the word *topography* on the *Our Ideas* poster.

7. Show the videos Using Light to Measure Distance (LiDAR Theory) and Using Light to Map Surfaces (LiDAR Uses).

Support Thinking

- If time permits, go outside and travel with learners across areas of varying height and slope. Ask: **What do you notice about the shape and height of the land as we travel?** *(It is going up or down; it is steep, not steep, or flat; it is difficult or easy to travel on; there are a lot of buildings around; it is a valley or hill.)*

- To support learner understanding of the word *topography*, tell learners that it comes from the roots *topo*, meaning "place," and *graph*, meaning "to write or draw." Have learners think of other words they know that come from similar roots, such as *utopia* (a good or nonexistent place), *dystopia* (a bad place), *graph* (a drawing of data), *graphite* (a soft mineral that leaves a gray streak, used to make pencil "lead"), and *bolígrafo* (Spanish for *pen*).

8. Give each group one copy of Pins and Pings, pgs. 76-77. Say: **Scientists use a technology called Light Detection and Ranging, or LiDAR, to learn about topography from a distance. LiDAR is a tool that sends out laser pulses of light from a device to a landscape. It then measures how long those pulses take to return. This timing helps determine the height of the surface. Data from LiDAR can be used to make a representation of the shape of land in an area, which is called a *topographic map*.** Write these words on the *Our Ideas* poster.

9. Say: **Look at the images on Pins and Pings. Will someone volunteer to read the information about LiDAR and pin screens?** After it is read, say: **Turn to a neighbor to discuss: How are the pin screen and LiDAR similar?** *(They both measure topography and create a three-dimensional image.)* **How are they different?** *(LiDAR collects data from a distance by using a laser pulse that moves across an area and measures how long those pulses take to return. The pins in a pin screen are all the same length and need to touch an object to measure its topography.)* Invite sharing.

10. Say: **Engineers use models to represent technologies when the real things are too big, expensive, or dangerous. Because LiDAR is expensive and difficult to build, you will create a model of it.** Demonstrate as you say: **You will use a bundle of straws as a model for the laser used in LiDAR. One way to make a model LiDAR is to collect the straws in a bundle, wrap a piece of foam around the middle, and wrap a rubber band around the foam to hold the bundle in place.**

11. Demonstrate how the straws react by pressing one end of the bundle onto a small, flat object, such as a roll of masking tape, to reveal its shape. (See photographs of this procedure on pg. 69.) Say: **The straws will touch a surface and show the topography underneath, similar to the pin screen.** As needed, pass the demonstration bundle of straws around so learners can feel it.

12. Say: **Your team will assemble a LiDAR model and make sure it works by pressing it on some items on your table. Then you will play a game in your groups. If you were here last time, the game will be familiar.**

13. Demonstrate the set up as you explain (a video demonstration is also available): One pair will be the Hiders and set up two manila folders to hide a *Data Collection Grid*. They will put two cups on the grid in secret. The other pair will be the Detectors. They must use a model LiDAR to figure out which boxes–A, B, C, or D–the cups are in. The Detectors will record what they find by placing the cups in the matching boxes on their own *Data Collection Grid*. Then, they will remove the barrier and check if they were correct. The pairs will switch roles and play again. As needed, give learners time to feel the setup.

Level Up!

In the PLANETS Worlds Apart Science Pathway, learners build three-dimensional topographic models and turn them into two-dimensional topographic maps. After they have a better understanding, they interpret topographic maps of Mars to choose the best landing site for a rover.

To support understanding of LiDAR and other science topics, see the resources on the Quick Links and More Resources webpage (weblink).

Mapping a Test Surface (15 min.)

14. Send one member of each group to retrieve two boxes of 100 straws, a piece of craft foam, a rubber band, two manila folders, a ruler, and four *Data Collection Grids*. Say: **When you have your materials, you may create your test surfaces, test your devices and evaluate the quality of the topographic data your devices collect.**

15. Circulate as groups are testing. Ask: **What happens when the straws hit an object?** *(Straws move up where they hit something. All the straws together show the object's shape.)* **How can you tell when the straws hit a flat area?** *(The straws are all the same height.)*

16. After you are sure learners have gotten the hang of the game, get the group's attention. Say: **The LiDAR devices you engineer must produce information about topography that scientists will use to understand the landscape of Mars. The places NASA is interested in have a more complicated topography than the simple one you just modeled. How can you record and represent where the landscape features are and how high the surface is, so someone else can understand?** *(We could represent how the landscape appears from the side and from above. We could create a 3D image like the one on* Pins and Pings *or a topographic map.)*

17. Say: **As engineers, we don't need to focus on creating a detailed topographic map. Our focus is designing a technology that captures the best information about where landscape features are located and how high they are. As you test, notice the raised shape in the straws, use a ruler to measure differences in height, and draw what the shape looks like from the side in *Side View* on *Test Surface Heights*, page 12 in your Engineering Notebooks. We also need to represent where the landscape features are in relation to the other features. A perspective from above is sometimes called a *bird's-eye view* because it is how a bird would see a landscape while flying over it. Draw what the landscape looks like from above in *Bird's Eye View (page 13).* Add labels as needed.** Add the term *birds'-eye view* to the *Our Ideas* poster.

18. As groups are testing, ask: **What data are you able to collect with your model LiDAR device?** *(The general shape and height of objects on the test surface.)* **How might this data be useful to scientists?** *(Scientists can use it to determine if there are any flat surfaces to land a spacecraft on a planet.)*

Teaching Tips

Learners may need to use tools to make the manila folder barrier slightly shorter or they may need to reach around the barrier.

If you have enough materials, have learners work in pairs.

Support Learner Differences

As needed, provide groups with a tub or other container to hold their materials.

