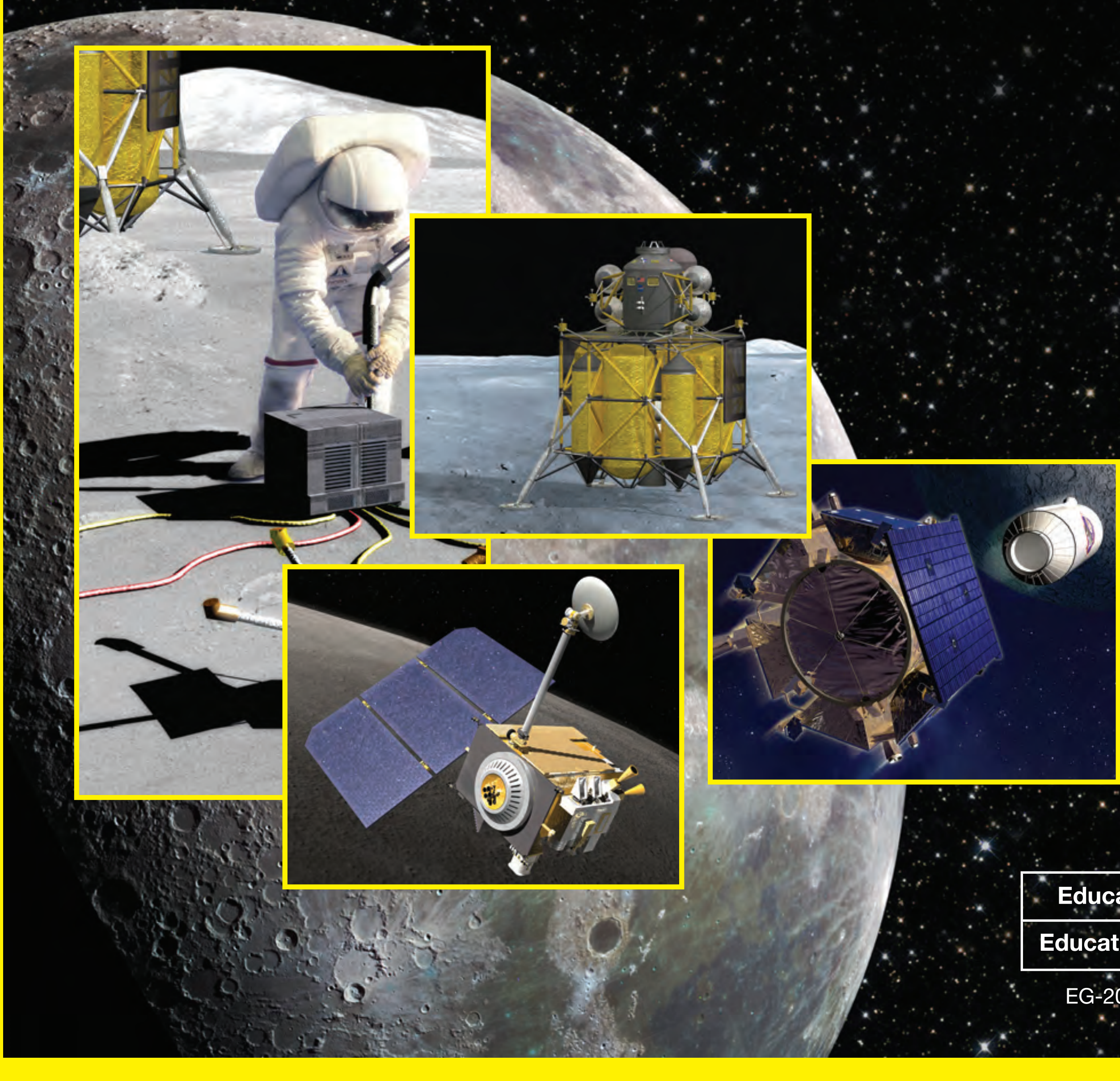
AMERICAN MUSEUM OF NATURAL HISTORY

FIELD TRIP TO THE MOON

LRO/LCROSS Edition

Informal Educator's Guide



Educational Product	
Educators	Grades 3–8

EG-2008-09-48-MSFC

Field Trip to the Moon

INFORMAL EDUCATOR'S GUIDE

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PROGRAM OVERVIEW

What is Field Trip to the Moon?

