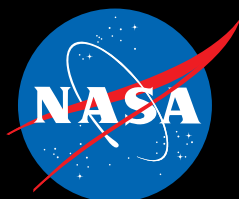
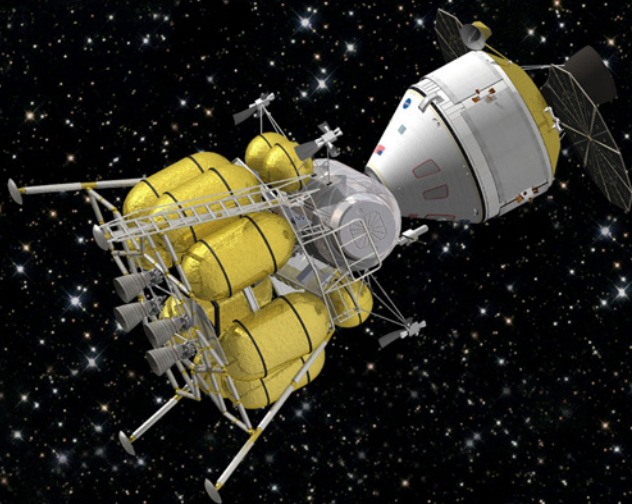




## EDUCATOR'S GUIDE





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## What Is Field Trip to the Moon?

The Field Trip to the Moon program uses an inquiry-based learning approach that fosters team building and introduces students to careers in science and engineering. The program components include a DVD and classroom investigations. The compelling DVD provides essential information about Earth and the Moon. The hands-on activities, which take up where the show leaves off, motivate students to use their cooperative learning skills to design a self-sufficient lunar station. Working in teams, students develop critical thinking skills, problem-solving techniques, and an understanding of complex systems as they discuss solutions to the essential questions they are presented.

## The DVD

The DVD consists of a three-minute Introduction, a 21-minute Feature Presentation (available with and without narration), and seven minutes of Extra Materials (includes “AstroViz: Our Moon” and Moon trivia questions). The show introduces students to the challenges and excitement of launching from Earth’s surface and journeying through space to land on the Moon. On the way, students will discover some of the differences between Earth and the Moon, and what makes our planet unique and habitable.

- Key segments include:
- Vehicle Assembly Building
  - Launch Pad
  - Launch into Earth’s orbit
  - Earth’s Magnetosphere
  - Spacecraft Flyby
  - Moon (approach, orbit, and landing)

## Classroom Investigations

The DVD presentation ends with a landing on the Moon. Students continue their lunar exploration with classroom activities that investigate the Moon’s habitability and sustainable resources. These activities culminate with plans for the design and creation of a lunar station.

The complete program, including all activities and the viewing of the DVD, will take approximately four class periods (40 minutes each). The students are assigned to one of six teams, with four to six students in each team. The teams are each given one of six topics to investigate:



The Ecosystem, Habitat, and Medical teams have more steps to complete than the other teams, so you may want to assign more students to these teams. During the course of the activity, teams will be sharing their results with each other. At the end of their investigations, the teams will bring together their findings to complete the lunar station as a class.

## Options

- You may choose to have your class investigate as few or as many topics as you wish.
- You may chose to have the entire class investigate one or all of the topics as a single team. If you do so, the best order to investigate the topic is: Navigation, Engineering, Geology, Ecosystem, Habitat, and Medical.



## National Science Education Standards Correlation

| NSES CONTENT STANDARDS                                  | DVD | ECOSYSTEM | GEOLOGY | HABITAT | ENGINEERING | NAVIGATION | MEDICAL |
|---|-----|-----------|---------|---------|-------------|------------|---------|
| <b>A Abilities necessary to do scientific inquiry</b>   | ●   | ●         | ●       | ●       | ●           | ●          | ●       |
| Understandings about scientific inquiry                 | ●   | ●         | ●       | ●       | ●           | ●          | ●       |
| <b>B Properties and changes of properties in matter</b> |     |           | ●       |         |             |            |         |
| Motions and forces                                      | ●   |           |         |         |             |            |         |
| Transfer of energy                                      | ●   | ●         |         |         | ●           |            |         |
| <b>C Structure and function in living systems</b>       |     |           |         |         |             |            | ●       |
| Reproduction and heredity                               |     | ●         |         |         |             |            |         |
| Regulation and behavior                                 |     | ●         |         | ●       |             |            |         |
| Populations and ecosystems                              |     | ●         |         |         |             |            |         |
| Diversity and adaptations of organisms                  | ●   | ●         | ●       | ●       | ●           | ●          | ●       |
| <b>D Structure of the Earth system</b>                  | ●   |           |         |         |             |            |         |
| Earth's history   | ●   |           |         |         |             |            |         |
| Earth in the solar system                               | ●   |           |         |         |             |            |         |
| <b>E Abilities of technological design</b>              |     | ●         | ●       | ●       | ●           | ●          | ●       |
| Understandings about science and technology             | ●   | ●         | ●       | ●       | ●           | ●          | ●       |
| <b>F Personal health</b>                                |     |           |         |         |             |            | ●       |
| Populations, resources, and environments                |     | ●         | ●       | ●       |             |            |         |
| Natural hazards   | ●   |           | ●       | ●       | ●           | ●          | ●       |
| Risks and benefits                                      |     |           |         |         |             |            | ●       |
| Science and technology in society                       | ●   |           |         |         |             |            |         |
| <b>G Science as a human endeavor</b>                    | ●   |           |         |         |             |            |         |
| Nature of science                                       | ●   |           |         |         |             |            |         |
| History of science                                      | ●   |           |         |         |             |            |         |



## Classroom Investigations

The classroom investigations will challenge students to explore the Earth's Moon to assess its habitability and potential for sustainable resources. Each team will have two tasks to complete, and each task will have specific objectives.



### Ecosystem Investigation

This team will investigate ecosystems and food webs. Using the information they gather, they will design a sustainable ecosystem for the lunar station.



### Geology Investigation

This team will locate and analyze resources at the chosen landing site. They will then determine the natural resources available and select a mining area.



### Habitat Investigation

This team will identify the living, working, and recreational space needed for humans on the Moon. They will then design a model of a sustainable habitat for humans.



### Engineering Investigation

This team will determine the energy resources available on the Moon and design a power station for the lunar station.



### Navigation Investigation

This team will choose one of two possible landing sites on the Moon. They will then pack the rocket so that all the needed materials from each team will fit in the cargo bay.



### Medical Investigation

This team will investigate various types of emergencies that may occur on the Moon and select the medical equipment that would be best suited for responding to those emergencies.

## Time Frame

Four class periods (40 minutes each) for the entire program.

## Materials

- A toolbox for each of the six topics. Please refer to the Materials List. Some items may be purchased as part of the NASA Kit from [URL].
- Task cards, data cards, and other reproducibles for each team. Please refer to the reproducibles.
- Optional: Name tags for each team.

## Preparation

Gather all materials and purchase the NASA Kit as needed. Using medium-sized cardboard boxes, create a toolbox for each team. In addition to placing and sorting materials into each toolbox, you will also need time to cut out the task, data, and other items from the reproducibles.



## Classroom Investigations: Procedure

### 1 Period One: Introducing and Viewing the DVD

#### 1. Establish prior knowledge (5-10 minutes)

Begin the conversation with a few essential questions about lunar exploration. Use the following questions to stimulate discussion:

- What have you heard or what do you know about human missions to the Moon?
- What do you think it would be like to visit the Moon? What do you think living there would be like?
- Are humans able to live there now? Why or why not?

#### 2. View Extra Materials (7 minutes – optional)

Show the extra materials on the DVD, which begins with “AstroViz: Our Moon,” a visualization about the formation of the Moon. Then challenge students to take part in the Moon trivia questions that follow. You may choose to pause after each question to read it aloud and to give your students a chance to vote on a class answer.

#### 3. Introduce Field Trip to the Moon and view the Introduction and Feature Presentation (25 minutes)

Explain to students that Field Trip to the Moon is a special program developed by NASA. The show will take them on a virtual mission to the Moon. On their journey they will discover some of the differences between Earth and the Moon, and what makes our planet unique and habitable. After watching the feature presentation, they will continue their mission by working in teams to design a permanent, self-sustaining lunar station where humans can live and work.

#### 4. Ask questions after viewing the feature presentation (3 minutes)

- What makes Earth habitable?
- How is being on the Moon different than being on Earth?



## Classroom Investigations: Procedure

### 2 Period Two: Investigation Task 1

**1. Recap feature presentation content and introduce activity** (5 minutes)

Call on volunteers to recount what they saw in the feature presentation. Have them identify the differences between the Earth and Moon, and what makes Earth habitable. Tell students that they will be working in six different teams to plan and design a lunar station. Further explain that each team will have different tasks to complete. When those tasks are completed the class will have planned a habitable and sustainable lunar station.

**2. Divide class into teams** (5 minutes)

Divide the students into six teams and assign a different investigation to each team. Select a student from each team to act as the Communications Officer (the person who will speak for the team). Distribute name tags and the appropriate toolbox to each team. Tell students that the toolbox contains the resources and materials that are needed to complete the tasks.

**3. Task 1: Teamwork** (20 minutes)

Distribute the Task 1 cards to each Communications Officer. Have the Communications Officers stand and read their first task to the entire class, so that teams are familiar with what the other teams are doing and can see how their tasks fit in with the entire plan. Make sure students understand what they are to do.

If there are no questions, have teams begin the first task. Explain that they will have 20 minutes to complete the task (you may want to write the stop time on the board), after which they will report their findings to the class. As they work on their tasks, check on each team's progress, providing assistance as necessary. You can use the Questions to Help Guide Student Investigations.

**4. Task 1: Reporting and discussion** (10 minutes)

After the first task is completed, have the Communications Officers share their team's progress with the rest of the class. Tell students that in order to complete Task 2, they may need to draw from other teams' reports. Encourage them to ask questions of other teams.

**5. Distribute additional reading** (homework)

The articles will enhance students' understanding of future plans for the exploration of the Moon and will provide a frame of reference for the tasks they are currently doing. Duplicate the articles and distribute them to the appropriate teams. Students can read the articles on their own or as a homework assignment.



## Classroom Investigations: Procedure

### 3 Period Three: Investigation Task 2

**1. Distribute Task 2 cards and recap Task 1** (10 minutes)

Distribute the Task 2 cards to each Communications Officer. Have the officer from each team briefly recap the findings from Task 1 and then read the second task to the class.

**2. Task 2: Teamwork** (30 minutes)

Make sure students understand what they are to do. If there are no questions, have teams begin the second task. Explain that they will have 30 minutes to complete the task (you may want to write the stop time on the board) and should finalize their project for presentation the next day. As teams work, check on their progress, providing assistance as necessary.

### 4 Period Four: Bringing It All Together

**1. Completion of lunar station** (25 minutes)

Have teams finalize their investigations and put all their designs and paper at the front of the room. (They can be taped to the board.) Have each team present their final project. Allow time for any questions the class may have.

**2. Final discussion** (15 minutes)

Facilitate discussion around the completed plans for the lunar station. Use the following questions to stimulate discussion:

- How have your ideas about living and working on the Moon changed after watching the DVD and working on these investigations?
- What problems did you and your team encounter as you completed each task? How did you and your team solve the problems?
- Do you think the lunar station you planned will be able to support a sustainable habitat for humans? Why or why not?
- What kinds of careers do you think are going to be important if humans are going to return to the Moon to live?



## Questions to Help Guide Student Investigations

As student teams work on their tasks, check on each team's progress and provide assistance as necessary. As you move about the room, you can use the questions below to help guide their investigations. For more structured support, you can also provide the teams with the questions.



### Ecosystem Investigation

#### Task 1

- What are the basic things that organisms need to live?
- What is an ecosystem?
- What organisms make up an ecosystem?
- What roles do consumers, producers, and decomposers play in an ecosystem?
- Of what value is a “green” space (ecosystem) on the Moon?
- Think about the ecosystem you will create on the Moon. What purpose will it serve?

#### Task 2

- What purpose will your ecosystem serve?
- What consumers, producers, and decomposers will you need for your ecosystem? How many of each will you need? Do you think you will need more consumers or more producers?
- Create a food web for them. Are there any missing links?
- How will you design your ecosystem so that it will fit into the designated space?



### Geology Investigation

#### Task 1

- What are some uses of the rocks and minerals found on the Moon?
- Which of these might provide water or oxygen?
- Which of these are strong and could be used in construction?
- Which of these would not be suitable for construction? Why?

#### Task 2

- You've chosen six of the metals and minerals. Do you want a mining site where you can mine large quantities of one or two of the metals and minerals? Or do you want a site where you can mine smaller quantities of most of the chosen minerals?
- Identify the metals and minerals you chose on the Lunar Mineralogical Map Key. Can you find those minerals and metals on the lunar map?
- Use the mining area cutouts to choose the best site.



## Questions to Guide Student Investigations (continued)



### Habitat Investigation

#### Task 1

- Name some of the things you do every day, like sleep and eat.
- What are some of the recreation activities/sports/exercise you participate in?
- Which of these things are necessary if you are to live on the Moon?

#### Task 2

- You've identified the different needs you'll have on the Moon. Now think about how much space you'll give to each one.
- Be creative and think about ways the space can be used in more than one way.



### Engineering Investigation

#### Task 1

- What activities on Earth require electricity?
- Think about living on the Moon. What activities on the Moon will you need electricity for?
- The Energy Source data cards tell you what kinds of energy are available on Earth. Are all of these kinds of energy available on the Moon?
- Which kinds of energy will be available on the Moon?

#### Task 2

- Which landing site did the navigation team choose?
- How does that affect your ability to generate energy?
- Can you use two kinds of energy? Think about ways that would work.



## Questions to Guide Student Investigations (continued)



### Navigation Investigation

#### Task 1

- What are the benefits and challenges of each landing site?
- What does the landing site need to provide for the lunar station?

#### Task 2

- What resources are available at the landing site you selected? Is there anything at the site that could be used in place of some of the cargo?
- Look at the six types of cargo. Which will you need the most of? Why? Which is the second most important type of cargo?
- Compare your list with the percentages. Does your number one have the highest percentage? Does your number two have the second highest percentage?
- What do you need less of? Take out some of that cargo.
- What do you need more of? Add some of that cargo.
- Try to rearrange the cargo so that there is no space left open.



### Medical Investigation

#### Task 1

- Can any of the items be substituted with something you might already have?
- Can any of the items be used in more than one way?

#### Task 2

- What are the symptoms of the patient?
- Look at the data cards that describe medical emergencies.
- Which description fits this emergency?



## Materials List

Using a medium-sized cardboard box, create a toolbox for each of the six investigations. Some materials are included in a NASA Kit.

### NASA Kit

You can purchase this optional kit from NASA at [URL]

It includes the following toolbox materials:

- Rock samples and rock slices, including sandstone, basalt, gabbro, and anorthosite. [ A good source for rocks is sciencekit.com ]
- Items made from the minerals found on the Moon (e.g. electronics board, silicon chip)
- Handheld magnifying glasses
- Drafting stencils
- Actual medical objects (e.g. protective gloves, bag valve mask, blood pressure cuff, stethoscope, penlight, pocket face mask, thermometer, burn care kit, bandages, heat and cold packs)
- Plastic name tags

### Ecosystem Toolbox

#### Materials to gather:

- Large pieces of paper
- Drawing materials
- Scissors
- Glue stick or tape
- Ruler

#### From the Reproducibles section:

- Task Cards 1 & 2 (cut and distribute separately)
- Food Web diagram
- Organism worksheets
- Article (distribute as homework at end of Task 1)



### Geology Toolbox

#### Materials from NASA Kit:

- Rock samples and rock slices
- Some items made from the minerals found on the Moon
- Handheld magnifying glasses

#### Materials to gather:

- Envelope (for Metals and Minerals data cards)
- Scissors

#### From the Reproducibles section:

- Task Cards 1 & 2 (cut and distribute separately)
- Metals and Minerals data cards (cut and place in a labeled envelope)
- Key of Lunar Metals and Minerals
- Plain geological maps of the South Pole and the Apollo 17 mining site
- Geological maps of the two sites with metals and minerals overlay
- Lunar Mining Area worksheet
- Article (distribute as homework at end of Task 1)





## Materials List (continued)

### Habitat Toolbox

#### Materials from NASA Kit:

- Drafting stencils



#### Materials to gather:

- Large pieces of paper
- Drawing materials
- Ruler

#### From the Reproducibles section:

- Task Cards 1 & 2 (cut and distribute separately)
- Sample Lunar Base designs
- Article (distribute as homework at end of Task 1)

### Navigation Toolbox

#### Materials to gather on your own:

- Large pieces of paper
- Drawing materials
- Ruler
- Scissors
- Glue stick or tape
- Large envelope



#### From the Reproducibles section:

- Task Cards 1 & 2 (cut and distribute separately)
- Maps of each landing site
- Pictures of rockets
- Cargo worksheets
- Cargo Packing List worksheet
- Article (distribute as homework at end of Task 1)

### Engineering Toolbox

#### Materials from NASA Kit:

- Drafting stencils



#### Materials to gather:

- Large pieces of paper
- Drawing materials
- Glue stick or tape
- Ruler
- Two envelopes (for Energy and Landing Site data cards)

#### From the Reproducibles section:

- Task Cards 1 & 2 (cut and distribute separately)
- Energy data cards (cut and place in a labeled envelope)
- Landing Site data cards (cut and place in a labeled envelope)
- Article (distribute as homework at end of Task 1)

### Medical Toolbox

#### Materials from NASA Kit:

- Actual medical objects



#### Materials to gather:

- Large pieces of paper
- Markers
- Three large envelopes

#### From the Reproducibles section:

- Task Cards 1 & 2 (cut and distribute separately)
- First Aid Tables
- Basic Lunar First Aid Kit data cards (cut and place in a labeled envelope)
- Additional First Aid Items data cards (cut and place in a labeled envelope)
- Emergency Scenario cards (cut and place in a labeled envelope)
- Article (distribute as homework at end of Task 1)

## What are the different parts of an ecosystem?

## What kind of ecosystem will you design for your lunar station?

### What to Do

1. Examine the food web diagram. On a sheet of paper, list the producers, consumers, and decomposers that are pictured.
2. As a group, decide on the type of ecosystem you will design for the lunar station. Consider:
  - How will the ecosystem be used? For example, will it be used as a farm to provide food, or will it produce oxygen for breathing? Or some combination?
  - What are some additional benefits from having access to an ecosystem within the lunar station?