Consider assigning learners to collaborative groups or to roles that value their abilities for this part of the activity. See the Intentional Grouping Strategies, pg. xxii.

Support Thinking

Direct learners to the side view image on *Pins and Pings*. Have them shine a light on the side of the LiDAR devices and view the shadows that are created. This process will help them see the differences in height and draw a side view of the landscape.

Reflect (10 min.)

19. Invite groups to share what they have learned. Ask: **What worked well? What didn't work so well? What was the best way to record what you learned?** Encourage learners to share their designs and drawings.

20. Revisit the Guiding Question on the *Our Ideas* poster: **How can we learn about the shape of the surface of Mars?** *(LiDAR shines a laser on the surface of a planet and measures how long it takes the laser to bounce back. This time lets us calculate how far away the surface is. By using many laser bounces, we can gather information about the topography.)* Remind learners of the terms *topography*, *topographic map*, and *LiDAR*.

21. Ask: **When might someone need to know about topography in everyday life?** *(Finding a place to play soccer or camp, using depth finders for fishing, etc.)* Have learners record their ideas on the *Our Ideas* poster. Consider returning to learners' ideas at the start of the next activity.

22. Point to the *Our Ideas* poster and ask. **What questions do you still/now have?** Record any new ideas.

23. Say: **Good job working as engineers today! Next time, you will use what you learned to design and test remote sensing devices to gather information from a distance so you can recommend the designs that gather the best information.**

Teaching Tip

Let learners know that peeking might help them with this challenge, but it won't help them when they are trying to determine the topography of the surface of a planet!

Level Up!

- After learners have tested their devices and recorded the information once, encourage them to use materials (such as stacks of pattern blocks taped together) to make the test surfaces more complex and challenging. They can also make improvements to their LiDAR models using materials from the table. For example, they can use smaller straws to increase the resolution or improve the model to keep the straws from falling out. (15 min.)

  The PLANETS Worlds Apart Science Pathway goes into more depth about how to interpret topographic maps.

- Refer to the Engineering Design Process poster (PDF). Ask: **What phases of the Engineering Design Process did you use today?** *(We investigated how LiDAR systems work.)*

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for use in Activity 6.
   - Store learners' technologies and collect testing setups and unused materials for use in Activity 6.

2. Plan ahead for Engineering Activity 6. See Activity 6 Materials Preparation on pg. 80.

3. Take time to reflect on the following educator prompts: **How did you help learners understand the ways in which the straw model is similar to and different from real LiDAR? How did you support learners in acquiring difficult vocabulary?**

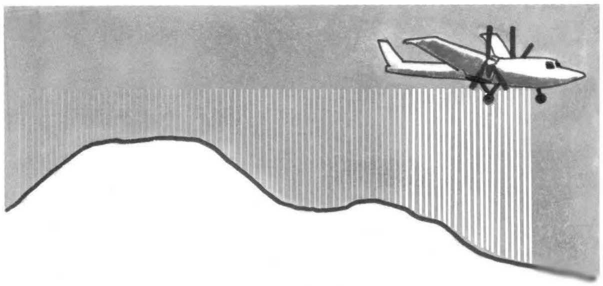
Remote Sensing Additional Resources

QR code leads to resources available for this unit.

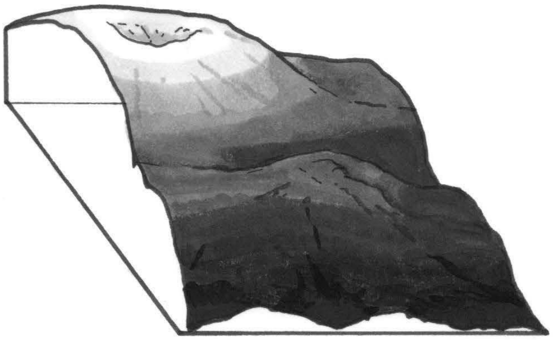
weblink: https://hov.to/248cf0d9

Pins and Pings

A Light Detection and Ranging (LiDAR) system measures the shape of land in an area, or **topography**, by using a laser pulse. It records the time it takes for light to go to the ground and back.

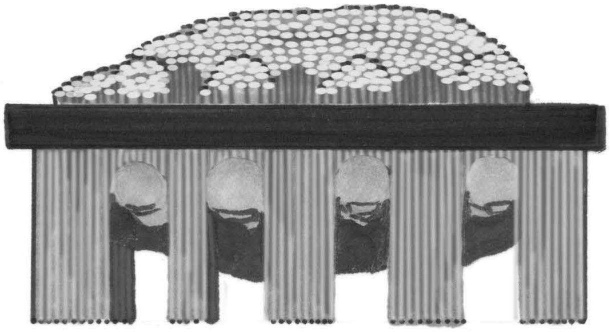


Side View

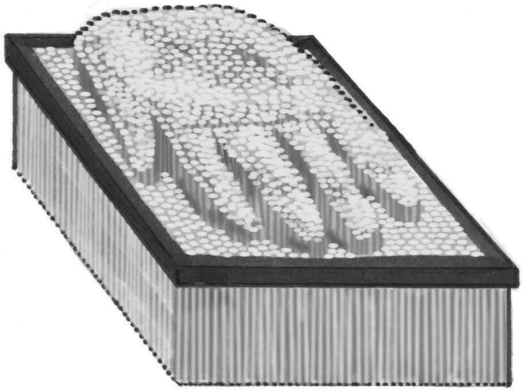


Bird's Eye View

Illustration of an airplane with LiDAR measuring topography and the three-dimensional model it creates after multiple scans.



Side View



Bird's Eye View

Illustration of a hand pushing up pins on a pin screen and the three-dimensional model of the hand a pin screen creates.

