Activity Four: Extract, Pack, Transport

EDUCATOR NOTES

Learning Objectives

Students will

- Gather data by spectroscopically locating simulated ilmenite
- Collect simulated ilmenite by mining the simulated lunar surface
- Gather data while extracting oxygen from the simulated ilmenite over time
- Design and test a cold fuel transfer system

Challenge Overview

In this activity, students will work in small groups to locate simulated ilmenite (ice with crushed effervescent tablets) and mine it. Students will work together to design a cold fuel transfer system to store the ilmenite discovered for transfer to Gateway. Future exploration missions will include visits to the Gateway, a space habitat in orbit around the Moon. NASA and its partners will use the Gateway to create a permanent presence in cislunar space that will drive activity with commercial and international partners, help explore the Moon and its resources, and leverage that experience toward human missions to Mars.

Suggested Pacing

60 to 90 min (with educator preparation the day before and one overnight for student projects)

National STEM Standards

Science and Engineering (NGSS)	
Disciplinary Core Ideas • MS-PS1-2 Matter and its Interactions: Analyze and interpret data on the properties of substances before and after the substances interact to determine of a chemical reaction has occurred. • MS-PS1-4 Matter and Its Interactions: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. • MS-PS3-3 Energy: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. • MS-PS3-4 Energy: Plan an investigation to determine the relationship among the energy transferred, type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. • MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. • MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. • MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. ***Crosscutting Concepts*** • Cause and Effect: may be used to predict phenomena in natural or designed systems. • Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system. • Influence of Science, Engineering, and Technology on Society and the Natural World: The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.	***Science and Engineering Practices*** • Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings. • Constructing Explanations and Designing Solutions: Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. • Planning and Carrying Out Investigations: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Asking Questions and Defining Problems: Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. • Developing and Using Models: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Technology (ISTE)	
Standards for Students • 1.1.d Empowered Learner: Students understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies. • 1.4.a Innovative Designer: Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems. • 1.4.c Innovative Designer: Students develop, test and refine prototypes as part of a cyclical design process.	• 1.5.b Computational Thinker: Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making. • 1.7.c Global Collaborator: Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.
Mathematics (CCSS)	
Mathematical Practices • MP.2: Reason abstractly and quantitatively. • 7.EE.3: Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.	***Mathematical Practices (continued)*** • 6.NS.C.5: Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero). • 6.G.A.2: Apply the formulas V = l w h and V = b h to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems.

Challenge Preparation

- Read the Introduction and Background section for this guide and the Educator Notes for this activity
- Prepare a divided plate for each group the day before. For each plate
  - Crush up three effervescent tablets and mix with enough crushed ice to fill one section of the plate. Work quickly so that the ice does not melt and activate the effervescent tablets
  - Place only crushed ice into the other sections of the plate
  - Store plates in a freezer until students are ready to conduct the test procedure
- Prepare materials and set up an area in the room where students can retrieve the items they plan on using
- This activity also requires leaving the liquids overnight (and a second night if you require a redesign) to record the amount of evaporation in the storage devices the students create. This schedule can be adapted to fit your situation but be aware that it takes several hours for evaporation. If students do not have time for testing their transfer system the next day, at least have them come to record the evaporation and test the transfer system another day.
- Do not leave specimen in an extremely warm area of the classroom or there will be nothing to measure the next day and transfer!
- Make a copy of the data tables for the teams to record their data

Materials

- Effervescent tablets
- Ice cubes, small flexible cooler packs, cold water, etc.
- White Styrofoam divided plates
- Cardstock
- Spoons
- Straws and coffee stirrers of various sizes
- Pipe cleaners
- Freezer, zipper disposable bags, quart size
- 8.5-inch X 11-inch red transparencies
- 8.5-inch X 11-inch blue transparencies
- Variety of recyclable materials for the cold storage device and transfer system, such as
  - Food storage tubs
  - Egg cartons
  - Small medicine cups
  - Film canisters
  - Plastic test tubes