Field Trip to the Moon uses an inquiry-based learning approach that fosters team building and introduces participants to careers in science and engineering. The program components include the Field Trip to the Moon DVD, LRO/LCROSS Activities, and Lunar Base Activities. Together these materials can be used to create your own workshop that introduces important concepts about the Earth and the Moon, and motivates participants to use their cooperative learning skills. Working as a full group or in teams, the participants can develop critical thinking skills, problem-solving techniques, and an understanding of complex systems as they discuss solutions to the essential questions in this program.

FIELD TRIP TO THE MOON DVD

The DVD presents a wide range of media to use in your workshop: an introduction; the Field Trip to the Moon feature presentation; LRO/LCROSS animations and interviews; and additional media including a visualization about the formation of the Moon, and Moon trivia questions. The feature presentation introduces viewers to the challenges and excitement of launching from Earth's surface and journeying through space to land on the Moon. On the way, viewers will discover some of the differences between Earth and the Moon, and what makes our planet unique and habitable.

LRO/LCROSS ACTIVITIES

This set of activities introduce NASA's Lunar Reconnaissance Orbiter (LRO) and the Lunar Crater Observation and Sensing Satellite (LCROSS). This mission is collecting data that will help scientists and engineers determine the best place to build a future lunar outpost. Each activity engages the participants in important topics related to the mission, including lunar landforms, impact craters, geologic history, spacecraft design, and the future of lunar exploration. Select two to three activities, depending on your time frame and age level of the group.

LUNAR BASE ACTIVITIES

This set of activities engages participants in the exploration of the Moon's habitability and sustainable resources. Participants plan for the design and creation of a lunar station. Teams of participants investigate six topics:

Ecosystem | Geology | Habitat | Engineering | Navigation | Medical

Each team considers important topics related to future lunar missions, including technological, environmental, and psychological factors. Throughout the investigation, teams share their results with each other. When the teams finish their individual tasks, the group comes together to complete the lunar station.

National Science Education Standards Correlation

NSES CONTENT STANDARDS	DVD	LRO/LCROSS ACTIVITIES: LAVA LAYERS	ORBITER	MOON TUNE	LANDFORMS	IMPACTS	LUNAR BASE ACTIVITIES: ECOSYSTEM	GEOLOGY	HABITAT	ENGINEERING	NAVIGATION	MEDICAL
A Abilities necessary to do scientific inquiry		✓			✓	✓					✓	
Understandings about scientific inquiry			✓	✓							✓	
B Properties and changes of properties in matter								✓				
Motions and forces	✓					✓						
Transfer of energy	✓									✓		
C Structure and function in living systems												
Reproduction and heredity												
Regulation and behavior							✓		✓			
Populations and ecosystems							✓					
Diversity and adaptations of organisms												
D Structure of the Earth system	✓											
Earth’s history	✓											
Earth in the solar system	✓									✓		
E Abilities of technological design			✓	✓			✓	✓	✓	✓		
Understandings about science and technology			✓							✓	✓	
F Personal health												✓
Populations, resources, and environments												
Natural hazards	✓				✓	✓						✓
Risks and benefits	✓					✓						✓
Science and technology in society				✓								
G Science as a human endeavor												
Nature of science	✓											
History of science												

FIELD TRIP TO THE MOON DVD

About the DVD

The Field Trip to the Moon DVD presents a wide range of media created using NASA engineering models and scientific data. The DVD was developed by the American Museum of Natural History in collaboration with NASA Exploration Systems Mission Directorate (ESMD), and working closely with Marshall Space Flight Center, Ames Research Center, and Goddard Space Flight Center.

The DVD includes the following media:

- **Introduction** (2:50)
  A short historical introduction to human exploration of the Moon.

- **Field Trip to the Moon Feature Presentation** (20:42)
  The complete journey: from launch, through Earth orbit, to Moon orbit and landing. Like NASA's astronauts, audience members will come face-to-face with the challenges and excitement of launching from Earth's surface and journeying through space to land on the Moon. Along the way, they discover some of the differences between the 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)

- **Field Trip to the Moon Feature Presentation – no narration** (20:42)
  The main program is also available with music but no narration, allowing for alternate descriptions.