More to Explore

Find out more about the Mars Rover Missions on the PLANETS website.

weblink: https://planets-stem.org/remote-sensing/rs-learners/

Engineering Activity 6: Put It Together: Creating a Remote Sensing Device

Educator Preview

Activity Snapshot

Learners work in groups to plan, create, and test remote sensing devices that use the different technologies from the previous activities to gather data from a distance.

Timing | 45 minutes

Get Ready and Team Up	5 min.
Design a Remote Sensing Device	30 min.
Reflect	10 min.
Total	**45 min.**

Prep Snapshot*

Prep Time 60 min.

If you have not yet done so, create model landscapes and (optional) Space Screens.

Set up a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection

- Collaboration
- Critical Thinking

Habits of Mind

- Consider problems in context.
- Weigh the implications of solutions.

Guiding Question

How can we create remote sensing devices to gather different types of data from a distance?

Learners Will Do

Design remote sensing technologies that gather specific types of data and test them.

Learners Will Know

Engineers apply what they learn from investigations to inform their design decisions.

Connecting Across Activities

Activity 5: Taking Shape	Activity 6: Put It Together	Activity 7: The Final Test
Last time, learners designed straw model LiDAR systems to gather data on topography. These systems are a third technology they can use when designing their complete remote sensing technologies.	**Today,** they combine tools and systems from previous Activities and use their engineering design process to design and test remote sensing devices.	**Next time,** they will use what they learned from testing to improve their devices.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/78d51c48

Materials and Preparation

Materials

For the model landscape sites and Space Screens

- Mineral Paper
- 4 boards, tri-fold
- 1 bottle of glue, white
- 20 cups, paper, 3 oz. (approx. 90 mL)
- 1 sheet of felt
- 1 sheet of foam, craft
- 1 knife, utility
- 1 sheet of paper
- 4 shoeboxes, with lids, 7" × 5" × 12" (approx. 18 cm × 13 cm × 30 cm)
- 6 sheets of Styrofoam, 12" × 12" × 1" (approx. 30 cm × 30 cm × 3 cm)
- 1 roll of tape, masking
- 1 set of pattern blocks (optional)

For each learner

- Engineering Notebook (PDF)

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF) Examples | Templates
- 12 sheets of cellophane, blue
- 12 sheets of cellophane, red
- 60 clips, binder, medium
- 25 cups, paper, 8 oz. (approx. 240 mL)
- 25 sheets of felt
- 25 sheets of foam, craft
- 25 folders, manila
- 20 mirrors
- 100 rubber bands
- 25 sheets of paper
- 50 sticks, craft
- 50 sticks, fuzzy
- 2000 straws, regular
- 2000 straws, thin

For each group of four

- 1 ruler
- 1 pair of scissors
- 1 roll of tape, masking
- light redirection system from Engineering Activity 3
- 2 Data Collection Grids
- Test Sites from Engineering Activity 4

Teaching Tip

Stores that display and sell shoes without boxes may have the shoeboxes in storage and donate them if asked.

Activity 6 Materials Preparation (60 min.)

Ahead of Time

1. Review the "In-Use Example" in the Prep & Setup Guide - Examples (PDF) to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. If you have not yet done so, read through the instructions for Model Landscape Assembly, pgs. 85-87 and Space Screen Assembly, pgs. 88-89. You can also watch a video about how to build the model landscapes. Then decide whether to use the Space Screens. This activity should be safe and inclusive. Use the Space Screens only if learners can reach through them safely. Make the choice that is best for your group but still allows all learners to gather data "remotely."
3. Before beginning this activity, make sure you have finished preparing the model landscapes and, if appropriate for your group, the Space Screens. There should be two models each of Site A and Site B, one behind each Space Screen, so multiple groups can access them during testing. (If your group is small, you will need only one model of each site.)

In Your Space

4. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.
5. Set up the model landscape sites and Space Screens.
6. Create a Materials Table with the materials listed above for the whole group and for each group of four.

Activity Guide

Get Ready and Team Up (5 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We designed model LiDAR devices to learn about the topography of Mars and answer questions about where it is safe to land.)*
2. Draw learners' attention to the three kinds of technology on the *Our Ideas* poster: light redirection systems, filters/scrapers, and LiDAR. Check for understanding of these technologies. If needed, return to these terms and have learners discuss the terms and make drawings for them. Say: **You will now use all the ideas you have investigated so far: light redirection systems, filters and scrapers, and LiDAR.**
3. Say: **Today we will start the final design challenge: designing a remote sensing device to gather information about Mars from far away.** Share the Guiding Question with learners aloud and in writing on the *Our Ideas* poster *(using multiple languages as needed)*: **How can we create remote sensing devices to gather different types of data from a distance?**
4. Organize learners into groups of four. Learners will stay in these groups for Activities 7–9.

Support Learner Differences

- If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).
- If learners have struggled with previous activities or concepts, consider starting them with Caris, the scientist who has the simplest mission (landforms). Once successful, learners can select a more challenging mission.

Design a Remote Sensing Device (30 min.)

Imagine and Plan (10 min.)

5. Have learners turn to *Remote Sensing Engineering Challenge, pg. 14,* in their Engineering Notebooks (PDF). Say: **When planning missions, NASA chooses sites on Earth that are similar to the planets they want to investigate, so engineers can design and test devices before sending them into space.**
6. Gather learners around the Space Screen setups. Demonstrate as you say: **The closed shoeboxes behind these screens contain model landscapes that represent sites on Earth that are similar to two sites on Mars that NASA scientists want to explore: Site A and Site B. The Screen makes it difficult to learn about the landscape. You will be on one side of the Space Screen. Site A and Site B will be on the other side. You will design remote sensing technologies to explore the sites through the Screen.** As needed, give learners time to feel and reach through the screens.
7. Say: **For your missions, you will design remote sensing devices to help scientists learn about other planets. Read the *NASA Scientist Cards, pgs. 15-17*, in your Engineering Notebooks**. After they have read, say: **Notice how the designs have different things they must do, or <u>criteria</u>. This is because the scientists have different questions. However, notice we all have the same limitations of materials and time. These are our <u>constraints</u>. With your group, choose a scientist whose mission sounds interesting.**

Teaching Tip

If you have enough materials, encourage learners to work in pairs. Consider strategic pairing and groups that place together learners who complement each other's strengths and areas where they are growing.