### Report to Class

- The type of ecosystem you will design for the lunar station.

## What will you take to the Moon to create your ecosystem?

### What to Do

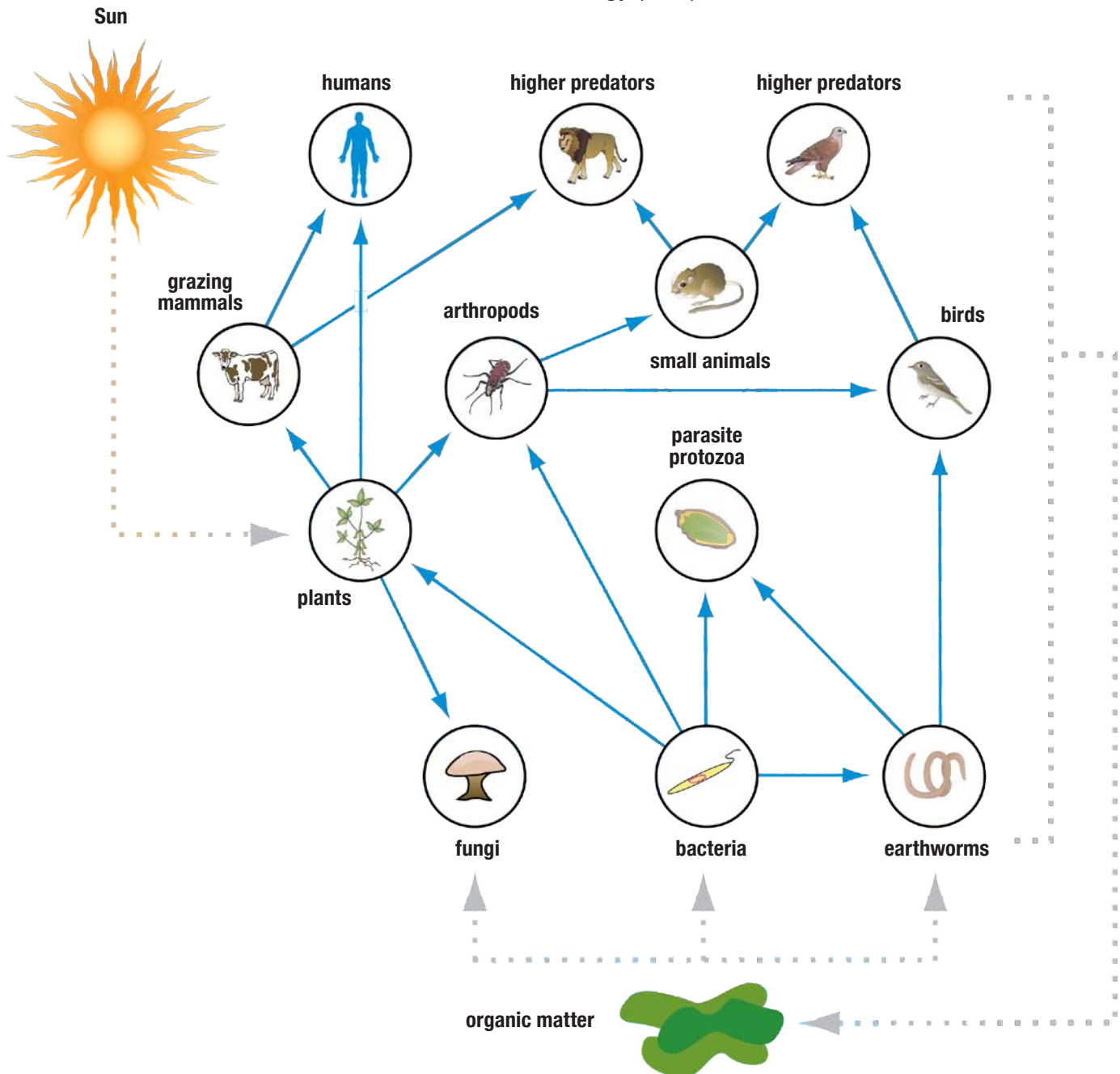
1. Cut out the cards on the Organisms worksheets. These are the organisms you can use to create your lunar ecosystem selected in Task 1.
2. Arrange organisms into categories: producers, consumers (primary, secondary, tertiary), and decomposers.
3. Select the organisms that will inhabit your ecosystem. Using the arrow cutouts, arrange the organisms to create a complete food web. You can use the blank cards to add organisms of your choice. Consider:
  - How much energy (food) does each organism consume and provide? Are there any missing links?
4. Once you are satisfied with your food web, draw an 8" by 8" square on a large sheet of paper. This represents the space available for your ecosystem on the lunar station.
5. Construct your lunar ecosystem by fitting the organism cards into the square.
  - Try to fit all the cards into the square so there are no empty spaces. Revise the food web if you have too many or too few organisms. Once you're satisfied with the organisms, glue them into the square.
5. Your ecosystem will fit into the lunar habitat designed by the Habitat Team.

### Present to Class

- The organisms in your designed ecosystem and the reason you chose them.

# Food Web

A food web is a combination of many different food chains. It shows the relationships between and among numerous producers, consumers, and decomposers in an ecosystem. In this sample food web, energy (food) moves in the direction of the arrows.



## Producers

Producers are plants that get their energy from the Sun and nutrients from the soil.

## Consumers

Consumers are animals or other organisms that get their energy by consuming (eating) something. There are three types of consumers. Primary consumers eat producers (plants). Secondary and tertiary consumers eat other consumers. Tertiary consumers are high-level consumers that are the top predators of an ecosystem.

## Decomposers

Decomposers are fungi, bacteria, or other organisms that break down organic matter (animal waste, dead plants and animals). This puts minerals (nutrients) back into the soil for plants to use again.

# Organism Cards

## Instructions

Cut out the organism cards along the dotted lines. Use the blank cards to add organisms of your choice.

The image shows a grid of organism cards designed for cutting out. At the top left, there is a small icon of a pair of scissors. The grid is divided into several sections by dotted lines. The organisms shown are: a green silhouette of a human (labeled HUMAN), a tree with yellow fruit (labeled TREE), potatoes with green sprouts (labeled POTATOES), a rainbow trout (labeled TROUT), a blue crab (labeled CRAB), a yellow sunflower (labeled SUNFLOWER), a mallard duck (labeled DUCK), a yellow chicken (labeled CHICKEN), a bee (labeled BEES), a mushroom (labeled MUSHROOM), a worm (labeled WORMS), a beetle (labeled BEETLES), and a green frog (labeled FROG). At the bottom of the grid, there are seven blank cards, each containing a green arrow pointing to the right.



# Organism Cards

## Instructions

Cut out the organism cards along the dotted lines. Use the blank cards to add organisms of your choice.

The image shows a grid of 12 organism cards, each with a dotted border for cutting. A pair of scissors icon is at the top left. The cards are arranged in a 4x3 grid:

- GRASS:** A patch of green grass growing in a brown soil mound.
- WHEAT:** Three stalks of wheat with golden heads and leaves.
- CACTUS:** A tall, columnar cactus with several arms.
- COW:** A brown and white spotted cow standing.
- GREEN ALGAE:** Several small, green, rod-shaped organisms with flagella.
- BUTTERFLY:** A colorful butterfly with black, yellow, and green wings.
- CORN:** Four stalks of corn with green leaves and yellow cobs.
- BACTERIA:** Two elongated, yellow rod-shaped organisms with flagella.
- SHEEP:** A white sheep with a large, curved, black horn.
- FLOWERING PLANT:** A cluster of pink flowers on green stems.
- ROBIN:** A red and black bird.
- ORGANIC MATTER:** A green, irregular shape representing organic matter.

# SEARCHING FOR WATER

**A NASA spacecraft will hit the Moon's South Pole in search of water.**

NASA announced today that a small spacecraft, to be developed by a team at NASA Ames, has been selected to travel to the moon to look for precious water ice at the lunar south pole.

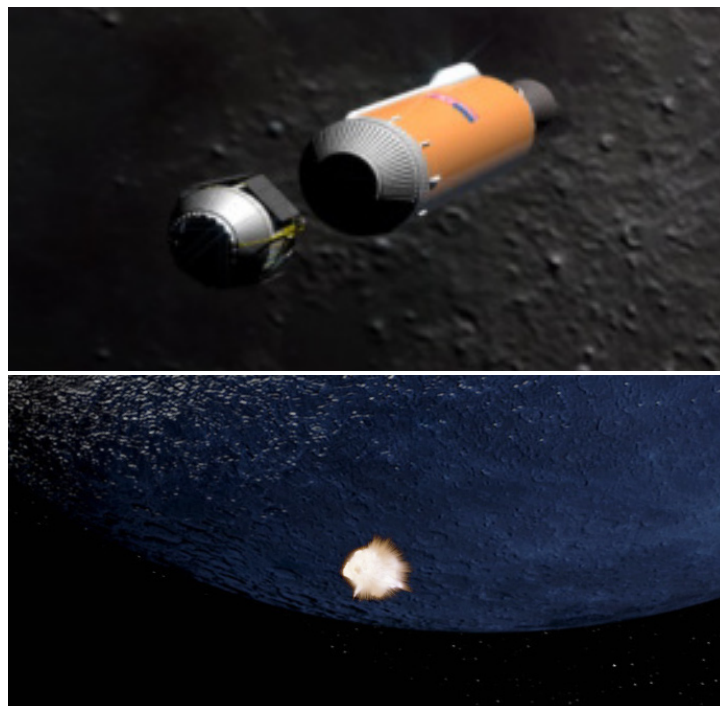
The name of the mission is LCROSS, short for Lunar CRater Observation and Sensing Satellite. LCROSS is a secondary payload: It will hitch a ride to the Moon on board the same rocket as the Lunar Reconnaissance Orbiter (LRO) satellite, due to launch from the Kennedy Space Center in October 2008.

“The LCROSS mission gives the agency an excellent opportunity to answer the question about water ice on the moon,” says Daniel Andrews of NASA Ames, whose team proposed LCROSS. “We think we have assembled a very creative, highly innovative mission.”

LCROSS will hunt for water by hitting the Moon twice, throwing up plumes that may contain signs of H<sub>2</sub>O. It works like this:

After launch, the LCROSS spacecraft will arrive in the Moon's vicinity independent of the Lunar Reconnaissance Orbiter. On the way to the Moon, the LCROSS spacecraft's two main parts, the Shepherding Spacecraft (S-S/C) and the Earth Departure Upper Stage (EDUS), will remain coupled. As the pair approach the Moon's South Pole, the upper stage will separate and then hit a crater in the South Pole area. A plume from the upper-stage crash will develop as the Shepherding Spacecraft heads in toward the Moon. The Shepherding Spacecraft will fly through the plume, using its instruments to analyze the cloud for signs of water and other compounds. Additional space- and Earth-based instruments also will study the 2.2 million-pound (1,000-metric ton) plume.

“This type of payload is not new to NASA,” says Scott Horowitz, associate administrator for the



**Top: LCROSS approaches the Moon.**  
**Bottom: The first of two impacts delivered by the split craft.**

Exploration Systems Mission Directorate, who made the selection. “We are taking advantage of the payload capability of the launch vehicle to conduct additional high risk/high payoff science to meet Vision for Space Exploration goals.”

Lunar Reconnaissance Orbiter and LCROSS are the first of many robotic missions NASA will conduct between 2008 and 2016 to study, map, and learn about the lunar surface to prepare for the return of astronauts to the Moon. These early missions will help determine lunar landing sites and whether resources such as oxygen, hydrogen, and metals are available for use for NASA's long-term lunar exploration objectives.

**NASA article from:**

[http://science.nasa.gov/headlines/y2006/10apr\\_lcross.htm](http://science.nasa.gov/headlines/y2006/10apr_lcross.htm)

## What metals and minerals are best suited for the construction of the lunar station?

### What to Do

1. Open the envelope labeled “Metals and Minerals data cards.” These 12 cards represent metals and minerals that can be mined from the lunar soil at your landing site.
2. Take turns reading the data cards aloud to learn more about each resource.
3. Examine the rocks and objects that may be associated with some of these metals and minerals.
4. Discuss each metal and mineral and how it might be used to build and maintain your lunar station.
5. Select six metals or minerals that you will use in the construction of the lunar station.

### Report to Class

- The six metals and minerals that your team selected and the reasons why you chose them.

## Which area of the chosen landing site is best for mining?

### What to Do

1. Take out the maps of the landing site that was selected by the Navigation Team (terrain of the region with and without the metals and minerals overlay) and the Key of Lunar Metals and Minerals.
2. Examine the resources available at your landing site.
3. Cut out the circular shape on the Mining Area Worksheet. This represents the largest area you are able to mine on the Moon. Place the sheet over the map with the metals and minerals overlay. Find the best place to mine.
4. Try to include as many of the six metals and minerals you selected in Task 1. If you cannot fit in all six resources, decide what other metals or minerals can be used as a substitute given the exact area you've selected.

### Present to Class

- The mining site your team selected, the metals and minerals available there, and the reasons you chose the site.

## Metals and Minerals

# SILICATES

Chemical Formula:  $\text{SiO}_2$

Silicates can be used to manufacture:

- glass
- solar cells
- computer chips
- oxygen

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## Metals and Minerals

# ALUMINUM OXIDE

Chemical Formula:  $\text{Al}_2\text{O}_3$

Aluminum can be used to manufacture:

- transportation vehicles (rovers, rockets)
- construction material (for base construction)
- oxygen
- solid rocket fuel
- electrical wiring

Note:

Aluminum is a light but strong metal.

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## Metals and Minerals

# TITANIUM OXIDE

Chemical Formula:  $\text{TiO}_2$

Titanium can be used to manufacture:

- transportation vehicles (rovers, rockets)
- construction material (for base construction)
- oxygen
- highly reflective paint (reflects a lot of light)

Note:

Titanium is a very light, strong metal that can withstand extreme heat.

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## Metals and Minerals

# IRON (II) OXIDE

Chemical Formula:  $\text{FeO}$

Iron can be used to manufacture:

- mining tools
- construction material (for base structures)
- stainless steel

Note:

Iron is a dense, strong metal.

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## Metals and Minerals

**SOLID WATER (ICE)**

Chemical Formula: H<sub>2</sub>O

Water can provide:

- liquid needed for life (people, plants, and animals)
- oxygen
- hydrogen
- steam for nuclear power station
- protective layer against radiation

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## Metals and Minerals

**MAGNESIUM OXIDE**

Chemical Formula: MgO

Magnesium can be used to:

- help build transportation vehicles (rovers, rockets)
- help make aluminum
- help maintain climate (low humidity)

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## Metals and Minerals

**SODIUM OXIDE**

Chemical Formula: Na<sub>2</sub>O

Sodium oxide can be used:

- to help purify metals (improves metal production)
- to provide light for street lamps
- as a substitute for water in a nuclear reactor
- in combination with other chemicals to make fertilizer

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## Metals and Minerals

**DIAMOND (CARBON)**

Chemical Formula: C

Diamonds can be used:

- to manufacture excellent mining drills

Note:

Diamonds are extremely rare and hard to mine.

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## Metals and Minerals

**GOLD**

Chemical Formula: Au

Gold can be used:

- to manufacture electrical wiring
- in computer chips
- to manufacture heat shielding
- to manufacture radiation shielding

Note:

Gold is very rare!

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## Metals and Minerals

**SILVER**

Chemical Formula: Ag

Silver can be used:

- to manufacture electrical wiring
- in computer chips
- in treatment of burns (as a specialized cream)

Note:

Silver is very rare!

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## Metals and Minerals

**PLATINUM**

Chemical Formula: Pt

Platinum can be used:

- to help in making fuel cells (provides electricity)
- in computer chips
- to manufacture electrodes for electrolysis (to create oxygen and hydrogen from water)

Note:

Platinum is very rare!

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## Metals and Minerals

**CALCIUM OXIDE**

Chemical Formula: CaO

Calcium can be used to manufacture:

- heat-resistant shielding
- construction material (base structures, concrete)
- oxygen
- supplements for healthy bones

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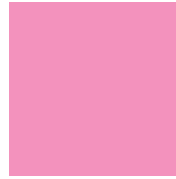
# Key of Lunar Metals and Minerals

## Instructions

Use this key to identify the metals and minerals available at your landing site.