- **LRO/LCROSS Media** (TK)
  Short media segments that introduce NASA's LRO/LCROSS mission, including animation, interviews with NASA scientists, and related mission details.

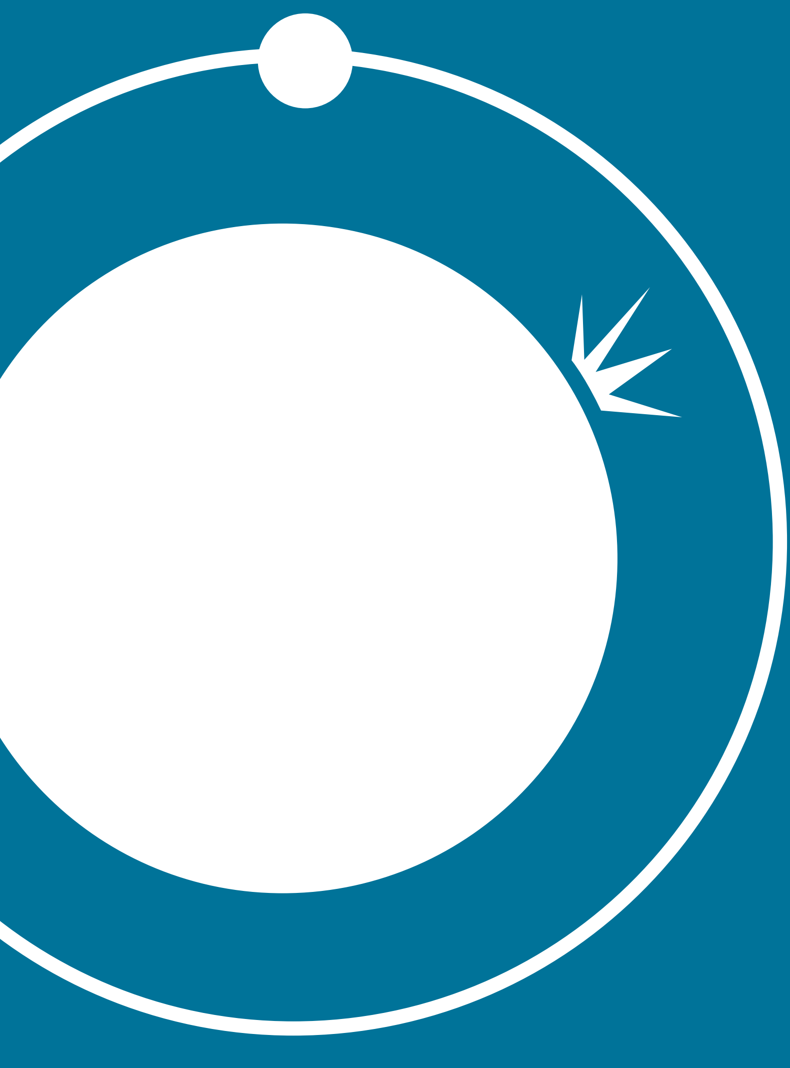
- **Our Moon** (2:22)
  A short annotated visualization about the formation of the Moon. Evidence suggests that the Moon formed when a Mars-sized object collided with the young Earth, and detailed computer models demonstrate that such an impact could form the Moon in just one month.

- **Lunar Trivia** (5:05)
  Multiple-choice questions about the Moon and lunar exploration to the key concepts.

Tech Specs

Use requires a DVD player (or computer) and a TV (or other monitor). The media is 16:9 resolution (anamorphic), so it will look best on widescreen TVs, but it is also formatted to display properly on standard definition TVs, with the black bars along the top and bottom of the screen typical of this format.

LRO/LCROSS ACTIVITIES



Time Frame
Up to two and a half hours, depending on which activities you select.

Preparation
Gather all materials for the activities you select. You will also need time to prepare the reproducibles. Read the background article to learn about NASA's LRO/LCROSS mission.

1 Phase One: Media Presentation (20 minutes)
Share with participants that in late 2008 NASA will be sending a spacecraft to explore the Moon: the Lunar Reconnaissance Orbiter (LRO) and the Lunar Crater Observation and Sensing Satellite (LCROSS). This mission will collect data that will help scientists and engineers determine the best place to build a future lunar outpost. View the LRO/LCROSS Media on the DVD.