8. Point to the *Our Ideas* poster. Say: **You explored different technologies that you can use in your designs: portable light redirection systems, filters, scrapers, and LiDAR. NASA often sends multiple remote sensing technologies on a single spacecraft to collect all the information they need. In the same way, you should combine multiple technologies to get the information the scientist needs.**

9. Answer any remaining questions about the design challenge.

10. Give each group a few minutes to imagine and plan their design, keeping their scientist's criteria and constraints in mind. It may be useful for learners to come up with ideas individually or in pairs, then combine those ideas into a single plan as a group. Learners can record their ideas on *Remote Sensing Plan, pg. 18*, in their Engineering Notebooks (PDF).

11. As groups are planning, circulate around the room and ask: **Which remote sensing technologies will help you gather the information your scientist needs?** *(Light redirection systems and LiDAR to learn about topography; light redirection systems, filters, and scrapers to search for minerals.)*

Create and Test (20 min.)

12. After groups have finished planning, have them gather materials from the Materials Table and begin creating their remote sensing devices. Say: **Remember, your devices must fit through the opening in the Space Screen to reach the model landscapes.**

13. Give learners an opportunity to test their remote sensing devices as they build using the *Test Sites* and *Data Collection Grids* from Engineering Activities 4 and 5.

14. When groups are ready to test their remote sensing devices on the model landscapes (Site A or Site B), remove the lids from the shoeboxes that are behind the Space Screens so that they can collect information.

15. Have groups record what they learn on *Data Collection Grids*. While they work, ask: **What types of information can you collect?** *(Information about the topography and information about the minerals.)* **Are you meeting your scientist's criteria? Are your remote sensing devices working the way you imagined they would?** Make sure learners visit Site A and Site B.

Level Up!

If there are unanswered questions on the chart, use these weblink: https://science.nasa.gov/mars/ to help learners research the answers for themselves. (10 min.)

Support Thinking

If learners are using scrapers in their devices, let them know that they may need to attach objects to extend the scrapers so they are able to reach the model landscapes.

Teaching Tip

Have learners gather small amounts of materials at a time to avoid running out of materials.

If the Space Screen is unstable, have learners take turns holding it still.

Support Learner Differences

As needed, provide groups with a tub or other container to hold their materials.

16. Let groups know when they have ten and five minutes remaining. If they need more time, inform them they will be able to improve their designs during the next session. Have groups label their remote sensing devices.

Reflect (10 min.)

17. Gather groups. Ask: **Did anything surprise you about collecting data with your remote sensing devices?** *(It was difficult to use certain technologies; different technologies were better at different tasks, etc.)* **How might you improve your designs?** *(Make them smaller; make them more accurate.)* Record ideas on the *Our Ideas* poster.

18. Revisit the Guiding Question on the *Our Ideas* poster: **How can we create remote sensing devices to gather different types of data from a distance?** *(It is necessary to combine technologies to get the data we need.)* Remind learners of the terms *criteria* and *constraints*.

19. Say: **Good job working as engineers today! The information your designs gather will help the scientists learn more about Mars and possibly expand our understanding of life and the solar system. Next time, you will improve your designs.**

After the Activity

1. Clean up:
   - Save the *Our Ideas* poster for Activity 7.
   - Label groups' designs and store them in a safe location.
   - Save any remaining materials for the next activity.
2. Plan ahead for Engineering Activity 7. See Activity 7 Materials Preparation on pg. 90.
3. Take time to reflect on the following educator prompt. **How did you help learners embrace and learn from failure during this activity?**

Support Thinking

Learners may say that they have failed. Emphasize that engineers think about designs failing, not about people failing. Explain that failure is an important way in which engineers gather information to improve their designs. Ask: **What did you learn from the failure of this design?** *(The system needs to be a different size; the model LiDAR needs more straws, etc.)*

Level Up!

Invite a family or community member to come in as a special guest and share their knowledge about topics related to light and landscapes. (45 min.)

Refer to the Engineering Design Process poster (PDF). Ask: **What phases of the *Engineering Design Process* did you use today?** *(We brainstormed, planned, created, and tested our remote sensing devices.)*

Remote Sensing Additional Resources

QR code leads to resources available for this unit.

weblink: https://hov.to/248cf0d9

Model Landscape Assembly

The final design challenge requires the educator to prepare model landscapes so learners can test their remote sensing devices. Read the following instructions or watch a setup video on how to build a model landscape.

Materials for each Model Landscape:

- Mineral Paper
- glue
- paper cups
- felt
- craft foam
- utility knife
- paper
- shoeboxes
- Styrofoam
- masking tape

Teaching TIps

- Make the sites in advance and keep them hidden. Learners must not see them until Activity 9.
- Styrofoam can create dust when cut. Consider cutting it underwater or (if you can do so safely) using a hot wire cutter to minimize dust. You could also wear a face mask while cutting.