**Silicates**



**Sodium Oxide**



**Aluminum**



**Diamond (Carbon)**



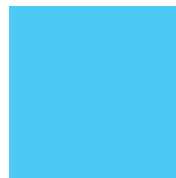
**Titanium Oxide**



**Gold**



**Ferrous Oxide (Iron)**



**Silver**



**Solid Water (Ice)**



**Platinum**



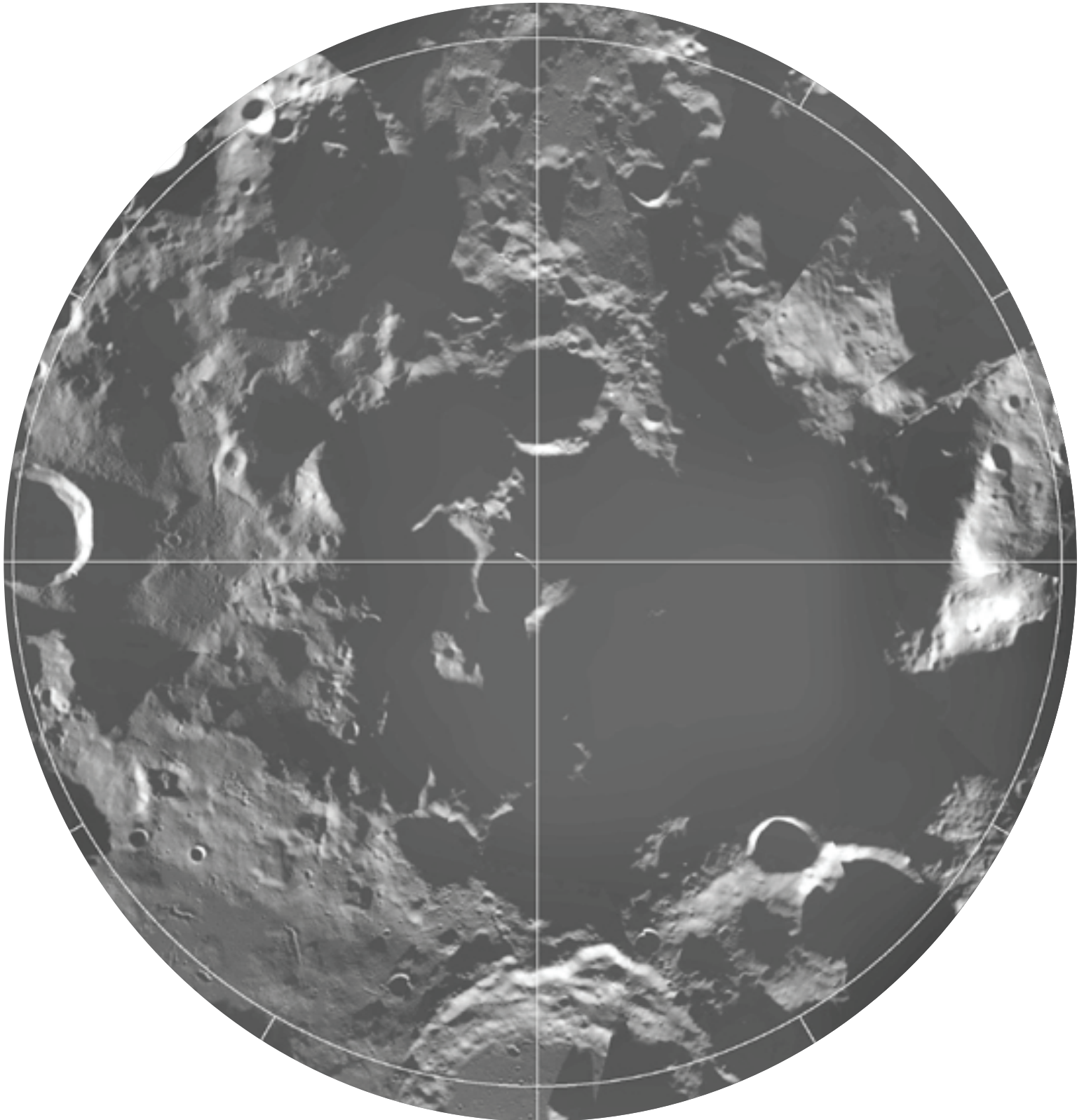
**Magnesium Oxide**



**Calcium Oxide**

## South Pole

This landing site always has a low level of sunlight. The Sun always appears on the horizon (like a constant sunset). Some areas are always in shadow and never receive sunlight. It is a heavily cratered terrain with few flat areas. There is evidence for frozen water (ice) deep in the craters. There is no geothermal activity.

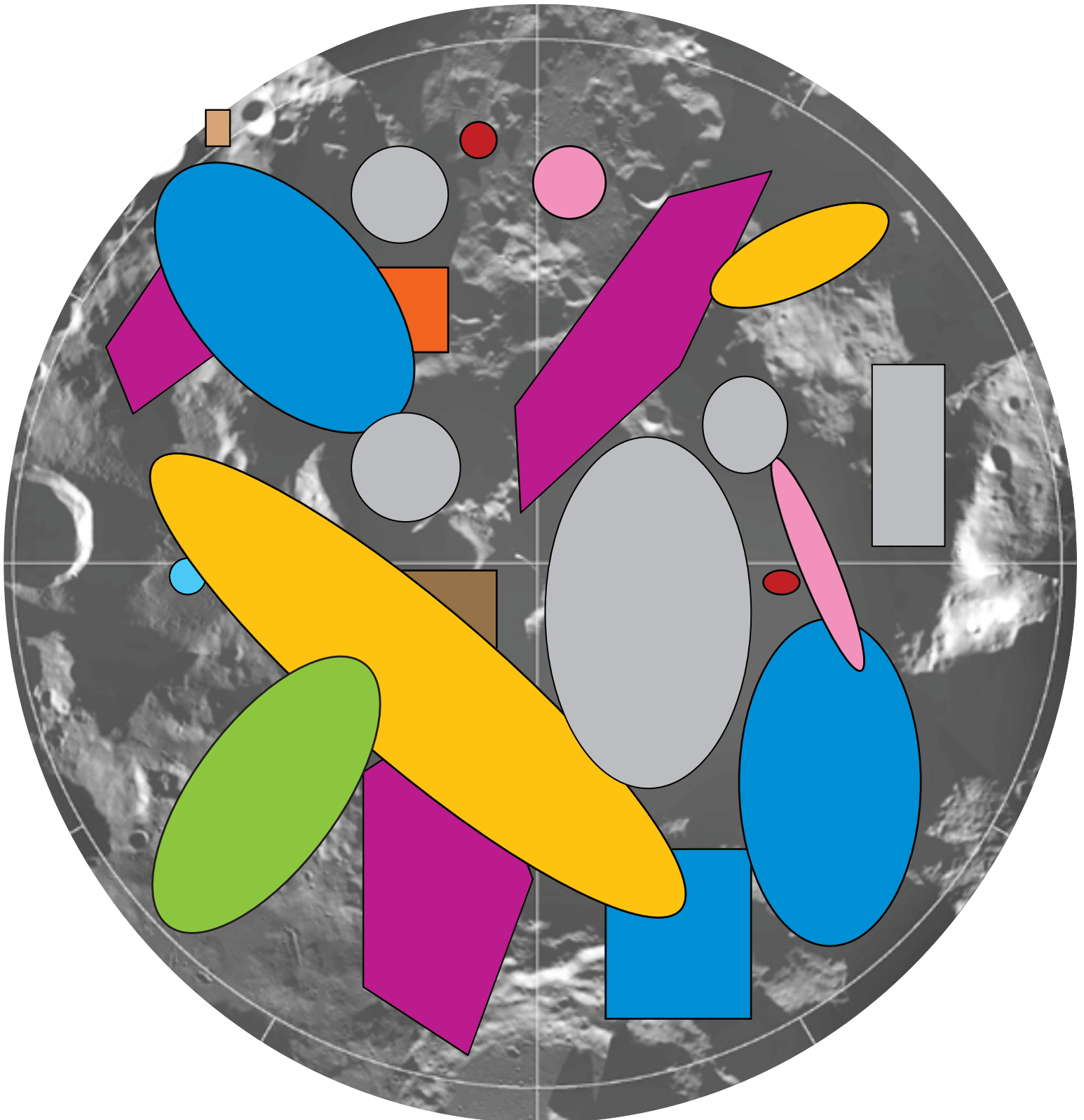




# South Pole

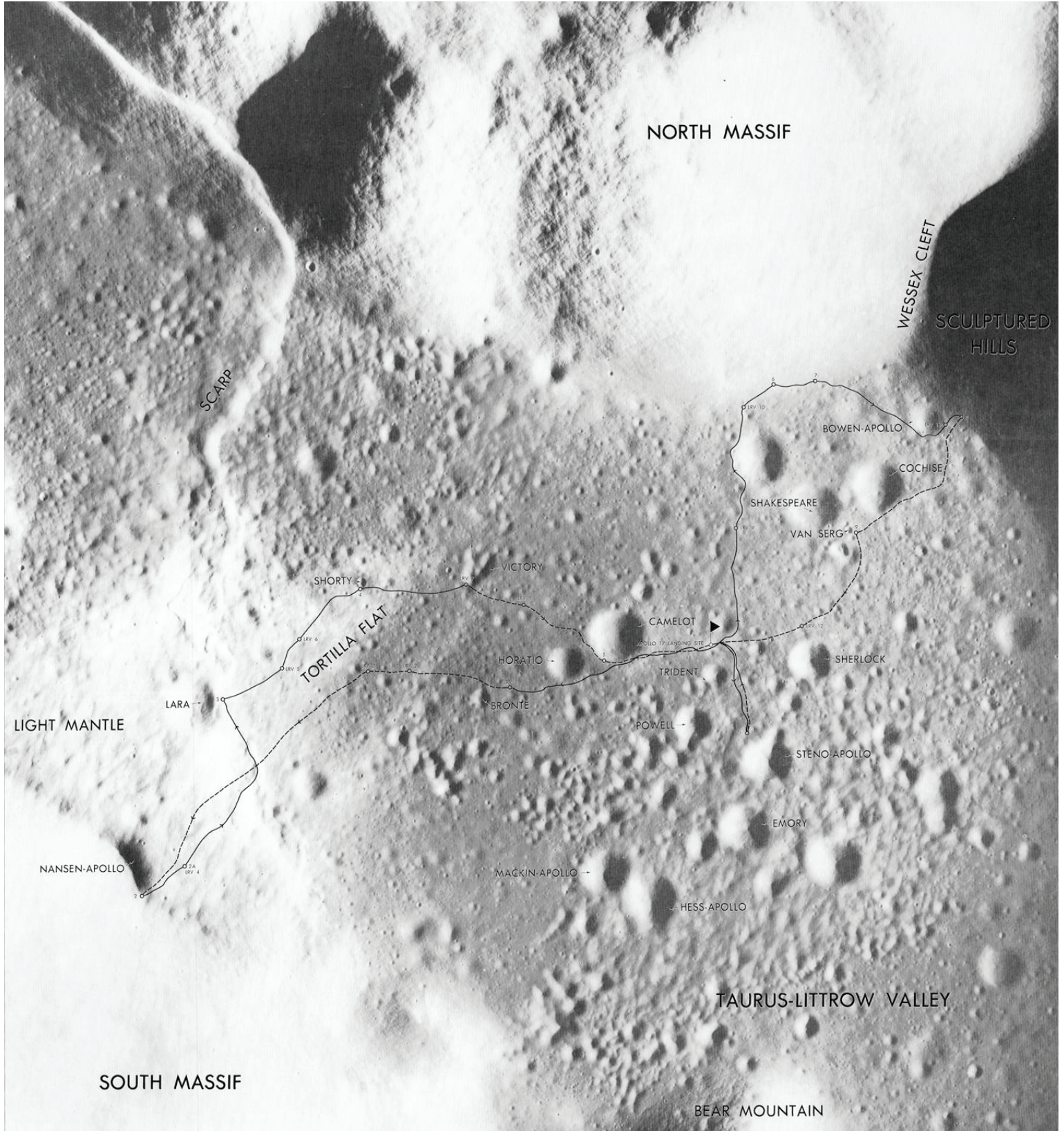
showing available  
metals and minerals

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# Valley of Taurus-Littrow

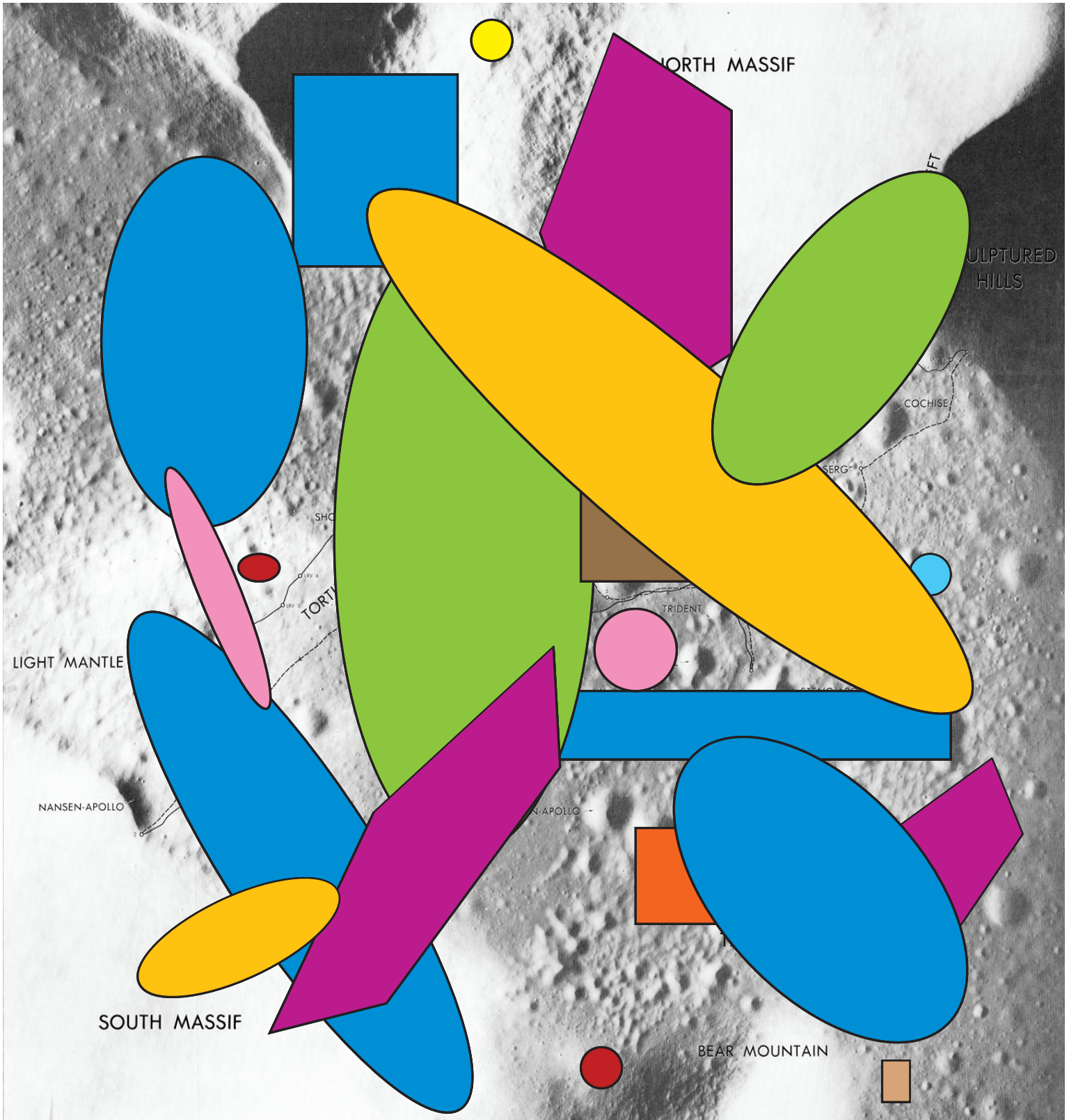
This landing site has a two-week-long day of direct sunlight, followed by a two-week-long night. This cycle repeats. It is in a smooth, deep, narrow valley between two different mountains, called the North and South Massif. There are no known water resources at this site. There is no active geothermal activity. This was the landing site of the Apollo 17 mission in December 1972.



# Valley of Taurus-Littrow

showing available metals and minerals

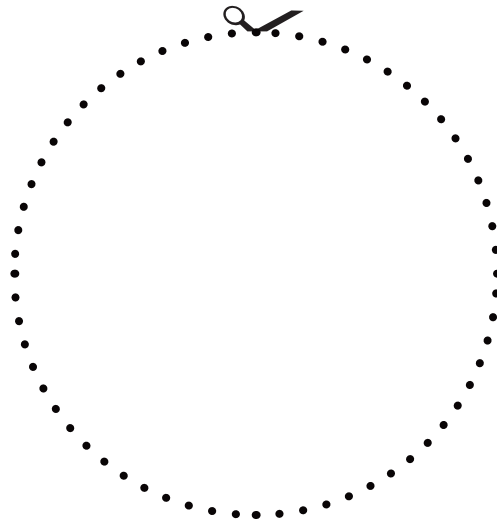
This landing site has a two-week-long day of direct sunlight, followed by a two-week-long night. This cycle repeats. It is in a smooth, deep, narrow valley between two different mountains, called the North and South Massif. There are no known water resources at this site. There is no active geothermal activity. This was the landing site of the Apollo 17 mission in December 1972.