- Bubble wrap
- Tin foil
- Clear wrap
- Insulated cups
- Cardboard or shoe boxes
- Clear tape
- Scissors
- Centimeter rulers
- Digital scale or balance
- Safety goggles
- Thermometer
- Graph paper
- Stopwatches

Safety

- Remind students about the importance of classroom and lab safety
- Use disposable latex-free gloves as necessary
- Ensure students wear protective goggles when reacting effervescent tablets
- Ensure students practice classroom safety while performing this activity and avoid creating slip hazards due to spills. Any floor areas that may get wet should be protected from foot traffic.
- Ensure students practice safe cutting techniques when using scissors and carefully support the piece being cut while using care on the placement of the hand not holding the scissors
- Ensure students avoid moving around the room with scissors or other sharp objects

Introduce the Challenge

- We learned many things about the Moon during the Apollo era flights. Much of this knowledge comes from the rock samples that the astronauts brought back with them from the Moon. These samples were one of the greatest benefits of sending humans to the lunar surface. Before their missions, the astronauts went through training to recognize different types of rocks and their significance. NASA's Vision for Space Exploration calls for a return to the Moon before going to Mars and beyond. We'll learn how to "live off the land" by making oxygen and rocket propellants from the local materials, and we'll be testing new technologies and operations. Living and working on the Moon will be a test run for living and working on Mars and beyond. In this lesson, you will locate and simulate the mining of ilmenite for its oxygen from the surface of the Moon. You will then collect the oxygen that is extracted from the ilmenite and design and build a cold storage device that can transfer the oxygen to the Gateway vehicle that will be orbiting the Moon.
- Review the problem with the students: How can I find and mine valuable resources from a simulated Moon surface?
- Optional video to help with background information: "NASA Now Minute: Cryogenics Test Laboratory" - YouTube: www.youtube.com/watch?v=2IixxONAeWw

Criteria	Constraints
Use only the materials provided.	Cannot add more liquid to the sample collected.
Cold storage devices must allow access to liquid to measure evaporation/ temperature change before and after the storage period.	Liquid should not leak out of the storage or transfer systems.
Cold storage device must be designed to hold the entire sample collected.	Device cannot be any larger than 20 cm^3.

Facilitate the Challenge

? ASK

- Ask your students if they have predictions relating to this activity and the “problem question” of how they could find and mine resources from the surface of the Moon. Remind students that the surface of the Moon is an extremely cold environment so the materials the astronauts will be collecting are cryogenic materials and will need to be stored in a manner to prevent evaporation of the oxygen that is mined from the regolith. Encourage students to share their hypothetical predictions with their group.
- Have the students put on their safety goggles (stress the importance of keeping eye protection on during this portion of the lesson)
- Have students observe their disposable plate Moon
- Have them draw a line down the center of the graph paper, label one side “Before Mining,” and sketch a drawing of the plate Moon
- Have them place the red transparency over half of the plate and place the blue transparency over the other half
- Have them look for ilmenite (effervescent tablets) by moving the transparencies around the plate. Ask: What color can you see the ilmenite through? What color hides the ilmenite? Explain that NASA researchers use colors to locate certain items on the surface of other celestial bodies, and that this is called “spectroscopically” locating the ilmenite.
- When the ilmenite is located, they should extract it from the section of the disposable plate it is in (take it off of the plate with the spoon) and place it into the zipper seal bag. Then have them zip the bag, making sure all the air is locked outside the bag.

IMAGINE

- Now it is time for your students to design a cold storage system that will be able to transfer the fluid safely to a spacecraft (cup). There are two separate aspects to this challenge: the fuel tank (cold storage device), and a system to transfer the fuel to a spacecraft.
- Show students the following video to give them background on cryogenics: "NASA Now Minute: Cryogenics Test Laboratory" - https://www.youtube.com/watch?v=2IixxONAeWw
- Explain that NASA is working on keeping cryogenic rocket fuel chilled without adding too much weight to a spacecraft. Cryogenic propellants are fluids chilled to extremely cold temperatures and condensed to form liquids. Because these fluids must be kept at low temperatures, handling and storing can be difficult. Developing cryogenic fuel management technologies is essential to NASA’s future missions in science and exploration for in-space propulsion, landers, and in-situ resource utilization. NASA is working on developing new solutions for in-space storage and transfer of cryogenic propellants for higher performance, longer distance, and ability

Share With Students

Brain Booster

Did you know that NASA has a series of videos called “NASA Explorers” that introduce viewers to the diversity of NASA’s workforce and the ambitious missions they are working on, such as studying Moon rocks, creating space tools, and training astronauts to return to the lunar surface?