Model Landscape Site A

Prepare two shoeboxes for Site A, each with the following features:

Must Have

- Lots of Mineral Paper (PDF) printed with triangles, the symbol for clay minerals, and stars, the symbol for sulfate minerals that form in water.
- At least one triangle on the *Mineral Paper* covered in felt, which also represents clay minerals. To do this, cut felt into a triangle shape and glue it over a triangle on the Mineral Paper.
- Mountains or varied terrain made from Styrofoam sheets and cups. Cups must be glued very securely so they do not fall off.
- No flat, open spaces.

Consider Adding

- At least one star on the *Mineral Paper* covered with foam. To do this, cut a piece of foam into a star shape and glue it over a star on the mineral paper. The star and foam both represent sulfate minerals, which form in water.
- At least one circle on each *Mineral Paper* covered with paper. To do this, cut a scrap of paper into a circle and glue it over a circle on the *Mineral Paper*. The circle and the paper represent volcanic minerals.
- Paper cups to create landforms.

An example of Test Site A, which features a low area on the left with two cups providing height and higher areas on the right. The left part of the lowlands is covered with blue Mineral Paper, while red Mineral Paper appears in the center lowlands and blue Mineral paper on the highland at the right side of the box.

Model Landscape Site B

Prepare two shoeboxes for Site B, each with the following features:

Must Have

- Flat, open space, at least 3" × 4" (7.5 cm × 10 cm).
- Mineral Paper, different colors.
- Craters, dips in terrain using Styrofoam sheets

Consider Adding

- At least one star on the mineral paper covered in foam, which represents sulfate minerals.
- At least one circle on each mineral paper is covered in paper, which represents volcanic minerals.
- Craters, dips in terrain using Styrofoam sheets.

Use a utility knife to cut foam sheets and build layers, or stack objects from around the room.

An example of Test Site B, which features a low area covered in blue Mineral Paper on the left. On the right, progressively higher areas appear like stair steps, all of which are covered with red Mineral Paper.

Space Screen Assembly

You will need to assemble four Space Screens in total, one for each model of Site A and one for each model of Site B. Before assembling Space Screens, determine whether the learners in your group can reach through them safely. Make the choice that is best for your group but still allows all learners to gather information "remotely."

Materials for each Space Screen:

- tri-fold board
- ruler
- utility knife
- felt (optional)
- scissors
- duct tape

1. Use a utility knife to cut a 12" × 22" (31 cm × 56 cm) rectangle approximately 10" (25 cm) from the bottom of the trifold board.

Tri-fold board with cutout

2. Optional: Cut a 1" (2.5 cm) wide fringe across four pieces of felt, leaving enough space around the edges to tape each piece to the board. Tape the two pieces of felt to each side of the board so the hole is completely covered.

Felt cut into fringe

Tri-Fold board with cutout and fringe

3. Label two of the screens “Site A” and two of the screens “Site B.” If time allows, decorate all screens using paint or stickers. Decorating the screens provides a visual reminder that they represent a significant distance between the engineers and the landscape site.

Space Screen “Site A” Front

4. Position the Space Screen at the edge of a table so learners can easily access it and reach inside.

Space Screen “Site A” Back

5. Tape one of the model landscapes to the table directly underneath the hole in the Space Screen. The model landscapes are positioned correctly if learners can reach through the Space Screen and collect data from the surface of each site. Keep the lid on the shoebox until groups are ready to test.
6. Tape the Space Screen to the table for extra stability.
7. Repeat to complete the remaining three Space Screens.
8. Position the Space Screens back-to-back or against a wall, so the model landscapes remain hidden as much as possible.

Educator view from Space Screen “Site A” as learners reach through to experiment

Engineering Activity 7: The Final Test: Improving a Remote Sensing Device

Educator Preview

Activity Snapshot

Learners improve their remote sensing devices by making them easier to use, more compact, or better able to gather high-quality data.

Timing | 45 minutes

Get Ready and Team Up	10 min.
Improve and Test	25 min.
Reflect	10 min.
Total	**45 min.**

Level Up Activities 10 min. each

Prep Snapshot*

Prep Time 35 min.

Copy Share-Out invitations.

Set up Space Screens and a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection

- Collaboration
- Creativity
- Critical Thinking

Habits of Mind

- Make evidence-based decisions.
- Persist and learn from failure.

Guiding Question

How can we improve our remote sensing devices?

Learners Will Do

Use test results to improve designs.

Learners Will Know

Engineers reflect upon, alter, and improve their designs.

Connecting Across Activities

Activity 6: Put It Together	Activity 7: The Final Test	Activity 8: Spread the Word
Last time, learners combined tools and systems from previous Activities and used their engineering design process to design and test remote sensing devices.	**Today,** they use what they learned from testing to improve their devices.	**Next time,** they will plan to share their designs at an Engineering Share-Out.

Activity Resources

Access background information, videos, and other resources using the link or QR code. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/f850a25a

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF) Examples | Templates
- crayons and markers
- Model landscape sites and Space Screens from Engineering Activity 6
- remaining materials from Engineering Activity 6
- 50 sticks, craft
- 75 sticks, fuzzy
- 50 sheets of paper

For each group of four

- remote sensing devices from Engineering Activity 6
- 1 pair of scissors
- 1 ruler
- 1 roll of tape, masking
- 2 Data Collection Grids (copied from pg. 62)

For each learner

- Engineering Notebook

Activity 7 Materials Preparation (35 min.)

Ahead of Time

1. Review the "In-Use Example" in the Prep & Setup Guide - Examples (PDF) to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. Make copies of the Engineering Share-Out Invitation, pg. 96 in this guide, to distribute to learners' family and friends.