# Mining Area

## Instructions

Cut out the circle along the dotted line and discard the piece you cut out. The open space represents the size of your mining area on the Moon. Take out the maps of the selected landing site. Move this sheet of paper over the version that shows the distribution of metals and minerals. Select the best location to mine.



# THE MOON IS A HARSH WITNESS

**The Moon has plentiful oxygen for future astronauts. It's lying on the ground.**

With binoculars, examine the rugged face of the Moon. It is pocked with thousands of impact craters from interplanetary asteroids and comets. Ever wonder why Earth, a much bigger target, apparently has so few craters? They're so rare that a pristine example, the Barringer Meteor Crater in Arizona, is actually a tourist attraction. Did Earth just get lucky and dodge the heavy artillery?

No, throughout the history of the solar system, Earth was bombarded even more than the Moon. But Earth is so geologically active that earthquakes, volcanoes, and plain old weather are continually crushing, melting, and reshaping its crust. In short, Earth is continually destroying evidence of its past, including evidence of ancient impact craters. Almost all the terrestrial craters that have been identified—only some 170 at last count—have been so eroded that essential clues have been erased.

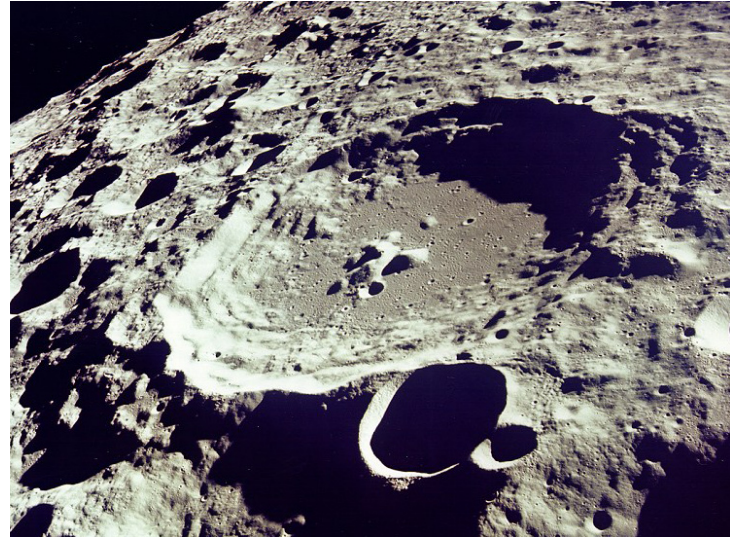
Not so the Moon. In fact, according to Paul Spudis, a senior planetary scientist at Johns Hopkins University's Applied Physics Laboratory, one of NASA's best reasons for returning to the Moon is to learn more about Earth.

"The Moon is a witness plate for Earth," declares Spudis, borrowing an apt term from weapons research. When scientists want to measure the type, amount, and pattern of damage done by an explosion, they set up diagnostic "witness plates" of various materials nearby to register the impact of shrapnel and radiation.

"Earth and the Moon occupy the same position in the solar system," Spudis explains. "While Earth is a very dynamic planet, the Moon is a fossil world with no atmosphere. So the Moon preserves a record of the early history of the solar system that is no longer readable on Earth."

That's not just speculation. In the early 1970s, the astronauts on the last three Apollo missions (15, 16,

and 17) returned deep-drill core samples from three different sites on the Moon. The cores drilled more than two meters into the lunar regolith (the layer of broken rock and dust covering the Moon).



The far side of the Moon is rough and filled with craters.

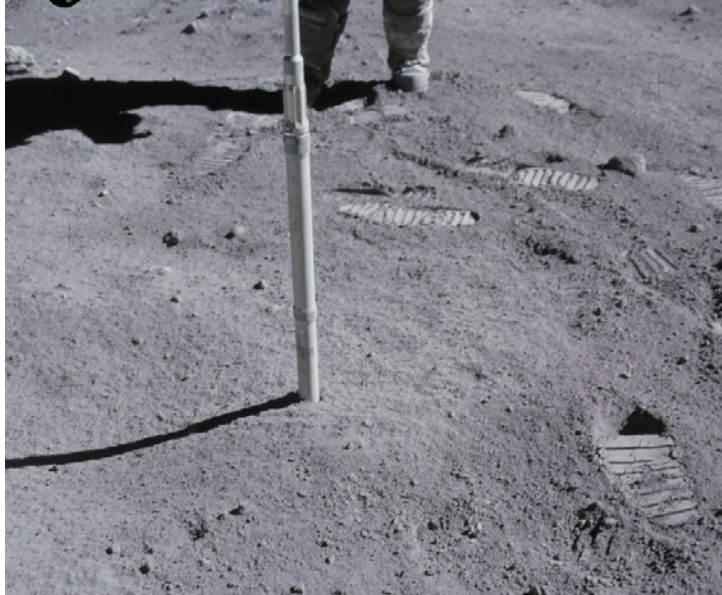
"The deepest samples brought up by those drill cores were 2 billion years old, and largely unchanged since they were laid down," Spudis says. And what a surprise recent re-analysis has revealed. "The lunar regolith traps particles from the solar wind. And drill cores show that the solar wind had a different chemical composition 2 billion years ago than it does today. There's no known explanation for that in solar theory. But that discovery is crucial for understanding the formation of Earth—and also the evolution of stars."

Another big question a return to the witness-plate Moon might help answer is, What caused the sudden mass extinctions of life forms on Earth that mark the ends of different geological eras?

The most famous is the so-called K-T extinction that wiped out the dinosaurs 65 million years ago, marking the end of the Mesozoic Era (the age of reptiles) and the beginning of the Cenozoic Era (the age of mammals). Much evidence suggests that an

# THE MOON IS A HARSH WITNESS

The Moon has plentiful oxygen for future astronauts. It's lying on the ground.



**Apollo 16 astronaut Charlie Duke (feet shown) drives a core sample tube into the lunar regolith.**

asteroid some 10 km wide slammed into Earth, creating such catastrophic climate change that photosynthesizing green plants died, starving more than half of all living beings worldwide; indeed, ground zero has been identified on Mexico's Yucatán Peninsula as the Chicxulub Crater, 160 km across.

There's evidence in the fossil record that such impacts occur periodically, "once every 26 million years," says Spudis. "Not everyone agrees, but I think it is pretty convincing."

Why would this happen? "Some theories are wild!" There might be a dark, distant companion of the Sun that periodically perturbs comets in the Oort Cloud, and the comets rain down on Earth. Or perhaps the solar system as a whole is moving in and out of the plane of the Milky Way galaxy, and this somehow triggers periodic episodes of bombardment.

Before we get carried away with theory, however, "we need to establish whether this really happens," Spudis cautions. Is Earth truly subjected to period-

ic bombardment? Again, the Moon holds the key: Close-up study of the floors of several hundred lunar craters could confirm or falsify a 26-million-year period. "We have to sample the stuff that got melted by the shock of impact and determine the craters' ages."

The Moon is a harsh—and reliable—witness for Earth.

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**NASA article from:**

[http://science.nasa.gov/headlines/y2007/26jan\\_harshwitness.htm](http://science.nasa.gov/headlines/y2007/26jan_harshwitness.htm)



## What basic human needs must be provided for in a lunar station?

### What to Do

1. Discuss the basic human needs for a lunar station. Consider:
  - What kind of spaces will you need for day-to-day living?
  - What kinds of work will you be doing on the Moon?
  - What types of recreation would you like to have?
  - What would you need to stay healthy?
  - What facilities are needed for recycling and waste management?

Note: Power supply will be developed by the Engineering Team.

2. Categorize these requirements and list them on a large sheet of paper. Categories can include living spaces, health, recreation, and work.

### Report to Class

- Your list of space requirements for living and working on the Moon.

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## What kind of lunar station would fulfill your list of requirements?

### What to Do

1. Design a lunar station that will fulfill your list of human requirements for living.
2. On a large sheet of paper, draw a rectangle that is 20" x 24". This represents the area of your lunar habitat. Use the stencils and ruler to help you draw rooms and buildings. Consider:
  - How much space is needed for each of your requirements?
  - Can any of the spaces serve two purposes?
  - Be sure to reserve a 8" x 8" space within your rectangle for the ecosystem constructed by the Ecosystem team.

### Present to Class

- The designed lunar station, its uses, and reasons you designed it the way you did.

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# MOONQUAKES

**NASA astronauts may need quake-proof housing.**

NASA astronauts are going back to the Moon, and when they get there they may need quake-proof housing.

That’s the surprising conclusion of Clive R. Neal, associate professor of civil engineering and geological sciences at the University of Notre Dame, after he and a team of 15 other planetary scientists reexamined Apollo data from the 1970s. “The Moon is seismically active,” he told a gathering of scientists at NASA’s Lunar Exploration Analysis Group (LEAG) meeting in League City, Texas, last October.

Between 1969 and 1972, Apollo astronauts placed seismometers at their landing sites around the Moon. The Apollo 12, 14, 15, and 16 instruments faithfully radioed data back to Earth until they were switched off in 1977.

And what did they reveal?

There are at least four different kinds of moonquakes: (1) deep moonquakes about 700 km below the surface, probably caused by tides; (2) vibrations from the impact of meteorites; (3) thermal quakes caused by the expansion of the frigid crust when first illuminated by the morning sun after two weeks of deep-freeze lunar night; and (4) shallow moonquakes only 20 or 30 kilometers below the surface.

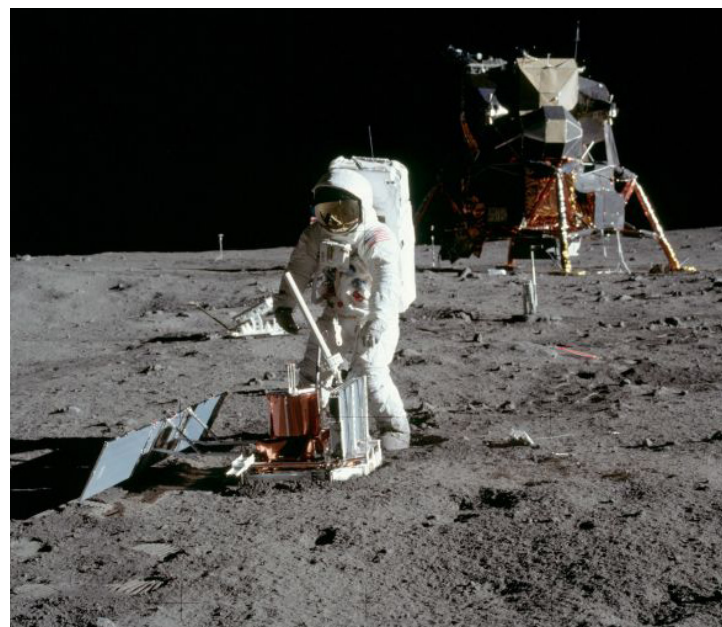
The first three were generally mild and harmless. Shallow moonquakes, on the other hand, were doozies. Between 1972 and 1977, the Apollo seismic network saw 28 of them; a few “registered up to 5.5 on the Richter scale,” says Neal. A magnitude 5 quake on Earth is energetic enough to move heavy furniture and crack plaster.

Furthermore, shallow moonquakes lasted a remarkably long time. Once they got going, all continued more than 10 minutes. “The Moon was ringing like

a bell,” Neal says.

On Earth, vibrations from quakes usually die away in only half a minute. The reason has to do with chemical weathering, Neal explains: “Water weakens stone, expanding the structure of different minerals. When energy propagates across such a compressible structure, it acts like a foam sponge—it deadens the vibrations.” Even the biggest earthquakes stop shaking in less than two minutes.

The Moon, however, is dry, cool and mostly rigid, like a chunk of stone or iron. So moonquakes set it vibrating like a tuning fork. Even if a moonquake isn’t intense, “it just keeps going and going,” Neal says. And for a lunar habitat, that persistence could be more significant than a moonquake’s magnitude.



**Buzz Aldrin deploys a seismometer in the Sea of Tranquillity.**

“Any habitat would have to be built of materials that are somewhat flexible,” so no air-leaking cracks would develop. “We’d also need to know the fatigue threshold of building materials,” that is, how much repeated bending and shaking they could withstand.





# MOONQUAKES

**NASA astronauts may need quake-proof housing.**

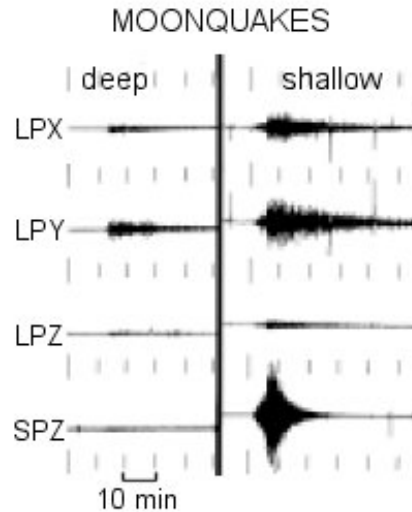
What causes the shallow moonquakes? And where do they occur? “We’re not sure,” he says. “The Apollo seismometers were all in one relatively small region on the front side of the Moon, so we can’t pinpoint [the exact locations of these quakes].” He and his colleagues do have some good ideas, among them being the rims of large and relatively young craters that may occasionally slump.

“We’re especially ignorant of the lunar poles,” Neal continues. That’s important, because one candidate location for a lunar base is on a permanently sunlit region on the rim of Shackleton Crater at the Moon’s South Pole.

Neal and his colleagues are developing a proposal to deploy a network of 10 to 12 seismometers around the entire Moon, to gather data for at least three to five years. This kind of work is necessary, Neal believes, to find the safest spots for permanent lunar bases.

And that’s just the beginning, he says. Other planets may be shaking, too: “The Moon is a technology test bed for establishing such networks on Mars and beyond.”

**NASA article from:**  
[http://science.nasa.gov/headlines/y2006/15mar\\_moonquakes.htm](http://science.nasa.gov/headlines/y2006/15mar_moonquakes.htm)



**Representative lunar seismograms from the Apollo 16 station.**



## What kinds of energy sources are available on the Moon?

### What to Do

1. As a team, discuss human activities on the Moon that will require electrical power. Write your list on a piece of paper.
2. Open the envelope labeled “Energy Source data cards.” They represent eight types of energy sources available on Earth.
3. Take turns reading each energy source aloud. Choose the energy sources that could be available to you on the Moon. Make a list of these.

### Report to Class

- List of human activities on the Moon that will require electrical power.
- List of energy sources that could be available on the Moon.

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## What kind of power plant will you design at the landing site?

### What to Do

1. Open the envelope labeled “Landing Site data cards.” Read the information about the landing site selected by the Navigation Team.
2. What challenges does the landing site pose in terms of generating electricity? How can you overcome these problems? Which energy sources will be available to you at the landing site?
3. Using the energy sources that you chose, design a power plant for your lunar station. Draw a model of it on a large piece of paper.

### Present to Class

- Your power plant design for the lunar station and the reasons why you chose these sources of energy.

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Energy Source  
**BIOMASS**

Biomass is usually thought of as garbage—dead trees, yard clippings, crops, sawdust, manure, food waste, and more.

Biomass can be burned in power plant furnaces to produce heat. The heat is used to boil water, and the steam that rises from the boiling water is used to turn turbines that generate electricity.

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Energy Source  
**HYDROPOWER**

Hydro means water.

Moving and falling water can be used to turn blades in large fans called turbines. As the turbines spin, they generate electricity.

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Energy Source  
**FOSSIL FUELS**

Fossil fuels are created by dead and decaying plants and animals that are subjected to bacterial processes, heat, and pressure over millions of years. This process chemically changes the organisms into fossil fuels. There are three main categories of fossil fuels: coal, oil, and natural gas.

When these fuels are burned, the heat turns generators that produce electricity.

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Energy Source  
**GEOHERMAL ENERGY**

Below the surface of the Earth's crust is hot liquid rock called magma (or lava). To access this energy, holes are drilled into the ground, and the hot water near the magma can be used to turn generators that make electricity.

This type of energy is available only when a planet or moon has volcanic activity.

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Energy Source

# SOLAR ENERGY

Energy from the Sun in the form of light can be collected with solar panels and turned into electricity.

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Energy Source

# NUCLEAR ENERGY (FISSION)

Nuclear energy is energy that is in the nucleus (core) of an atom, the tiny particles that make up every object in the universe.

When atoms are split apart, they release energy that can be used to produce electricity.

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Energy Source

# WIND ENERGY

Wind is air in motion. This moving air can turn blades in large fans called turbines. As the turbines spin, they generate electricity.

A planet or moon must have an atmosphere in order to have wind.

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Energy Source

# HYDROGEN FUEL CELL

There are large amounts of hydrogen in water and in the lunar soil. Hydrogen can be used in special fuel cells to generate electricity.

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Landing Site

# SOUTH POLE

This landing site always has a low level of sunlight. The Sun always appears on the horizon (like a constant sunset). Some areas are always in shadow and never receive sunlight.

It is a heavily cratered terrain with few flat areas. There is evidence for frozen water (ice) deep in the craters. There is no geothermal activity.