Learn more: www.youtube.com/playlist?list=PL2aBZuCeDwlTmIkf6-R2QUhxhWkLzwCtM

On Location

Image of astronaut on Moon: www.nasa.gov/specials/artemis/

As NASA prepares to send astronauts back to the Moon under Artemis, the agency has identified 13 candidate landing regions near the lunar South Pole. Each region contains multiple potential landing sites for Artemis III, which will be the first of the Artemis missions to bring crew to the lunar surface, including the first woman to set foot on the Moon. The chosen regions are considered scientifically significant because of their proximity to the lunar South Pole, which is an area that contains permanently shadowed regions rich in resources and in terrain unexplored by humans.

Learn more: www.nasa.gov/press-release/nasa-identifies-candidate-regions-for-landing-next-americans-on-moon/

to carry heavier payloads than current propellants.

- Ask students what they know about cold and room temperature liquids and evaporation. (Examples might be warmer liquids evaporate faster than cold, and liquids exposed to more air evaporate faster.)
- Challenge students to design a cold storage device and a way to transfer the fuel from the storage device to a spacecraft. The transfer of fuel will take place during another class session. Remind students that the device cannot exceed 20 cm^3.
- The spacecraft can be just a measuring cup. The main design focus is the cold fuel storage and the transfer of the liquid, not the spacecraft.
- Only provided materials may be used. Allow groups time to explore the materials.

PLAN

- Teams will brainstorm and sketch their idea for a system that will keep their samples cold
- Remind them that their system must be large enough to hold the sample of ilmenite but cannot exceed 20 cm^3 in volume
- The design of the cold storage unit should also allow the team access to the sample to measure evaporation and temperature change before and after the storage period
- The transfer system that the teams design must move the sample from the storage unit to the spacecraft (measuring cup) as quickly as possible
- Be sure all students are communicating and collaborating, and that suggestions and ideas are being documented
- Assess the students' discussions and brainstorming as they are working in their small groups

CREATE

- Teams will build their cold storage device after receiving the educator's approval of their sketch. Review the sketch for any safety issues prior to giving approval.

TEST

- Leave the cold storage units overnight, measuring the liquid temperature before and after the storage time-period
- Measure the amount of evaporation that occurred overnight
- Teams should record their data on the student handout. The handout can also be used to formally assess the students' collaboration and understanding of the challenge.
- Transfer of the sample will also occur the next day. Teams will demonstrate the transfer of fuel from the cold storage device to the spacecraft (measuring cup).
- After teams have tested their fluid transfer system, they should record their observations and answer all the challenge questions on the student handout

IMPROVE

- Allow teams to redesign their cold-storage system if there is time

SHARE

- Engage students with the following discussion questions:
  - What designs were most successful in keeping the sample the coldest? Why?
  - Which designs prevented the most evaporation? Why?
  - Which designs transferred the most fuel to the spacecraft? Why?
  - What information could engineers working on this project learn from your team's results?
  - What do you think would be the best way to present your results?
- Optional: Have student groups share the tool they have invented with other classes or grade levels
- Optional: Share student results on social media using #NextGenSTEM. Be sure to include the module and activity name

Extensions

- Include a budget for the design. Make a cost per item used and require students to stay within a certain budget or bid for contract with the lowest cost solution.
- Interview parents or grandparents about technology in their lifetime. What was the newest technology they remember as they were growing up? (e.g., color television, telephones) What did they think life would be like now? (e.g., flying cars, etc.)