In Your Space

3. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.
4. Arrange the Space Screens according to the Space Screen Assembly, pgs. 88-89,of this guide.
5. Create a Materials Table with the remaining materials from Activity 6.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We designed remote sensing devices to answer scientists' questions and tested them on the test sites.)* Have groups share their results, discuss problems, or give advice from the last activity. Ask: **Which scientist did you choose to work with, and were you able to collect the information they needed?** *(The scientists are Jaime, Caris, and Alex. Learners may or may not have gathered the information they needed about topography, landing sites, and minerals.)* **What about your design is working well?** *(Features of the light redirection systems, filters, scrapers, and LiDAR.)* **What challenges did you encounter?** *(Positioning the remote sensing device and interpreting the data it provides, etc.)*

2. Say: **Today, you will improve your remote sensing devices to make sure that they can collect all the information your scientist needs about minerals, topography, and landforms. Refer to *Remote Sensing Plan, page 18* in your Engineering Notebooks (PDF), and add notes as you improve.** Share the Guiding Question with learners aloud and in writing on the *Our Ideas* poster *(using multiple languages as needed)*: **How can we improve our remote sensing devices?**

3. Organize learners into their groups of four from the previous activity.

Support Learner Differences

If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).

Improve and Test (25 min.)

4. Allow groups to collect materials and begin working. Ask: **How are you improving your design?** *(We are making it fold up so it can be smaller; we are focusing on one area to get more detailed data.)* **Are your improvements working out the way you thought they would? What else can you do to improve?** *(Find a way to use fewer materials or make the device easier to position.)*

5. Have groups test their improved remote sensing devices and record the data they collect on *Data Collection: Improve, page 21* in their *Engineering Notebooks*.

6. As groups are working, circulate among them and ask questions such as the following: **Is your device collecting better-quality data for the scientists? How do you know?** *(Comparisons that the device can distinguish between minerals better or can measure topography better, etc.)* **What types of information are you able to collect so far?** *(Information about topography and minerals, data in the form of light, data in the form of sound, etc.)*

Level Up!

Room on a spacecraft is usually very limited, so another way to improve a remote sensing device is to make it as small and compact as possible. Share examples of spacecraft with multiple remote sensing instruments, such as the Mars Reconnaissance Orbiter. Learners can challenge themselves to make their remote sensing devices compact enough to fit into a box of a specific size. To make the box, fold a piece of paper in half to form a 8.5" × 5.5" rectangle. Challenge learners to fit their devices on the rectangle. (10 min.)

7. Let groups that are still working know when there are ten and five minutes remaining. Have groups label their remote sensing devices.

Reflect (10 min.)

8. Have each group come up with an answer to the Guiding Question: **How can we improve our remote sensing devices?** *(We can adjust the positioning of the light redirection system and LiDAR. We can choose different filters or scrapers to use. We can make the device smaller.)* Have learners record their answers on the *Our Ideas* poster.

9. Ask: **Why is it important to try to improve, even when things are working pretty well?** *(It is good to try to be better; there is always room for improvement, this is how we discover new ways of doing things, etc.)*

10. Say: **Good job working as engineers today! Next time, you will make a plan to share what you have done with an audience.** Hand out copies of Engineering Share-Out Invitation, pg. 96, for learners to give to caregivers, family, and friends.

Support Thinking

Tell learners that the Lunar Reconnaissance Orbiter is a spacecraft that launched in 2009 to investigate the surface of the Moon. It has six instruments onboard to investigate temperature and radiation. It also includes one "technology demonstration." This is an instrument being tested to see if it works. Even NASA must do experiments before getting things right! Explain that failure is natural in engineering. Engineers gain information from failed designs and use it to make future designs better.

Level Up!

Refer to the Engineering Design Process (PDF) poster. Ask: **What phases of the *Engineering Design Process* did you use today?** *(We iterated our remote sensing devices and tested them again.)*

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for Activity 8.
   - Save each group's design, the Space Screens, and the landscape sites for the Engineering Share-Out.

2. Plan ahead for Engineering Activity 8. See Activity 8 Materials Preparation on pg. 98.

3. Take time to reflect on the following educator prompt: **How did you support constructive group work during this activity?**

Remote Sensing Additional Resources

QR code leads to resources available for this unit.

weblink: https://hov.to/248cf0d9

Engineering Share-Out Invitation

You're invited to the Engineering Share-Out

Come see your young engineer showcase their remote sensing device!

Date: ______________________________

Time: ______________________________

Location: ___________________________

Grantee

Educator Guide

Engineering Activity 8: Spread the Word: Preparing for the Engineering Share-Out

Educator Preview

Activity Snapshot
Learners recommend a remote sensing device to be sent on a spacecraft.

Timing | 45 minutes

Get Ready and Team Up	10 min.
Share-Out Preparation	25 min.
Reflect	10 min.
Total	**45 min.**

Prep Snapshot*

Prep Time **40 min.**

Set up Space Screens and a Materials Table.

**See Materials & Preparation for full info.*

21st Century Skills

Connection
- Collaboration
- Communication

Habits of Mind
- See themselves as problem solvers.
- Make evidence-based decisions.

Guiding Question
How can we share information about our remote sensing device design with others?

Learners Will Do
Plan and create materials for communicating learning and designs to others.

Learners Will Know
Engineers have valuable knowledge to share about the problem they have solved.

Connecting Across Activities

Activity 7: The Final Test	Activity 8: Spread the Word	Activity 9: Sum It Up
Last time, learners used what they learned from testing to improve their devices.	**Today,** they plan to share their designs at an Engineering Share-Out.	**Next time,** they will meet with community members at the Engineering Share-Out to have conversations about their designs and remote sensing.

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/36f54972

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF) Examples | Templates
- crayons and markers
- Model landscape sites and Space Screens from Engineering Activity 7
- remaining materials from Engineering Activity 7
- ways to record ideas, such as chart paper, index cards, or sticky notes

For each group of four

- remote sensing devices from Engineering Activity 7

For each learner

- Engineering Notebook (PDF)

Activity 8 Materials Preparation (40 min.)