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Landing Site

# VALLEY OF TAURUS-LITTROW

This landing site has a two-week-long day of direct sunlight, followed by a two-week-long night. This cycle repeats.

It is in a smooth, deep, narrow valley between two different mountains, called the North and South Massif. There are no known water resources at this site. There is no active geothermal activity.

This was the landing site of the Apollo 17 mission in December 1972.

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## BREATHING MOON ROCKS

The Moon has plentiful oxygen for future astronauts. It's lying on the ground.



**Apollo 17 geologist Harrison Schmitt scoops up some oxygen-rich moon rocks and soil.**

An early, persistent problem noted by Apollo astronauts on the Moon was dust. It got everywhere, including into their lungs. Oddly enough, that may be where future Moon explorers will get their next breath of air: The Moon's dusty layer of soil is nearly half oxygen.

The trick is extracting it.

"All you have to do is vaporize the stuff," says Eric Cardiff of NASA's Goddard Space Flight Center. He leads one of several teams developing ways to provide astronauts with the oxygen they'll need on the Moon and Mars.

Lunar soil is rich in oxides. The most common is silicon dioxide ( $\text{SiO}_2$ ), "like beach sand," says Cardiff. Also plentiful are oxides of calcium ( $\text{CaO}$ ), iron ( $\text{FeO}$ ), and magnesium ( $\text{MgO}$ ). Add up all the O's: 43% of the mass of lunar soil is oxygen.

Cardiff is working on a technique that heats lunar soils until they release oxygen. "It's a simple aspect of chemistry," he explains. "Any material crumbles into atoms if made hot enough." The technique is called vacuum pyrolysis—*pyro* means "fire," *lysis*

means "to separate."

"A number of factors make pyrolysis more attractive than other techniques," Cardiff explains. "It requires no raw materials to be brought from Earth, and you don't have to prospect for a particular mineral." Simply scoop up what's on the ground and apply the heat.

In a proof of the principle, Cardiff and his team used a lens to focus sunlight into a tiny vacuum chamber and heated 10 grams of simulated lunar soil to about 2,500°C. Test samples included ilmenite and Minnesota Lunar Simulant, or MLS-1a. Ilmenite is an iron/titanium ore that Earth and the Moon have in common. MLS-1a is made from billion-year-old basalt found on the north shore of Lake Superior and mixed with glass particles that simulate the composition of the lunar soil. Actual lunar soil is too highly prized for such research now.

In their tests, "as much as 20 percent of the simulated soil was converted to free oxygen," Cardiff estimates.

What's leftover is "slag," a low-oxygen, highly metallic, often glassy material. Cardiff is working with colleagues at NASA's Langley Research Center to figure out how to shape slag into useful products like radiation shielding, bricks, spare parts, or even pavement.

The next step: increase efficiency. "In May, we're going to run tests at lower temperatures, with harder vacuums." In a hard vacuum, he explains, oxygen can be extracted with less power. Cardiff's first test was at 1/1,000 Torr. That is 760,000 times thinner than sea level pressure on Earth (760 Torr). At 1 millionth of a Torr—another thousand times thinner—"the temperatures required are significantly reduced."

Cardiff is not alone in this quest. A team led by Mark



## BREATHING MOON ROCKS

The Moon has plentiful oxygen for future astronauts. It's lying on the ground.

Berggren of Pioneer Astronautics in Lakewood, CO, is working on a system that harvests oxygen by exposing lunar soil to carbon monoxide. In one demonstration they extracted 15 kg of oxygen from 100 kg of lunar simulant—an efficiency comparable to Cardiff's pyrolysis technique.

D.L. Grimmatt of Pratt & Whitney Rocketdyne in Canoga Park, CA, is working on magma electrolysis. He melts MLS-1 at about 1,400°C so it is like magma from a volcano, and uses an electric current to free the oxygen.

Finally, NASA and the Florida Space Research Institute, through NASA's Centennial Challenge, are sponsoring MoonROx, the Moon Regolith Oxygen competition. A \$250,000 prize goes to the team that can extract 5 kg of breathable oxygen from JSC-1 lunar simulant in just eight hours.

The competition closes June 1, 2008, but the challenge of living on other planets will last for generations.

Got any hot ideas?

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### NASA article from:

[http://science.nasa.gov/headlines/y2006/05may\\_moonrocks.htm](http://science.nasa.gov/headlines/y2006/05may_moonrocks.htm)



Slag, a low-oxygen by-product of Cardiff's device. Slag may prove useful as a raw material for bricks, pavement, or radiation shielding.



## Where should you land on the Moon? What makes a good landing site?

### What to Do

1. Examine the maps of the South Pole and the Valley of Taurus-Littrow. Find the best place to land your rocket. Try to find a site that offers both a balance of safety and availability of resources. Consider:
  - Is the site flat, bumpy, or mountainous?
  - What is the availability of energy sources at the site?

### Report to Class

- The chosen landing site, its important features, the available resources, and the reasons you chose it.



## What supplies will you take to the Moon, and how will you pack them in the cargo bay?

### What to Do

1. Take out the Cargo Packing List. Follow the first step to prioritize the cargo that you will bring to the Moon.
2. Draw a 10" x 10" square on a large sheet of paper. This space represents the cargo bay of your rocket.
3. Cut out the six sets of shapes on the Cargo worksheets. These shapes represent cargo that you can pack into your rocket. The number on each one represents the percentage of volume that it will occupy in the cargo bay.
4. Based on your priority list, fit the shapes in the cargo bay, beginning with the supplies you'll need the most of. For example, if food is your number one priority, there should be a greater percentage of food packed in the cargo bay. Note:
  - Try to pack the cargo so there are no empty spaces.
  - Use only the shapes given. Do not cut to make them "fit" in the cargo bay.
5. Follow the second step on the Cargo Packing List worksheet to calculate the percentages of each type of packed cargo. A fully packed cargo bay will equal 100%. Repack the cargo bay if necessary.

### Present to Class

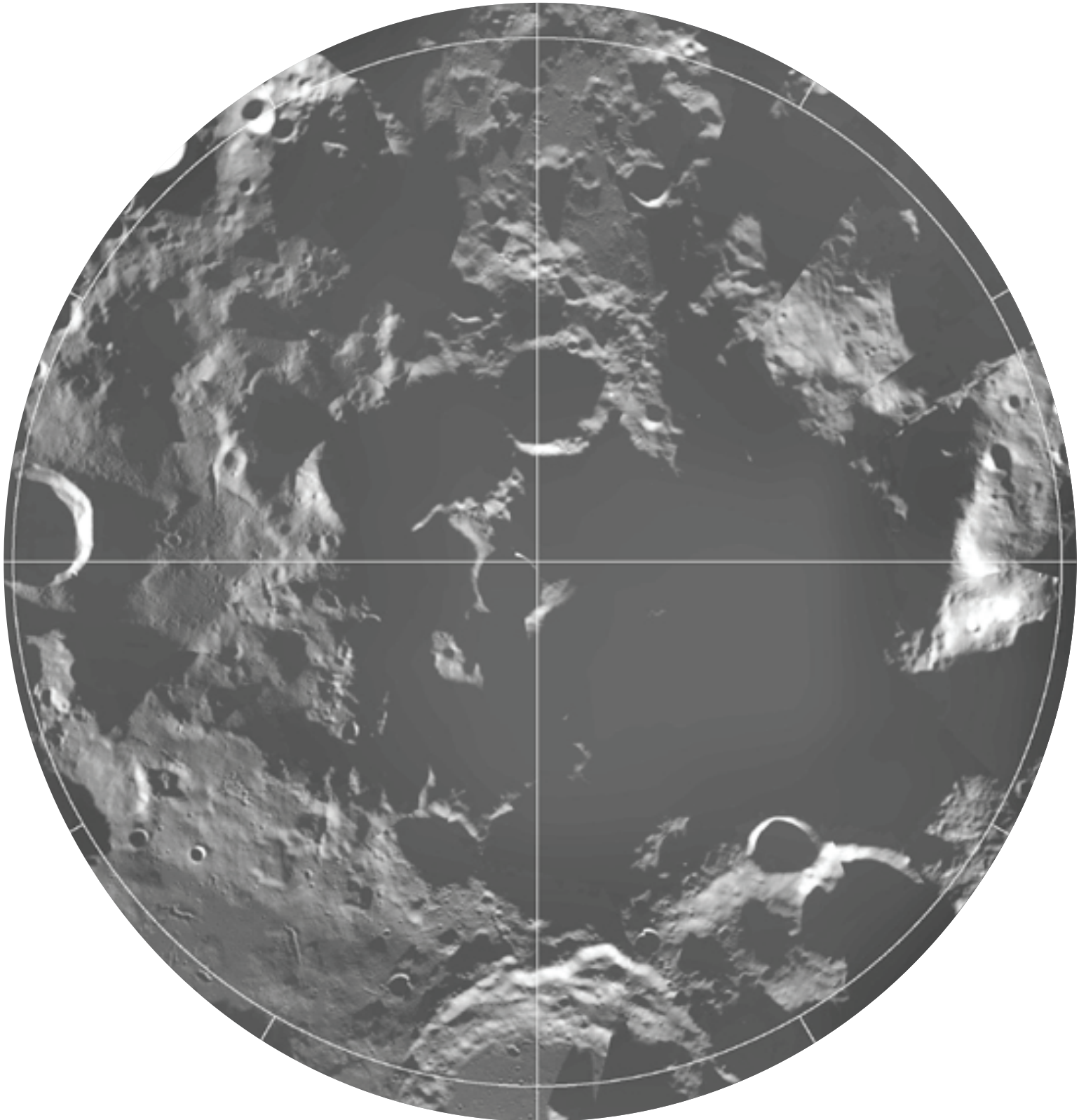
- The packed cargo bay and the reasons you chose the cargo you did.





## South Pole

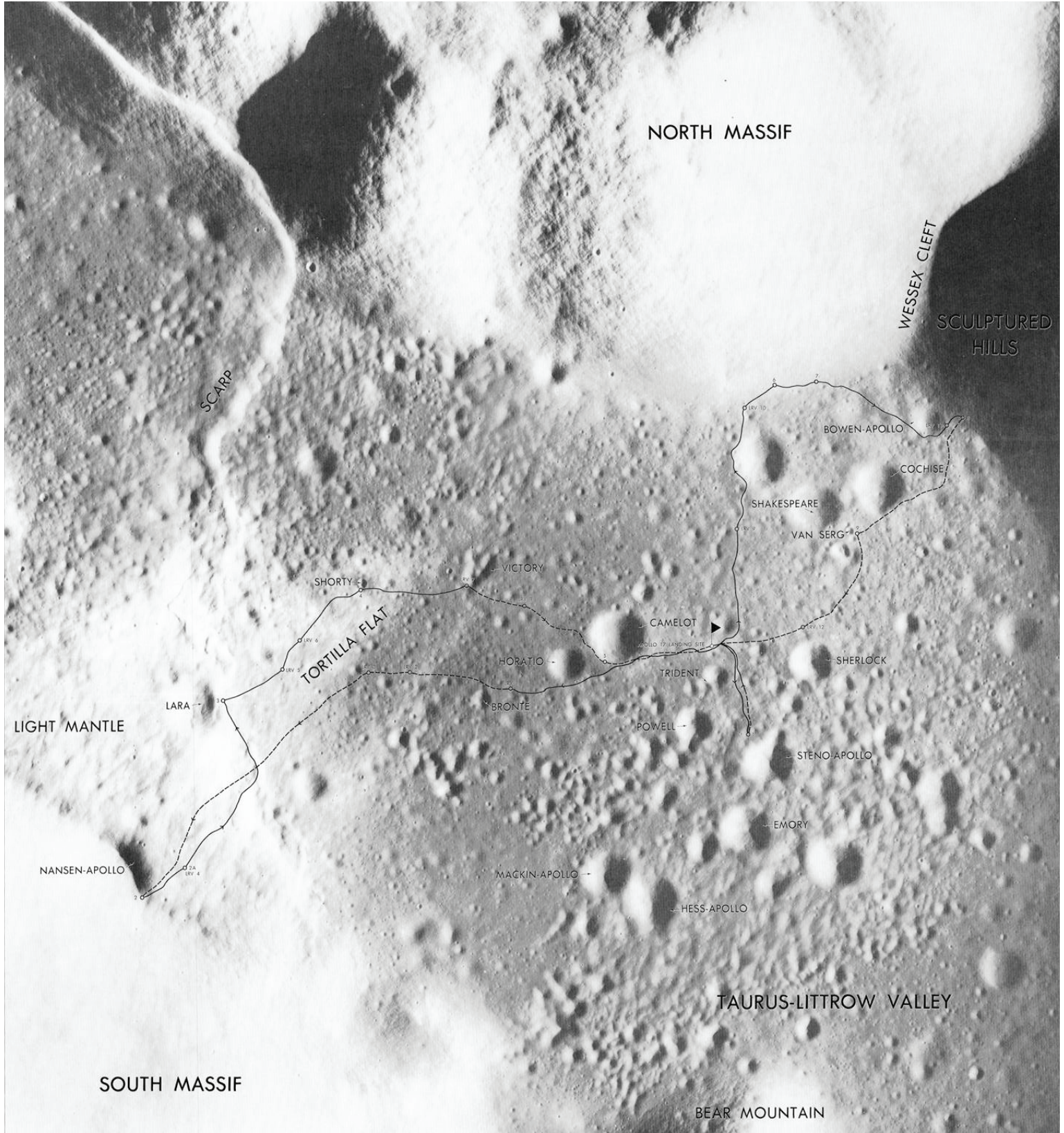
This landing site always has a low level of sunlight. The Sun always appears on the horizon (like a constant sunset). Some areas are always in shadow and never receive sunlight. It is a heavily cratered terrain with few flat areas. There is evidence for frozen water (ice) deep in the craters. There is no geothermal activity.





# Valley of Taurus-Littrow

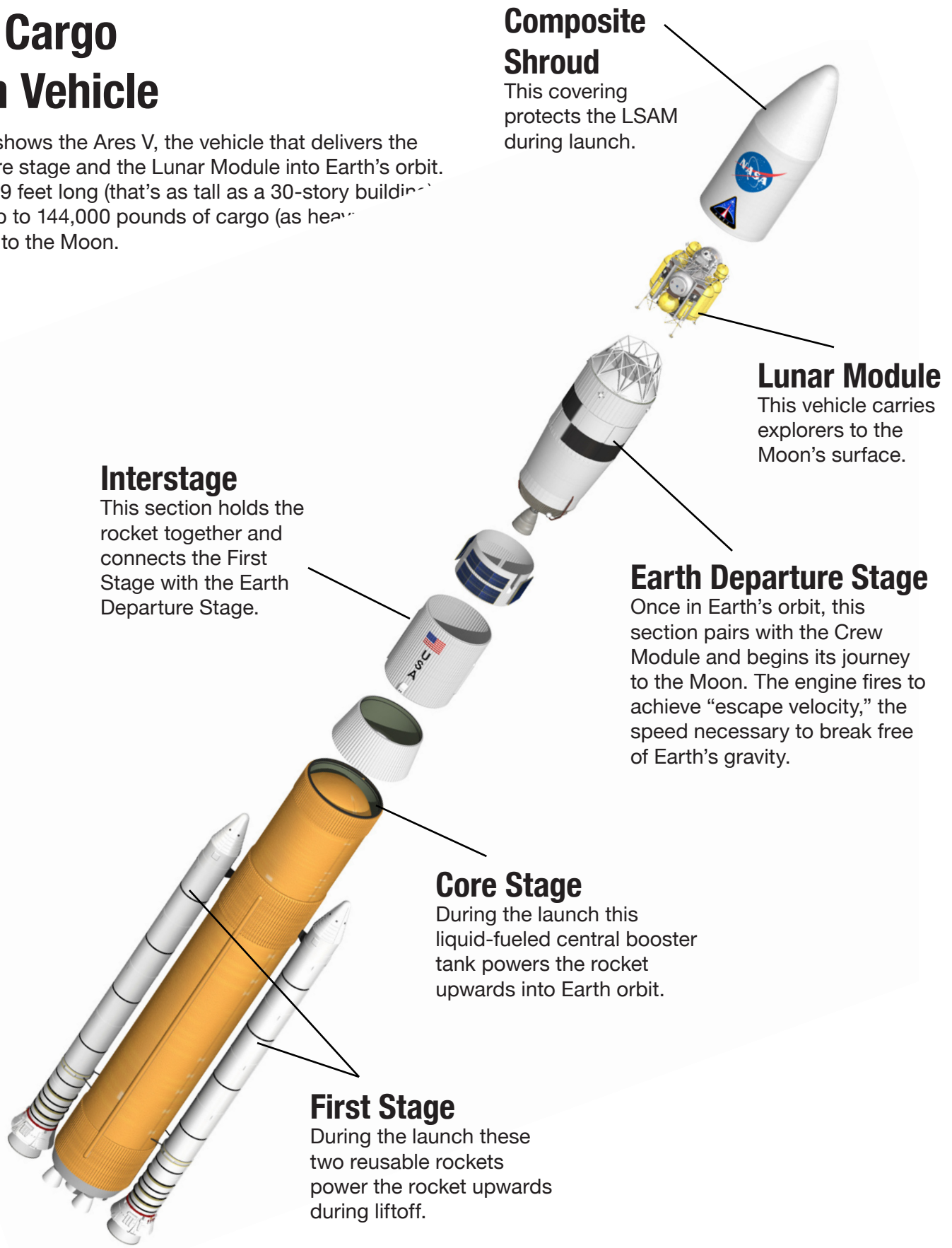
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## Ares V Cargo Launch Vehicle

This diagram shows the Ares V, the vehicle that delivers the Earth departure stage and the Lunar Module into Earth's orbit. The craft is 309 feet long (that's as tall as a 30-story building) and can get up to 144,000 pounds of cargo (as heavy as 10 school buses) to the Moon.