References

Moon Mining Activity - www.nasa.gov/pdf/146862main_Moon_Mining_Educator.pdf
Cryogenic Propellant Storage and Transfer Activity https://www.nasa.gov/news-release/nasa-tests-game-changing-composite-cryogenic-fuel-tank/
First Woman Camp Experience https://www.nasa.gov/stem-content/first-woman-graphic-novel/

Resource

Cryogenic Propellant Storage and Transfer (CPST) https://www.nasa.gov/news-release/nasa-tests-game-changing-composite-cryogenic-fuel-tank/

Activity Four: Extract, Pack, Transport

STUDENT HANDOUT

Your Challenge

In this activity, you will be working in small groups to locate simulated ilmenite (ice with crushed effervescent tablets) and mine the ilmenite. You will work together to design a cold fuel transfer system to store the ilmenite that you have discovered for transfer to Gateway, a space habitat in orbit around the moon.

Criteria	Constraints
Use only the materials provided.	Cannot add more liquid to the sample collected
Cold storage devices must allow access to the liquid to measure evaporation and temperature change before and after the storage period.	Liquid should not leak out of the storage or transfer systems.
Cold storage device must be designed to hold the entire sample collected.	Device cannot be any larger than 20 cm^3.

?ASK

- Put on your safety goggles and observe your disposable plate Moon with your team
- Draw a line down the center of the graph paper, label one side “Before Mining,” and sketch a drawing of your plate Moon
- Place the red transparency over half of the plate and place the blue transparency over the other half
- Look for ilmenite (effervescent tablets) by moving the transparencies around the plate. What color can you see the ilmenite through? What color hid the ilmenite? NASA researchers use colors to locate certain items on the surface of other bodies. This is called “spectroscopically” locating the ilmenite.
- When the ilmenite is located, extract it from the section of the disposable plate it is in (take it off of the plate with the spoon) and place it into the zipper seal bag. Zip the bag, making sure all the air is locked outside the bag

IMAGINE

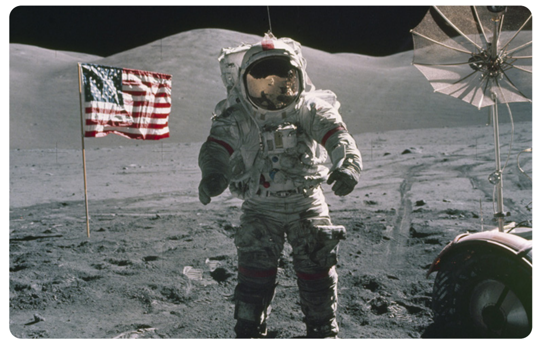
Now it is time to design a cold storage system that will be able to transfer the fluid safely to a spacecraft (cup). There are two separate aspects to this challenge: the fuel tank (cold storage device), and a system to transfer the fuel to a spacecraft.

- NASA is working on keeping cryogenic rocket fuel chilled without adding too much weight to a spacecraft. Cryogenic propellants are fluids chilled to extremely cold temperatures and condensed to form liquids. Because these fluids must be kept at low temperatures, handling and storing can be difficult. Developing cryogenic fuel management technologies is essential

Share With Students

FUN FACT!

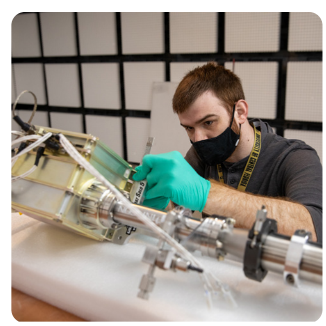
American astronauts have planted six American flags on the Moon. But that doesn't mean the United States has claimed it; in fact, an international law written in 1967 prevents any single nation from owning planets, stars, or any other natural objects in space.



This is an Apollo 17 Astronaut standing upon the lunar surface with the United States flag in the background.

Learn more: https://solarsystem.nasa.gov/Moons/earths-Moon/overview/#otp_pop_culture

CAREER CORNER



Nate Cain, Credit: NASA

Nate Cain, an electronics engineer at NASA’s Kennedy Space Center in Florida, prepares to conduct electromagnetic interference (EMI) testing for the Mass Spectrometer Observing Lunar Operations (MSolo) instrument. On the Moon, it will help analyze the chemical makeup of landing sites, with later missions studying water on the lunar surface..