Ahead of Time

1. Review the "In-Use Example" in the Prep & Setup Guide - Examples (PDF) to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. Invite people from the community, including families and friends of learners, to the Engineering Share-Out.

In Your Space

3. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.
4. Create a Materials Table with the materials remaining from Engineering Activity 7.
5. Arrange the Space Screens according to the Space Screen Assembly, pgs. 88-89.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We improved our remote sensing devices and tested them again to better answer scientists' questions.)* If learners describe specific improvements, you can note them on the *Our Ideas* poster.

Support Learner Differences

If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).

2. Say: **You'll be sharing information about your remote sensing devices with others.** Share the Guiding Question with learners aloud and write it on the *Our Ideas* poster *(using multiple languages as needed)*: **How can we share information about our remote sensing device design with others?**

3. Organize learners into the same groups of four as the last session.

Share-Out Preparation (25 min.)

4. Say: **We tested our remote sensing devices on test sites on Earth. NASA needs to choose remote sensing devices to send to space onboard spacecraft. We need to explain how our devices work.**

5. Give each group time to think about the following questions: **What are the important ideas you think we should share?** *(Our design process; the problem of gathering information from a distance; the definition of remote sensing; technologies for remote sensing; how our devices solve the problem of collecting information from a distance; the types of data our devices collect to answer the scientists' questions; the criteria our devices meet, etc..)* **How do you think we should share our findings?** *(Posters; drawings, mapping or graphing our findings; recording a video or audio message; staging a performance; writing a description, etc.)* When everyone is ready, discuss as a whole group.

6. The Share-Out is a chance for learners to explain their thinking and reflect on what they learned about remote sensing throughout the unit. As a group, agree upon a structure for the Share-Out. Possible structures include the following:
   - Storytelling: Groups use the evidence they've collected to tell stories about the Test Sites and what the scientists might find there.
   - Gallery Walk: Groups stand at their stations and explain their technologies, posters, graphs, maps, writings, drawings, or audio or videos on small devices.
   - Pair-Share: Groups pair off and share their choices with one another.
   - Screening: The whole group watches video or audio files that learners have created. If time permits, they can make slideshows or animations.
   - Performance: Some people play scientists asking questions about learners' remote sensing devices. You can develop script cards to include adults in the play.
   - Discussion: Learners and community members share their knowledge. You can write discussion prompts to lead this discussion.

Support Thinking

To support learners' understanding of different methods of presenting information, have learners recall or share examples of different sharing methods they have used in the past.

7. Say: **With your groups, prepare to communicate your designs and the information you gathered. Allow groups to collect materials and begin working.**
8. Rotate among the groups to provide support as needed. Ask: **What do you want everyone to know about your device?** *(How our device works. What information it can collect about the landscape or the minerals.)* **How will you communicate the different types of information your device collected?** *(Drawing a map of the model landscape sites, demonstrating how the remote sensing technologies work, etc.)*
9. As groups are practicing, give them time to finish creating their remote sensing devices. Let learners know when they have five minutes remaining.

Reflect (10 min.)

10. Have groups pair up and discuss the Guiding Question on the *Our Ideas* poster: **How can we share information about our remote sensing device design with others?** *(By talking, writing, or drawing; discussing with others; making records such as videos and audio recordings, etc.)*
11. Say: **Good job working as engineers today! In the next session, you will share your designs and the information you collected with others.** Have each group discuss: **Why is it important to share what we have done and learned with others?** *(So others can build on our knowledge; so we don't make the same mistakes, etc.)*

Support Learner Differences

Some learners may disengage if the Share-Out contains too much whole-group discussion. Think about what your learners need and ensure they choose an appropriate Share-Out structure.

If you have learners who speak multiple languages, encourage them to share in their preferred languages. Circulate and ask groups: **Where can you include your preferred language or other languages you know in your share-out?** Encourage learners to make welcome signs and present in different languages spoken by the audience.

All learners should contribute to the Share-Out, but not everyone will feel comfortable presenting in the same style. Indigenous learners may feel it is inappropriate to present directly as the center of attention. Ensure nonverbal presentation methods are available, and encourage participation behind the scenes, not just in presenting in front of the class.

This discussion can be an opportunity to have learners share and learn from one another about what methods feel most comfortable for them. They can celebrate the diversity of ways in which they can communicate.

Teaching Tip

Let groups know that they will have time to finish their designs as part of preparing for the Share-Out.

Level Up!

Refer to the [Engineering Design Process poster (PDF)](). Ask: **What phases of the *Engineering Design Process* did you use today?** *(We planned how to communicate about our remote sensing devices.)*

After the Activity

1. Clean up:
   - Keep the *Our Ideas* poster for use in the Engineering Share-Out.
   - Save each group's design and presentation materials, the Space Screens, and the landscape sites for the Engineering Share-Out.
2. Take time to reflect on the following educator prompt: **What methods did learners choose to present their designs? What did you learn from the methods they chose?**

Remote Sensing Additional Resources

QR code leads to resources available for this unit.

weblink: https://hov.to/248cf0d9

Educator Guide

Engineering Activity 9: Sum It Up: Engineering Share-Out

Educator Preview

Activity Snapshot

Learners present their recommendations about remote sensing devices.

Timing | 45 minutes

Get Ready and Team Up	10 min.
Engineering Share-Out	25 min.
Reflect	10 min.
Total	**45 min.**

Prep Snapshot*

Prep Time 40 min.
(several days in advance)

Set up Space Screens and a Materials Table.

Invite community members.

See Materials & Preparation for full info.

21st Century Skills

Connection

- Collaboration
- Communication

Habits of Mind

- See themselves as problem solvers.
- Make evidence-based decisions.