### Composite Shroud

This covering protects the LSAM during launch.

### Lunar Module

This vehicle carries explorers to the Moon's surface.

### Earth Departure Stage

Once in Earth's orbit, this section pairs with the Crew Module and begins its journey to the Moon. The engine fires to achieve "escape velocity," the speed necessary to break free of Earth's gravity.

### Interstage

This section holds the rocket together and connects the First Stage with the Earth Departure Stage.

### Core Stage

During the launch this liquid-fueled central booster tank powers the rocket upwards into Earth orbit.

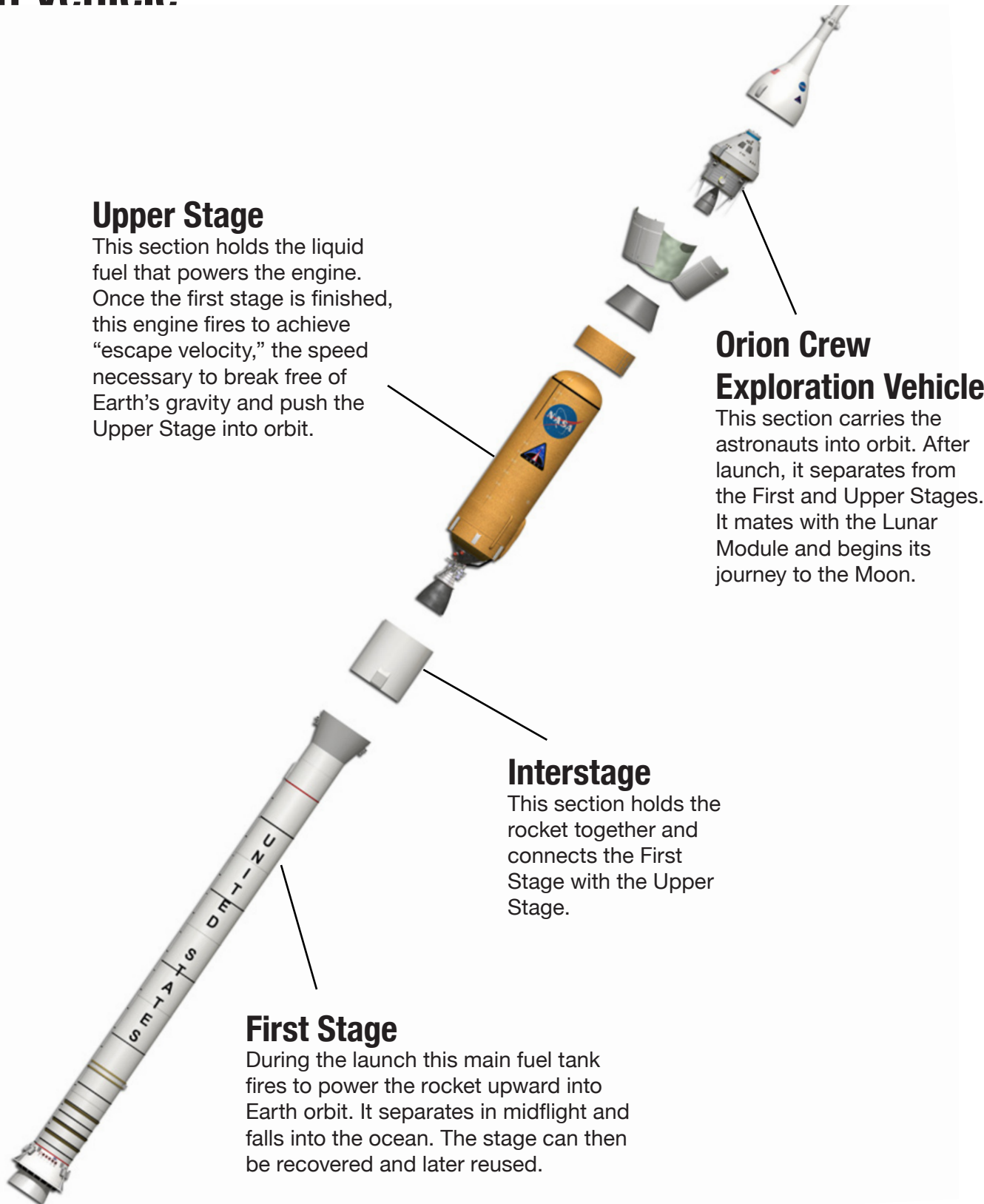
### First Stage

During the launch these two reusable rockets power the rocket upwards during liftoff.



## Ares 1 Crew Launch Vehicle

This diagram shows the four stages of the Ares 1 Crew Launch Vehicle.



### Upper Stage

This section holds the liquid fuel that powers the engine. Once the first stage is finished, this engine fires to achieve "escape velocity," the speed necessary to break free of Earth's gravity and push the Upper Stage into orbit.

### Orion Crew Exploration Vehicle

This section carries the astronauts into orbit. After launch, it separates from the First and Upper Stages. It mates with the Lunar Module and begins its journey to the Moon.

### Interstage

This section holds the rocket together and connects the First Stage with the Upper Stage.

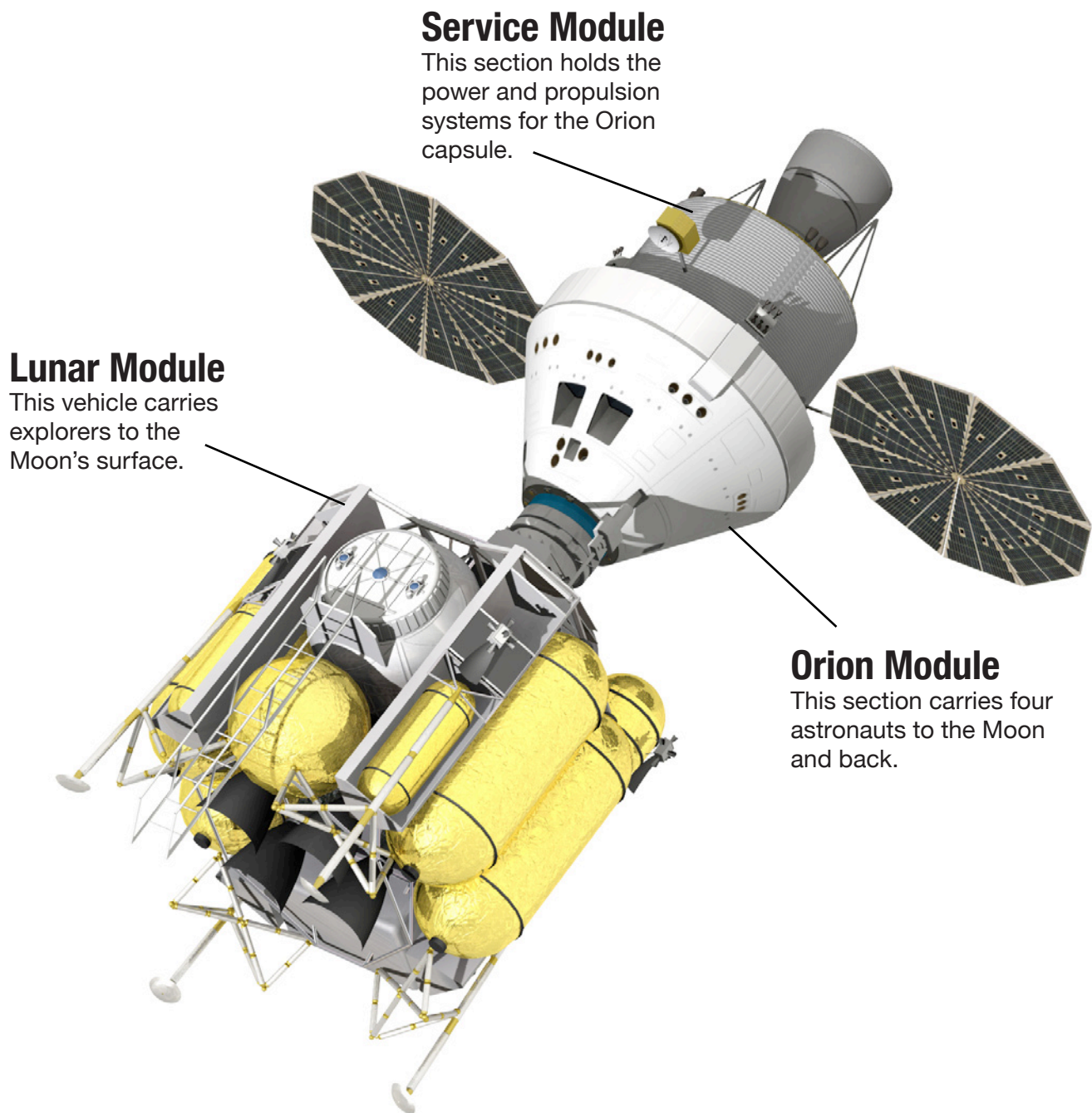
### First Stage

During the launch this main fuel tank fires to power the rocket upward into Earth orbit. It separates in midflight and falls into the ocean. The stage can then be recovered and later reused.



## Orion and Lunar Module

This diagram shows the spacecraft that will journey from the Earth to the Moon. These vehicles bring a crew of four astronauts and all their cargo.











## Cargo Packing List

### Prioritize Cargo

Below are six types of cargo that you will need to pack into your rocket's cargo bay, which has a limited amount of space. Prioritize the importance of each cargo to transport, and write numbers 1 to 6 on the left column (1 being the most supplies needed, 6 being the least). When prioritizing, be sure to consider the resources available at the selected landing site, and what is needed for survival and the construction of a lunar base.

### Calculate Actual Percentage of Cargo Packed

After you have packed the cargo shapes into the 10" x 10" cargo bay, determine if the packed cargo reflects your priority list. On a separate sheet of paper, count the percentages of each type of cargo. Check it against your prioritized list. For example, the highest percentage should match the cargo prioritized as 1. If the percentages don't match the priorities, repack the cargo bay and recalculate the percentages. Write the final percentages on the right column. If you pack the cargo bay completely with no empty spaces, you will have 100 percent cargo.

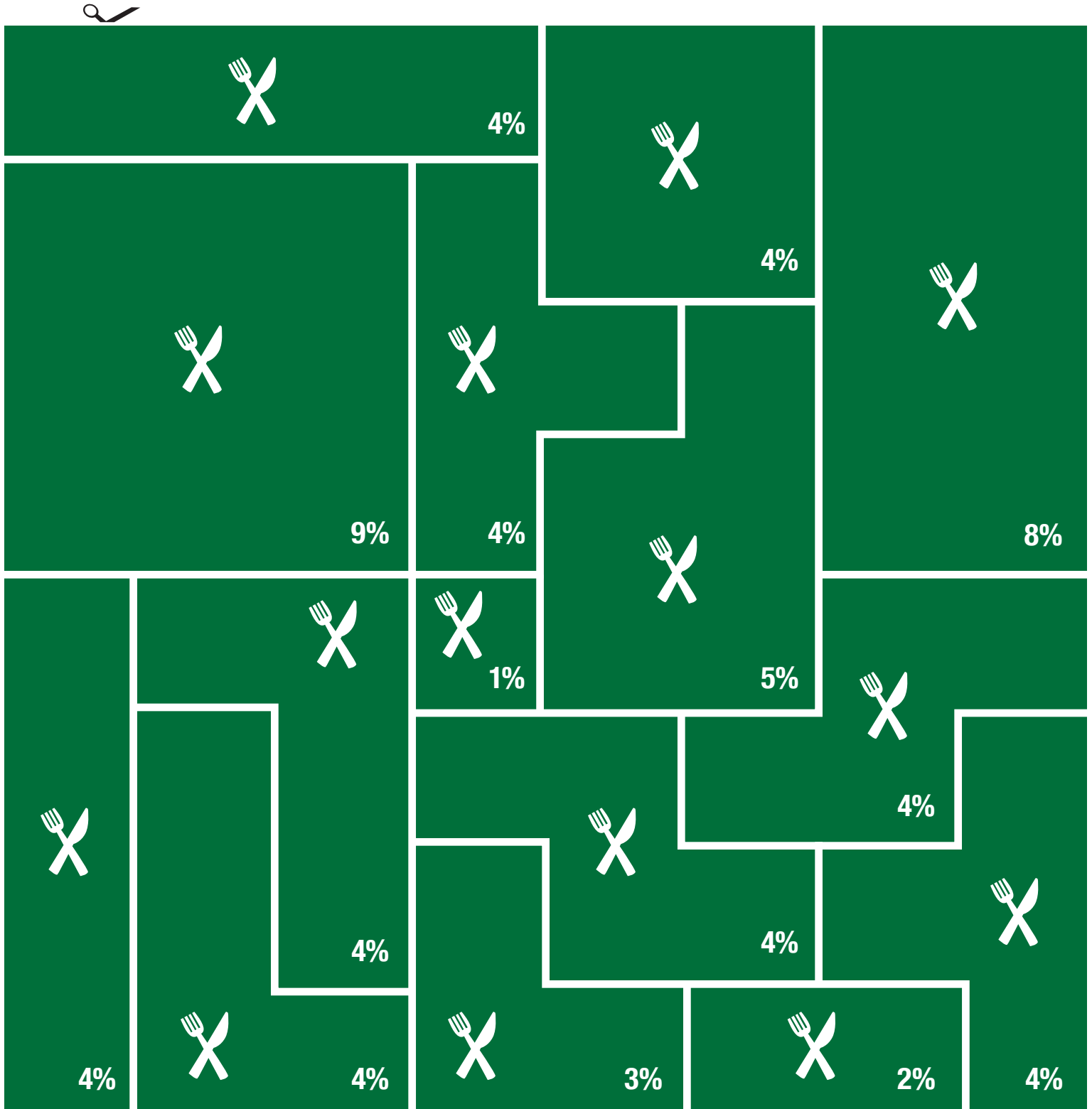
| PRIORITY | TYPE OF CARGO  | % PACKED CARGO |
|----------|--|----------------|
|          |  <b>Food</b><br>Examples: dried, frozen, and canned foods such as tortillas and peanut butter                 |                |
|          |  <b>Supplies</b><br>Examples: space suits, clothing, medical supplies, toiletries                            |                |
|          |  <b>Life Support</b><br>Examples: oxygen, water, air filters, water purification system                     |                |
|          |  <b>Mining Equipment</b><br>Examples: shovels, pickaxes, drills, robots, rotary wire brush                  |                |
|          |  <b>Power Equipment</b><br>Examples: generators, wires, electrical cords, outlets, light bulbs, solar cells |                |
|          |  <b>Building Equipment</b><br>Examples: power tools, construction materials, bricks, metal structures       |                |
|          |  | <b>TOTAL %</b> |
|          |  |                |



## Food Cargo

### Instructions

Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).





# Supplies Cargo

## Instructions

Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).

A large red rectangular area containing 18 white cargo icons (suitcases) and percentage values. A small scissors icon is at the top left. The cargo icons are arranged in a grid-like pattern with percentage values next to them. The percentages are: 4%, 4%, 4%, 9%, 4%, 4%, 8%, 1%, 5%, 4%, 4%, 4%, 4%, 4%, 4%, 3%, 2%, 4%.