Learn more: www.nasa.gov/image-feature/engineer-tests-msolo-instrument-for-viper to NASA's future missions in science and exploration for in-space propulsion, landers, and in-situ resource utilization. NASA is working on developing new solutions for in-space storage and transfer of cryogenic propellants for higher performance, longer distance, and ability to carry heavier payloads than current propellants. It is now your challenge to design a cold storage device and a way to transfer the fuel from the storage device to a spacecraft.

- The spacecraft can be just a measuring cup. The main design focus is the cold fuel storage and the transfer of the liquid, not the spacecraft
- Only provided materials may be used, so take a look at the materials your teacher has provided

PLAN

- Brainstorm and sketch your team's idea for a system that will keep your samples cold
- Remember that your system must be large enough to hold the sample of ilmenite
- The design of the cold storage unit should also allow your team access to the sample to measure evaporation and temperature change before and after the storage period
- The transfer system design must move the sample from the storage unit to the spacecraft (measuring cup) as quickly as possible
- Be sure all suggestions and ideas from your team members are being documented

CREATE

- Your teams will build the cold storage device after receiving your educator's approval of your sketch

TEST

- Leave the cold storage units overnight, measuring the liquid temperature before and after the storage time-period
- Measure the amount of evaporation that occurred overnight
- Record your data on the student handout
- Transfer of the sample will also occur the next day. Your team will demonstrate the transfer of fuel from the cold storage device to the spacecraft (measuring cup).
- After you have tested your team's fluid transfer system, record your observations and answer all the challenge questions

IMPROVE

- Redesign their cold-storage system if there is time

SHARE

Read and discuss the following questions with your team and be prepared to share with the other teams:

- What designs were most successful in keeping the sample the coldest? Why?
- Which designs prevented the most evaporation? Why?
- Which designs transferred the most fuel to the spacecraft? Why?
- What information could engineers working on this project learn from your team's results?
- What do you think would be the best way to present your results?

Experiment and Record

Design 1

Measurements of your storage system: L(cm)____ W(cm)____ H(cm)____ Total volume: (cm^3)________

Cold Storage

1. Before storage period record:

Mass of an entire storage device without liquid (in grams)	Amount of liquid in cold fuel storage (in cm^3)	Mass of entire device with liquid (in grams)	Temperature of liquid at start of test (in degrees Celsius)

2. Storage time:____

3. After storage period record:

Temperature (in degrees)	Mass of entire device (in grams)	Difference in mass due to evaporation (in grams)

Transfer System

1. Mass of transfer system: (grams)______________________________

2. Results of transfer spacecraft.

Amount of liquid at start of transfer (in cm^3)	Amount of liquid at end of transfer in spacecraft (in cm^3)

(The spacecraft can be a measuring device to make it easier to see how much was transferred.)

Experiment and Record

Redesign

Measurements of your storage system: L(cm)____ W(cm)____H(cm)____ Total volume: (cm^3)________

Cold Storage

1. Before storage period record:

Mass of an entire storage device without liquid (in grams)	Amount of liquid in cold fuel storage (in cm^3)	Mass of entire device with liquid (in grams)	Temperature of liquid at start of test (in degrees Celsius)

2. Storage time:____

3. After storage period record:

Temperature (in degrees Celsius)	Mass of entire device (in grams)	Difference in mass due to evaporation (in grams)

Transfer System

1. Mass of transfer system: (grams)______________________________________

2. Results of transfer spacecraft.

Amount of liquid at start of transfer (in cm^3)	Amount of liquid at end of transfer in spacecraft (in cm^3)

(The spacecraft can be a measuring device to make it easier to see how much was transferred.)

Quality Assurance

Each team is to review another team's design, then answer the following questions

Team Name:	Yes	No	Notes
Was the team able to store 30 mL of liquid overnight?			
Was the team able to transfer all 30 mL of liquid?			
Did the team correctly record data?			

List specific strengths of the design

List specific weaknesses of the design

How would you improve the design?