Guiding Question

How can we share information about our remote sensing device design with others?

Learners Will Do

Communicate design choices to others and support these with evidence.

Learners Will Know

Engineers have valuable knowledge to share about the problem they have solved.

Connecting Across Activities

Activity 8: Spread the Word	Activity 9: Sum It Up	Science Pathway
Last time, learners planned to share their designs at an Engineering Share-Out.	**Today,** they have conversations about their designs and remote sensing.	**Next time**, learners experience the science of this topic in the PLANETS Worlds Apart Science Pathway (optional).

Activity Resources

Access videos and digital resources using the link or QR code below. More information for teaching this curriculum is available in the Educator Guide Introduction, pgs. iii-xxvi. Access more PLANETS units, research, and pathways at https://planets-stem.org/.

QR Code for Activity Resources

weblink: https://hov.to/0be34884

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document). See Prep & Setup Guide (PDF)
  Examples | Templates
- crayons and markers
- Model landscape sites and Space Screens from Engineering Activity 7
- remaining materials from Engineering Activity 7
- ways to record ideas, such as chart paper, index cards, or sticky notes

For each group of four

- remote sensing devices from Engineering Activity 7
- presentation materials from Activity 8

For each learner

- Engineering Notebook (PDF)

Activity 9 Materials Preparation (40 min.)

Ahead of Time

1. Invite people from the community, including families and friends of learners, to the Engineering Share-Out.
2. If your Share-Out includes asking the scientists' questions, invite family, peers, and other staff members to play the roles of the scientists using the Scientist Cards, or plan to ask questions on behalf of the scientists yourself.

In Your Space

3. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.
4. Arrange the Space Screens according to the Space Screen Assembly, pgs. 88-89.
5. Post learners' engineering design process depiction and have chart paper, index cards, or sticky notes available.

Activity Guide

Get Ready and Team Up (10 min.)

1. Ask: **If you did the last activity, what did you do and why?** *(We prepared to share our remote sensing designs in the Engineering Share-Out.)*
2. Share the Guiding Question with learners aloud and in writing on the *Our Ideas* poster (using multiple languages as needed): **How can we share information about our remote sensing device design with others?**
3. Organize learners into the same groups of four as the last session.
4. Give learners five minutes to set up for the Share-Out so they can present in the ways that they have planned.

Engineering Share-Out (25 min.)

5. When learners are ready, invite guests into the room and explain how the Share-Out will proceed. Carry out the steps of the Share-Out as the class has planned.
6. As they experience the Share-Out, invite families and other guests to think about their family, cultural, or other knowledge related to what they observe here today and share that knowledge with learners individually or the event as a whole.
7. If you or other adults ask questions to learners, consider asking the following: **What are some things you investigated to help you solve this problem?** *(Changing the path of light with mirrors, measuring the topography of model landscapes, investigating the minerals on the model landscape, etc.)* **What did you test that worked well? What did not work so well? If you had more time, how would you improve your design? Are there any elements of another group's design that you would incorporate? How did your engineering design process help you reach this final design?** *(Reminding us to investigate so we had all the information we needed; reminding us to iterate rather than sticking to our first designs, etc.)*
8. At the end of the Share-Out, say: **Great job being remote sensing engineers and communicating your findings!** Have learners thank the guests.

Support Learner Differences

- If new learners are joining you, lead an inclusion activity (pgs. xx-xxi) and use other engagement strategies as necessary (pgs. viii-xvi).
- To ensure the Share-Out is accessible as possible, provide tactile, audio, and video resources from throughout the pathway to attendees as appropriate.
- Encourage learners to share in their preferred language. This practice may also help ensure inclusivity for the learners' invited families and guests.

Teaching Tip

Print the list of questions in Step 3 below for your guests to ask the learners after they share.

Reflect (10 min.)

9. Say: **Now that you are done testing remotely, you can visit the Earth-based testing sites.** Uncover the model landscapes for Site A and Site B for learners and guests to examine.
10. Ask: **What similarities and differences do you notice between the information you gathered and the model landscapes?** *(We missed some minerals, we thought the area was steeper than it actually was, etc.)* **How could you further improve your remote sensing devices?** *(We could use smaller straws to get more detail about topography, we could add more scrapers or cellophane to better identify minerals, etc.)*
11. Ask one or more of the following questions: **Which phases of your engineering design process were most helpful to you?** *(The Iterate phase because we could make our devices better, etc.)* **What did you enjoy most about being part of this NASA mission team?** *(Solving problems and working with scientists and other engineers to prepare for a mission to space, etc.)* **Do you consider yourself an engineer? Why or why not?** *(Yes, because I figure out how to make things to solve problems and I help people by designing technologies, etc.)*
12. Say: **Good job working as engineers today! Can you imagine other problems you might solve using your engineering design process?** *(Engineering challenges at home, at school, or in the local community, etc.)*

After the Activity

1. Clean up:
   - Collect the Engineering Notebooks.
   - Decide if you want to keep the *Our Ideas* poster. Term cards can be kept for the future.
   - Reset the space in which you held the Share-Out.
   - Save the model landscape sites, Space Screens, and any unused materials for use when teaching these activities in the future.
2. Take time to reflect on the following educator prompt: What strategies did you use to help learners feel comfortable when sharing their design ideas during this activity? How might these strategies work for other activities in the future?
3. If time permits, read the *PLANETS Remote Sensing* Science Pathway and consider implementing it so that learners can extend their understanding of remote sensing and the relationships between scientists and engineers.

Level Up!

If your learners enjoyed this planetary engineering design challenge, they would also enjoy the Rover Observation and Discoveries in Space (ROADS) student challenges. Show your learners the [NASA National Student Challenges]() weblink. (15 min to review weblink, 10-15 hours per challenge)

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