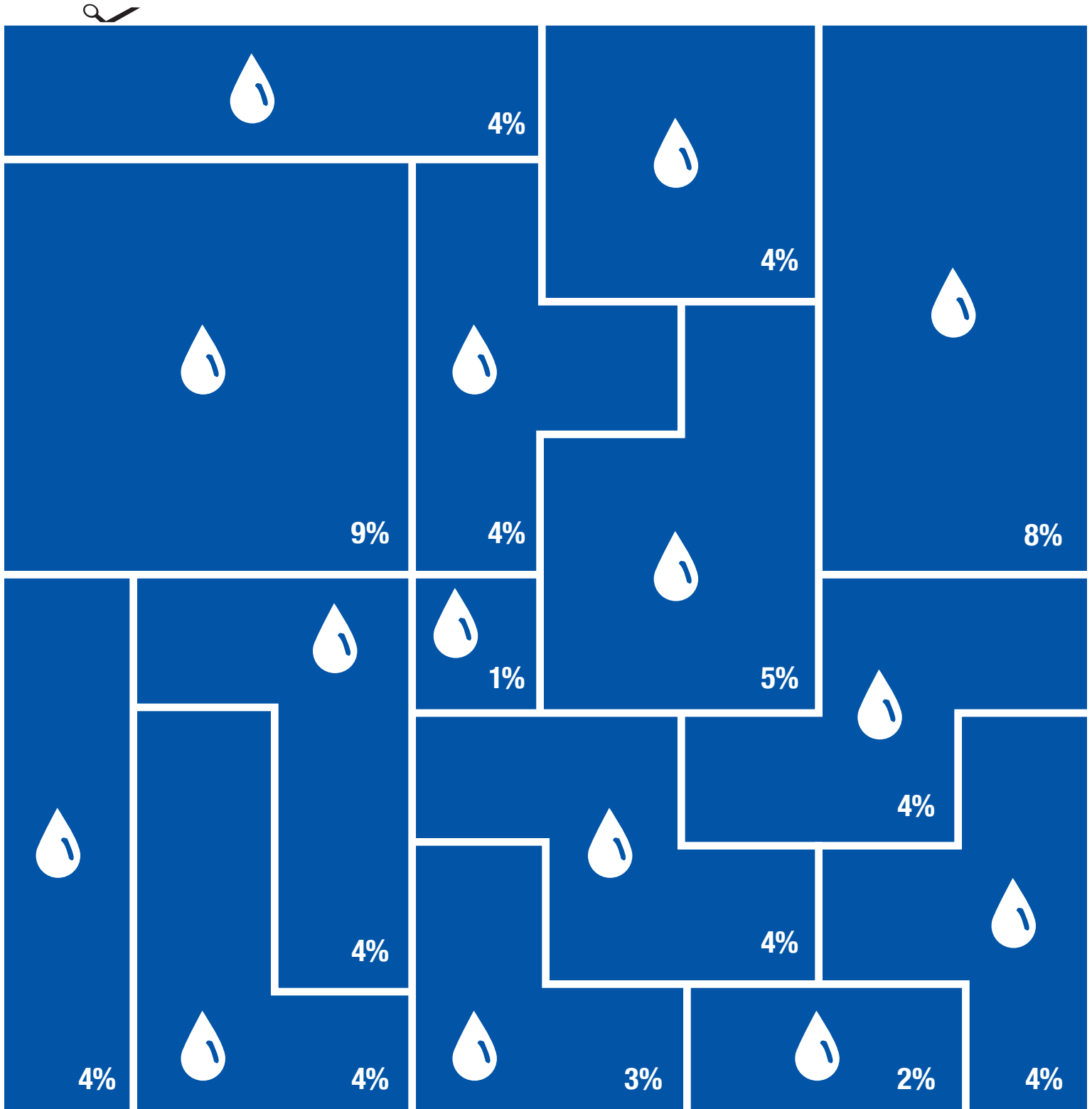




# Life Support Cargo

## Instructions

Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).





# Mining Equipment Cargo

## Instructions

Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



|    |    |    |
|----|----|----|
| 4% | 4% |    |
| 9% | 4% | 8% |
| 4% | 1% | 5% |
| 4% | 4% | 4% |
| 4% | 4% | 4% |
| 4% | 3% | 2% |
| 4% |    | 4% |



# Power Equipment Cargo

## Instructions

Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



The image shows a large yellow rectangle divided into 18 irregular shapes, each containing a lightning bolt icon and a percentage value. The shapes are intended to be cut out for use in a cargo packing activity. The percentages are as follows:

- Top-left: 4%
- Top-right: 4%
- Second row, left: 9%
- Second row, middle: 4%
- Second row, right: 8%
- Third row, left: 4%
- Third row, middle: 1%
- Third row, right: 5%
- Fourth row, left: 4%
- Fourth row, middle: 4%
- Fourth row, right: 4%
- Fifth row, left: 4%
- Fifth row, middle: 4%
- Fifth row, right: 3%
- Sixth row, left: 4%
- Sixth row, middle: 2%
- Sixth row, right: 4%



# Building Equipment Cargo

## Instructions

Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).

A large purple rectangular area containing 18 white cargo shapes, each with a percentage value. A small scissors icon is at the top left. The cargo shapes are arranged in a grid-like pattern with varying sizes and orientations. Each shape is a white silhouette of a cargo unit with a percentage value printed next to it.

| Percentage | Count |
|------------|-------|
| 1%         | 1     |
| 2%         | 1     |
| 3%         | 1     |
| 4%         | 10    |
| 5%         | 1     |
| 8%         | 1     |
| 9%         | 1     |



## A HITCHHIKER'S GUIDE TO THE MOON

**NASA plans to put a laser in orbit around the Moon to map its surface for future explorers.**

Imagine trekking in a lunar rover across miles of the Moon's rough surface. Your mission: to explore a crater with suspected deposits of ice.

In every direction, the gray terrain looks more or less the same. Wouldn't want to get lost in this place! you think to yourself. You arrive where the rover's digital map says the crater should be ... but it's not there! In a flash, you realize that your map is wrong. The crater's true position must be slightly different. But how different? A kilometer? Ten kilometers? In which direction?

Mission aborted.

The story is fiction, but it raises a real-life issue: the need for accurate maps of the Moon's terrain.

According to NASA's Vision for Space Exploration, astronauts will return to the Moon as early as 2015. This is a key step en route to Mars and beyond. On the Moon, which is practically in Earth's backyard, astronauts can learn how to live on an alien world before attempting longer voyages to other planets.

However, our current maps of the Moon are not very precise. In some areas, near Apollo landing sites, for instance, the locations of craters and ridges are well known. They were extensively photographed by lunar orbiters and Apollo astronauts. But much of the lunar surface is known only approximately.

"If you ask, Where is a crater on the far side of the Moon?, chances are there's probably many kilometers of uncertainty in its true positioning," says David Smith, a scientist at NASA's Goddard Space Flight Center. Even on the near side of the Moon, Smith adds, errors in the true global position of features may be as large as a kilometer.

To improve this situation, NASA plans to send a high-precision laser altimeter to orbit the Moon and create a three-dimensional map of its surface.

When completed, the map will be so accurate that we'll know the contours of the Moon better than we do some remote regions on Earth. Astronauts will be able to use it like a USGS hiking map.

The laser is named "LOLA," short for Lunar Orbiter Laser Altimeter. It's scheduled to launch in 2008 onboard the Lunar Reconnaissance Orbiter spacecraft. LOLA works by bouncing pulses of laser light off the lunar surface as it orbits the Moon. By measuring the time it takes for light to travel to the surface and back, LOLA can calculate the round-trip distance. LOLA is capable of timing pulses with a precision of 0.6 nanoseconds, corresponding to a distance error of no more than 10 cm.



**A 3-D map of the Martian volcano Olympus Mons, produced in the late 1990s by MOLA, the Mars Orbiter Laser Altimeter. LOLA, a close relative of MOLA, will produce similar views of the Moon.**

"In a sense, the Moon is an ideal object for making these kinds of observations because it has no atmosphere to interfere with the propagation of the laser pulses," says Smith, who is the principal investigator for LOLA.

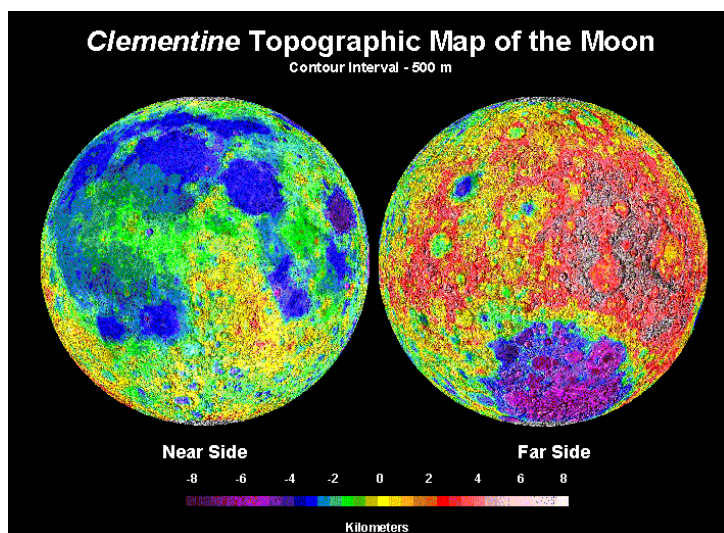
LOLA will map the Moon for at least a year, orbiting from the Moon's North Pole to the South Pole and back every 113 minutes. As it orbits, LOLA will send out laser pulses 28 times per second. Each pulse consists of five laser spots in a cross-like pattern, spanning about 50 meters of lunar surface. Altogether, LOLA will gather more than four billion measurements of the Moon's surface altitude.

After taking into account uncertainties in LOLA's orbit, the overall error in the true elevation of lunar



## A HITCHHIKER'S GUIDE TO THE MOON

NASA plans to put a laser in orbit around the Moon to map its surface for future explorers.



A map of the Moon's surface based on Clementine's laser altimeter. LOLA will produce a far superior 3-D map of the Moon.

features should be no more than a meter, while the true horizontal locations of those features should be known to within 50 m or less. The next-best laser ranging map, made by the Clementine mission in 1994, had an error of 100 m vertically and a horizontal resolution as coarse as 30 km.

This new map, combined with high-resolution images of the lunar surface taken by a camera onboard the spacecraft, will offer by far the best three-dimensional model of the Moon ever created.

Uses abound.

"A detailed knowledge of the shape of the Moon, how and where it diverges from a perfect sphere, can tell us a lot about how the Moon formed," notes Smith.

It'll make a great video game, too. Imagine flying around a photorealistic 3-D moonscape, over hills, in and out of craters, around Apollo landing sites. Astronaut training, anyone?

For people actually living on the Moon, LOLA-style maps will be indispensable. Imagine getting

caught outside, moonwalking, during a solar flare. Check your LOLA map for the nearest cave: instant shelter. Disoriented by moon dust? LOLA has your bearings.

Misplaced a crater? Unimaginable.

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### NASA article from:

[http://science.nasa.gov/headlines/y2005/24may\\_lola.htm](http://science.nasa.gov/headlines/y2005/24may_lola.htm)

## What medical supplies should you bring to the Moon?

### What to Do

1. Review the First Aid Tables that outline possible types of emergencies that may occur on the Moon.
2. Open the envelope labeled “Basic Lunar First Aid Kit.” These 11 data cards represent the items that are available in your first aid kit.
3. Open the envelope labeled “Additional First Aid Items.” Take turns reading these 14 data cards aloud. Discuss each first aid item. Consider:
  - How could it be used in emergencies?
  - Does it have more than one use?
  - Can it be substituted with something you already have?
4. Select five items to add to your first aid kit.

### Report to Class

- The items in your Basic Lunar First Aid Kit.
- The five additional items your team picked and the reasons why you chose them.

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## How would you treat an injured person on the Moon?

### What to Do

1. Open the envelope labeled “Emergency Scenario.” Have someone reach in and pick one card without looking, and read it out loud to your team.
2. Identify the symptoms of the injured person. Then find those symptoms on the cards that describe medical emergencies. Identify the procedure for treating the injured person. How should you treat him or her?
3. Choose the items you need from your first aid kit. Do you have everything you need? Have you chosen the right items in Task 1?
4. On a large piece of paper, write your treatment decisions and the items you will use from your first aid kit.
5. If there is time left, pick another emergency scenario card from the envelope and repeat the task.

### Present to Class

- The scenario, your diagnosis, your treatment decisions, and the items from your first aid kit.

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**First Aid Emergencies on the Moon**

**ENVIRONMENTAL EMERGENCIES**

Environmental emergencies are conditions brought on or worsened by some element in the patient’s surroundings. These emergencies throw off the human body’s natural systems affecting the cells’ ability to function normally. These situations can be fatal if the patient is not treated quickly.

| TYPE OF EMERGENCY | IMMEDIATE ACTION TO TAKE |
|-------------------|--------------------------|
|-------------------|--------------------------|

**Cold Exposure**

Results from increased body heat loss or decreased body heat production or both. This renders the body incapable of maintaining its constant core temperature of 98.6°F or 37°C.

**Signs and symptoms:** drowsiness, muscle stiffness, exhaustion, changes in skin color from red to grey, changes in breathing patterns from rapid to slow

- Prevent further heat loss
- Rewarm the patient as quickly and as safely as possible
- Give oxygen
- Monitor heart and blood pressure
- Stay alert for complications; provide CPR if cardiac arrest occurs

**Heat Exposure**

Results from decreased body heat loss or increased body heat production or both. The human body cannot maintain its constant core temperature of 98.6°F or 37°C.

**Signs and symptoms:** muscle cramps, weakness, faintness, headache, initial deep and rapid breathing, nausea, skin can be normal-to-cool temp, pale, moist, dry or hot

- Move patient to a cool place
- Give oxygen
- If skin moist, pale and cool, place patient in cool environment and fan to promote cooling
- If skin hot and dry or moist, cool patient by applying cold compresses at each side of neck, under armpits, and behind each knee
- Lie patient down and elevate legs
- Monitor heart and blood pressure

**Dust Inhalation**

Lunar dust is extremely fine and static. It clings to everything and is hard to remove. When inhaled, it causes congestion and hay fever-like symptoms. Lunar dust can also irritate the eyes.

**Signs and symptoms:** congestion, cough, watery eyes, runny nose, sneezing, and fatigue

- Medication to relieve congestion
- Give oxygen
- Give antibiotics to prevent respiratory infection
- Minimize lunar dust exposure
- Monitor heart and blood pressure

**Radiation Sickness**

Space radiation, especially coming from solar wind, is one of the main health hazards of spaceflight. It has enough energy to damage or kill cells, leading to health problems ranging from acute to long-term.

**Signs and symptoms:** nausea, vomiting, fatigue, burning, shortness of breath and headache

- Painkillers and anti-nausea drugs
- Antibiotics
- If there are burns, wrap them in sterile dry dressing
- Give oxygen
- Keep patient warm
- Monitor heart and blood pressure



**First Aid Emergencies on the Moon**

**MEDICAL EMERGENCIES**

Medical emergencies are situations usually brought about by illness or by substances that affect the function of the body.

**TYPE OF EMERGENCY**

**IMMEDIATE ACTION TO TAKE**

**Viral Infection**

An invasion of foreign cells in the body that causes harm to the host.

**Signs and symptoms:** fatigue, body aches, sore throat, and fever

- Minimize contamination
- Rest
- Antiviral medicine
- Monitor heart and blood pressure

**Stress**

Change in the body's inside balance when external demands become greater than personal resources.

**Signs and symptoms:** inability to concentrate, memory problems, anxiety, easily irritated, desire to escape or run away

- Anxiety medications
- Oxygen
- Monitor heart and blood pressure
- Rest

**Allergic Reaction**

An exaggerated response by the immune system to a foreign substance or allergen.

**Signs and symptoms (for minor allergic reactions):** itching, rashes and hives, nasal congestion and watery eyes

**Signs and symptoms (for major allergic reactions):** difficulty swallowing, difficulty breathing, swelling of face, eyes or tongue, and chest feeling tight

- Give oxygen
- Medications:  
Benadryl – minor reaction  
Epinephrine – major reaction
- Monitor heart and blood pressure

**Cardiac Arrest**

When the heart stops beating.

**Signs and symptoms:** sudden unresponsiveness, no normal breathing, and no pulse. Skin may have a bluish tinge, especially around the lips and under the fingernails

- Perform CPR (cardiopulmonary resuscitation)
- Use a defibrillator to jump-start the heart

**First Aid Emergencies on the Moon**  
**INJURY EMERGENCIES**

Injury emergencies are traumatic external force situations that cause physical injury or wounds to the body.

**TYPE OF EMERGENCY**

**IMMEDIATE ACTION TO TAKE**

**Musculoskeletal**

**Fractures** – broken bones.

**Signs and symptoms:** pain, swelling, discoloration, and deformity

**Sprains or Strains** - injury to joints or muscles.

**Signs and symptoms:** pain, swelling, bruising, and reduced mobility

**Dislocations** – displacement of bone from its normal position.

**Signs and symptoms:** pain, swelling, reduced mobility, discoloration, and deformation

- Prevent further movement by splinting
- Apply cold packs to reduce swelling and pain
- Give oxygen
- Elevate injury if no spinal injury suspected
- Monitor heart and blood pressure

**Soft Tissue**

Injury to skin, muscles, nerves, blood vessels, and organs.

**Signs and symptoms:** swelling, pain, and discoloration at injury site, possible breaks in the skin with external bleeding. Be on the lookout for shock. Signs and symptoms of shock: anxiety, dizziness, thirst, shallow rapid breathing, and cool, clammy skin.

- Control bleeding
- Prevent further injury
- Reduce risk of infection
- Give oxygen
- Monitor heart and blood pressure
- Treat for shock: maintain oxygen administration, keep patient warm, and elevate legs if possible.

**Head Injuries**

Injuries to the head must be treated with care as the skull encases the brain and part of the spinal cord. Improper care will result in severe consequences.

**Signs and symptoms:** confusion, irregular breathing, blood and fluid coming from ears or nose, nausea and/or forceful vomiting

- Immobilize head/neck/body
- Establish and maintain open airway
- Give oxygen
- Suction if necessary
- Immobilize patient to long board
- Monitor heart and blood pressure

**Burns**

Complicated injuries because in addition to damaging skin structure and compromising its function, burn injuries can impact most body outer systems as well.

**Signs and symptoms:** vary with burn depth (superficial to full thickness) and include pink-red dry, white and moist, or charred skin, swelling, blistering, pain, or numbness

- Remove patient from burn source and stop burning process
- Ensure open airway and adequate breathing
- Cover burn injury with dry, sterile dressings
- Maintain body temperature
- Give oxygen
- Monitor heart and blood pressure

Basic Lunar First Aid Kit

# PROTECTIVE GLOVES

- A form of personal protective equipment that acts as a barrier against infection
- Helps prevent skin from coming in contact with foreign blood and other body fluids
- Gloves are for single use only and must never be reused.

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Basic Lunar First Aid Kit

# BAG VALVE MASK

- A manual resuscitator for persons who cannot breathe on their own
- Consists of a self-inflating bag, a face mask, an oxygen reservoir valve, and an oxygen reservoir
- When used with an oxygen source, the bag valve mask will deliver close to 100% oxygen to the patient.

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Basic Lunar First Aid Kit

# BLOOD PRESSURE CUFF

- A medical tool placed on the upper arm and used to measure blood pressure
- Blood pressure is the force of blood pushing on the inside walls of blood vessels. It is expressed as a ratio.

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Basic Lunar First Aid Kit

# STETHOSCOPE

- A medical tool used to listen to the heart, breathing, as well as other sounds inside of the body
- To listen to sounds, you place the head against the intended body part (heart, chest, stomach).

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**Basic Lunar First Aid Kit  
PENLIGHT**

- Used to assess pupil reaction (the black part of the eye) to bright light
- Patient is instructed to look ahead as penlight comes from the side to shine into each eye.
- A quick pupil reaction to the light indicates good light accommodation.

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**Basic Lunar First Aid Kit  
DEFIBRILLATOR**

- A device that will deliver an electric shock to bring the heart back to a normal rhythm with a pulse
- Comes with pads to apply to the chest
- The defibrillator is intended for use with heart-attack patients.
- Patients must be unresponsive, with no breathing and no pulse.

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**Basic Lunar First Aid Kit  
SUCTION UNITS**

- Suctioning involves the removal of body fluids that may cause suffocation.
- Electronic units must produce a vacuum adequate to suction substances from the patient’s mouth and throat.
- Hand-powered devices do not require any energy source other than the medic to create the vacuum.

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**Basic Lunar First Aid Kit  
OXYGEN**

- Used to maintain adequate respirations
- The preferred method for delivering oxygen is by a mask. Oxygen is kept under pressure in a tank.
- With each inhalation, the patient draws in the contents of the bag, which is 100% oxygen.

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**Basic Lunar First Aid Kit**

**ORAL AIRWAY KIT**

- A semicircular device of hard plastic that holds the tongue away from the back of the throat
- Allows for suction and assisted respirations

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**Basic Lunar First Aid Kit**

**CARDIOPULMONARY RESUSCITATION (CPR)**

- CPR is a method of artificial breathing and circulation administered to a patient who is not breathing and has no heartbeat.
- The artificial breaths are given through the mouth using a pocket face mask. The circulation is accomplished by compressing the chest
- The Auto-Pulse is a non-invasive cardiac pump that provides consistent and effective chest compressions in cardiopulmonary resuscitation (CPR).

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**Basic Lunar First Aid Kit**

**POCKET FACE MASK**

- Used in the mouth-to-mask technique in which the exhaled air of the medic ventilates the patient
- A one-way valve at the ventilation port prevents exposure to the patient's exhaled air.

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**Additional First Aid Items**  
**THERMOMETER**

- Used to measure body temperature

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**Additional First Aid Items**  
**BURN CARE KIT**

- Contains items for the emergency management of burns. These include items that stop the burning process, and prevent further contamination (dry, sterile dressings) while en route to the hospital.

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**Additional First Aid Items**  
**EPINEPHRINE**

- Epinephrine is used to treat life-threatening allergic reactions caused by insect bites, foods, medications, latex, and other causes.

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**Additional First Aid Items**  
**ERYTHROMYCIN**

- Erythromycin is an antibiotic used to treat bacterial infections that affect the ears, skin, lungs, intestines, and urinary tract.
- It is also used before some surgery or dental work to prevent infection.

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**Additional First Aid Items**

**MORPHINE**

- Morphine is a narcotic used to relieve severe pain. It blocks much of the pain but also has a calming effect.

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**Additional First Aid Items**

**TYLENOL**

- Tylenol is used to treat headaches, muscle aches, arthritis, backaches, toothaches, colds, and fevers.

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**Additional First Aid Items**

**DRESSINGS**

- Dressings cover open wounds, help control bleeding, and prevent further contamination.
- Dressings should be sterile, or free of any bacteria, virus, or spore that can cause infection.

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**Additional First Aid Items**

**BANDAGES**

- Bandages are used to hold dressings in place.
- It is not necessary for a bandage to be sterile, but it should be clean and free of debris.

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**Additional First Aid Items**

**SPINE BOARD**

- Provides stabilization and immobilization of head, neck, torso, pelvis, and extremities (arms and legs)
- For proper immobilization of a patient, padding and straps are used with the long board.

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**Additional First Aid Items**

**RIGID SPLINTS**

- Used to immobilize injuries to the arms and legs
- Splinting prevents movement of the affected body part, reducing further injury.

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**Additional First Aid Items**

**VACUUM STRETCHER**

- The vacuum stretcher provides maximum support of the head, neck, torso, pelvis, and extremities.
- Provides comparable spinal immobilization to the long spine board, with increased comfort

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**Additional First Aid Items**

**EMERGENCY BLANKET**

- Used to maintain body heat

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**Additional First Aid Items**  
**STERILE WATER**

- Used to clean out wounds and other soft-tissue injuries

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**Additional First Aid Items**  
**HEAT AND COLD PACKS**

- Cold is used to reduce swelling and pain.
- Heat can be used to gently rewarm.

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**Scenario**

**ENVIRONMENTAL  
EMERGENCY**



Medics respond to a call from an astronaut who has taken shelter in a cave. She doesn't know it, but the temperature regulator on her spacesuit has malfunctioned, causing the temperature inside to fall. The astronaut is confused, and her face looks puffy and pink through the shield of her helmet. Her skin looks waxy. The astronaut states that she had been out for over an hour when she began to feel very tired.

- How would you treat this patient?
- What are the best items you can pull out of your kit to treat this patient?

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**Scenario**

**ENVIRONMENTAL  
EMERGENCY**



A lunar construction astronaut was outside working on the radiation shield for the lunar station when his air-dust filter malfunctioned. This caused him to gulp in a handful of moon dust. Medics find the astronaut crawling on the ground with a hacking cough. He has red, watery eyes, is wheezing, and complains of difficulty breathing.

- How would you treat this patient?
- What are the best items you can pull out of your kit to treat this patient?

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**Scenario**

**MEDICAL  
EMERGENCY**



In the lunar station kitchen, the chef tastes a new dish of "Moon-jack" soup. Soon after, he begins to have difficulty breathing. He turns bright red and his skin breaks out in a rash. Medics find the chef seated, leaning forward, sweating and clutching his chest. He has a hard time speaking but manages to state that he might be having an allergic reaction to the newly bioengineered spices used in the soup.

- How would you treat this patient?
- What are the best items you can pull out of your kit to treat this patient?

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**Scenario**

**INJURY  
EMERGENCY**



A technician fixing the antenna on the lunar station trips and falls 10 meters (30 feet). The bone in the lower part of her right leg (femur) is broken. Medics find the technician lying against the wall, clutching her leg and screaming in pain. She is pale, complaining of difficulty breathing and nausea.

- How would you treat this patient?
- What are the best items you can pull out of your kit to treat this patient?

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**Scenario**

**INJURY  
EMERGENCY**



In the lunar nuclear power plant, a technician burned his hand while running a lab experiment. Medics find the technician seated, holding the affected hand upward. The hand is red, with skin peeling and blistering. The technician states that he felt really tired and nauseous. As soon as he sat down, threw up, and is really thirsty.

- How would you treat this patient?
- What are the best items you can pull out of your kit to treat this patient?

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## **DON'T BREATHE THE MOON DUST**

**When humans return to the Moon and travel to Mars, they'll have to be careful of what they inhale.**

This is a true story. In 1972, Apollo astronaut Harrison Schmitt sniffed the air in his Lunar Module, the Challenger. “[It] smells like gunpowder in here,” he said. His commander Gene Cernan agreed. “Oh, it does, doesn’t it?”

The two astronauts had just returned from a long moonwalk around the Taurus–Littrow valley, near the Sea of Serenity. Dusty footprints marked their entry into the spaceship. That dust became airborne—and smelly.

Later, Schmitt felt congested and complained of “lunar dust hay fever.” His symptoms went away the next day; no harm done. He soon returned to Earth and the anecdote faded into history.

But Russell Kerschmann never forgot. He’s a pathologist at the NASA Ames Research Center studying the effects of mineral dust on human health. NASA is now planning to send people back to the Moon and to Mars. Both are dusty worlds—extremely dusty. Inhaling that dust, says Kerschmann, could be bad for astronauts.

“The real problem is the lungs,” he explains. “In some ways, lunar dust resembles the silica dust on Earth that causes silicosis, a serious disease.” Silicosis, which used to be called “stone-grinder’s disease,” first came to widespread public attention during the Great Depression, when hundreds of miners drilling the Hawk’s Nest Tunnel through Gauley Mountain in West Virginia died within half a decade of breathing fine quartz dust kicked into the air by dry drilling—even though they had been exposed for only a few months. “It was one of the biggest occupational-health disasters in U.S. history,” Kerschmann says.

This won’t necessarily happen to astronauts, he assures, but it’s a problem we need to be aware of—and to guard against.



**Moon-walking astronaut Harrison Schmitt.**

Quartz, the main cause of silicosis, is not chemically poisonous: “You could eat it and not get sick,” he continues. “But when quartz is freshly ground into dust particles smaller than 10 microns (for comparison, a human hair is 50+ microns wide) and breathed into the lungs, they can embed themselves deeply into the tiny alveolar sacs and ducts where oxygen and carbon dioxide gases are exchanged.” There, the lungs cannot clear out the dust by mucus or coughing. Moreover, the immune system’s white blood cells commit suicide when they try to engulf the sharp-edged particles to carry them away in the bloodstream. In the acute form of silicosis, the lungs can fill with proteins from the blood, “and it’s as if the victim slowly suffocates” from a pneumonia-like condition.

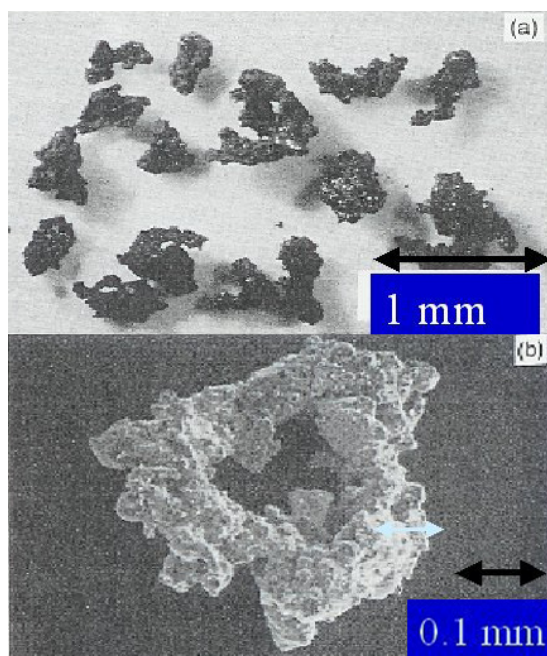
Lunar dust is, like quartz, a compound of silicon and (to our current knowledge) is not poisonous. But like the quartz dust in the Hawk’s Nest Tunnel, it is extremely fine and abrasive, almost like powdered glass. Astronauts on several Apollo missions found that it clung to everything and was almost impossible to remove; once tracked inside the

# DON'T BREATHE THE MOONDUST

**When humans return to the Moon and travel to Mars, they'll have to be careful of what they inhale.**

Lunar Module, some of it easily became airborne, irritating lungs and eyes.

Martian dust could be even worse. It's not only a mechanical irritant, but also perhaps a chemical poison. Mars is red because its surface is largely composed of iron oxide (rust) and the oxides of other minerals. Some scientists suspect that the dusty soil on Mars may be such a strong oxidizer that it burns any organic compound, such as plastics, rubber or human skin, as viciously as undiluted lye or laundry bleach.



**Microscopic images of moon dust.**

featured in the movie *Erin Brockovich* (Universal Studios, 2000). That was a surprising finding of a 2002 National Research Council report called “Safe on Mars: Precursor Measurements Necessary to Support Human Operations on the Martian Surface.”

The dust challenge would be especially acute during the windstorms that occasionally envelop Mars from the poles to the equator. Dust whips through the air, scouring every exposed surface and sifting into every crevice. There's no place to hide.

To find ways of mitigating these hazards, NASA is soon to begin funding Project Dust, a four-year study headed by Masami Nakagawa, associate professor in the mining engineering department of the Colorado School of Mines. Project Dust will study such technologies as thin-film coatings that repel dust from tools and other surfaces, and electrostatic techniques for shaking or otherwise removing dust from space suits.

These technologies, so crucial on the Moon and Mars, might help on Earth, too, by protecting people from sharp-edged or toxic dust on our own planet. Examples include the alkaline dust blown from dry lakes in North American deserts, wood dust from sawmills and logging operations, and, of course, the abrasive quartz dust in mines.

“If you get Martian soil on your skin, it will leave burn marks,” believes University of Colorado engineering professor Stein Sture, who studies granular materials like Moon and Mars dirt for NASA. Because no soil samples have ever been returned from Mars, “we don't know for sure how strong it is, but it could be pretty vicious.”

Moreover, according to data from the Pathfinder mission, Martian dust may also contain trace amounts of toxic metals, including arsenic and hexavalent chromium—a carcinogenic toxic waste

The road to the stars is surprisingly dusty. But, says Kerschmann, “I strongly believe it's a problem that can be controlled.”

**NASA article from:**

[http://science.nasa.gov/headlines/y2005/22apr\\_dontinhale.htm](http://science.nasa.gov/headlines/y2005/22apr_dontinhale.htm)



**Ecosystem**

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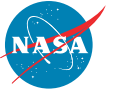
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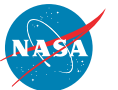
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**Geology**

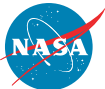
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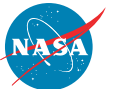
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**Habitat**

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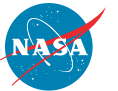
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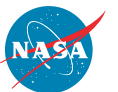
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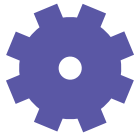
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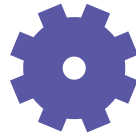






**Engineering**

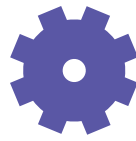
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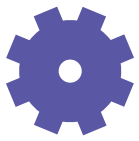
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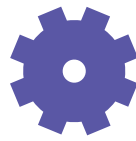
**Engineering**



**Engineering**



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**Engineering**





**Navigation**

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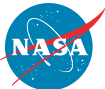
**Navigation**



**Navigation**



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**Navigation**





**Medical**

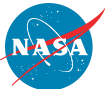
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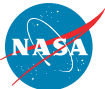
**Medical**



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**Medical**



# Field Trip to the Moon: An Interactive Lunar Experience EDUCATOR REPLY CARD

To achieve America's goals in Educational Excellence, it is NASA's mission to develop supplementary instructional materials and curricula in science, mathematics, geography, and technology. NASA seeks to involve the educational community in the development and improvement of these materials. Your evaluation and suggestions are vital to continually improving NASA educational materials.

**Please take a moment to respond to the statements and questions below. You can submit your response through the Internet or by mail. Send your reply to the following Internet address:**

**[https://neei.gsfc.nasa.gov/edcats/urls/exp/field\\_trip\\_reply\\_card.html](https://neei.gsfc.nasa.gov/edcats/urls/exp/field_trip_reply_card.html)**

**You will then be asked to enter your data at the appropriate prompt.**

Otherwise, please return the reply card by mail. Thank you.

1. With what grades did you use the educator guide?

Number of Teachers/Faculty:

\_\_\_ K-4 \_\_\_ 5-8 \_\_\_ 9-12 \_\_\_ Community College  
College/University - \_\_\_ Undergraduate \_\_\_ Graduate

Number of Students:

\_\_\_ K-4 \_\_\_ 5-8 \_\_\_ 9-12 \_\_\_ Community College  
College/University - \_\_\_ Undergraduate \_\_\_ Graduate

Number of Others:

\_\_\_ Administrators/Staff \_\_\_ Parents \_\_\_ Professional Groups  
\_\_\_ General Public \_\_\_ Civic Groups \_\_\_ Other

2. What is your home 5- or 9-digit zip code? -

3. This is a valuable educator guide?

Strongly Agree  Agree  Neutral  Disagree  Strongly Disagree

4. I expect to apply what I learned in this educator guide.

Strongly Agree  Agree  Neutral  Disagree  Strongly Disagree

5. What kind of recommendation would you make to someone who asks about this educator guide?

Excellent  Good  Average  Poor  Very Poor

6. How did you use this educator guide?

Background Information  Critical Thinking Tasks  
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 Group Discussions  Hands-On Activities  
 Integration Into Existing Curricula  Interdisciplinary Activity  
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 Other: Please specify:

7. Where did you learn about this educator guide?

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8. What features of this educator guide did you find particularly helpful?

9. How can we make this educator guide more effective for you?

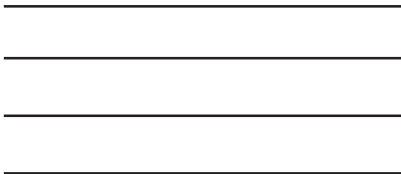
10. Additional comments:

Today's Date:

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