2 Phase Two: LRO/LCROSS Activities
This set of activities engages participants in the exploration of important topics about the LRO/LCROSS mission, including lunar landforms, impact craters, geologic history, spacecraft design, and the future of lunar exploration. Select two to three of the activities, depending on your time frame and age level of the group.

Lava Layers
Age Level: 5-9 *Time Frame: 40 minutes*

In this activity, participants will learn about lunar stratigraphy created by lava flows from multiple volcanic eruptions.

Build the Orbiter
Age Level: 8-14 *Time Frame: 60 minutes*

In this activity, participants will build a model of NASA's Lunar Reconnaissance Orbiter (LRO), built from edible or non-edible materials. They will learn about the instruments the spacecraft will carry and how these instruments will help us better understand the Moon and plan for a future lunar outpost.

The Moon Tune
Age Level: 7-12 *Time Frame: 20 minutes*

This song activity will introduce participants to how the Moon formed and changed through time, NASA missions that will search for water and other resources on the Moon, and the future of lunar outposts.

Impact Craters
Age Level: 5-14 *Time Frame: 45 minutes*

In this activity, participants will explore what happens when a meteorite, asteroid, or other object hits the Moon. They will explore what features the impacts create by dropping balls of different sizes and weights from different heights.

Moon Landforms
Age Level: 9-14 *Time Frame: 40 minutes*

In this activity, participants will identify landforms on the surface of the Moon using photographs taken from the Apollo spacecraft.

ABOUT THE LRO/LCROSS MISSION

A NASA spacecraft preparing for future human exploration of the Moon.

The United States has begun a program to extend human presence in the solar system, beginning with a return to the moon. Returning to the moon will allow scientists to explore fundamental questions about the history of Earth, the solar system and the universe—and about our place in them. It will also allow us to test technologies, systems, flight operations and exploration techniques that will enable future missions to Mars and beyond.

The first step in this endeavor will be to launch the Lunar Reconnaissance Orbiter (LRO), an unmanned satellite that will create a comprehensive map of the moon's features. It will also identify resources that will aid in the design of a lunar outpost. LRO follows in the footsteps of Ranger, Lunar Orbiter, and Surveyor. These predecessors to the Apollo mission searched for the best possible landing sites.

The goals of LRO go beyond the requirements of these previous missions because building a lunar outpost means spending extended periods on the lunar surface. LRO will focus on the selection of safe landing sites, and identification of lunar resources. It will study how the lunar radiation environment will affect humans. The satellite will spend at least one year in a low polar orbit approximately 31 miles (50 km) above the moon's surface, collecting detailed information. The LRO payload, comprised of six instruments and one technology demonstration, will provide key data sets to enable a safe and productive human return to the moon.

The Lunar Crater Observation and Sensing Satellite (LCROSS) is another component of the return to the moon endeavor. The two main parts of the LCROSS mission are the Shepherding Spacecraft (S-S/C) and the Centaur rocket. Just like on Earth, water is a crucial resource on the Moon and it is not practical to transport the amount of water needed for human exploration.

The LCROSS mission will search for water on the moon. It will do this by sending the Centaur rocket crashing into the moon's surface. The impact will produce a crater and will eject tons of debris and potentially water ice and vapor above the lunar surface.

The Lunar Reconnaissance Orbiter (LRO) in orbit around the Moon.

At the same time the scientific instruments aboard the Shepherding Spacecraft will take pictures of the rocket's descent and impact on the moon. Four minutes later, the Shepherding Spacecraft will follow almost the exact same path as the rocket, descending down through the big plume, analyzing it with special instruments. The analysis will look specifically for water (ice and vapor), hydrocarbons and hydrated materials. The Shepherding Spacecraft will continually collect data and transmit it back to Earth before it too crashes. The Centaur crash will be so big that we on Earth may be able to view the resulting plume of material it ejects with a good amateur telescope.

The LRO mission and the LCROSS mission are scheduled for launch on an Atlas V 401 rocket in late 2008. LRO, the Shepherding Spacecraft and the Centaur will be connected to each other for launch, but then the LRO will separate one hour after launch.

NASA article adapted from:
http://lro.gsfc.nasa.gov
http://lcross.arc.nasa.gov

Lava Layers

In this activity, participants will learn about lunar stratigraphy created by lava flows from multiple volcanic eruptions.

Age Level
5-9

Time Frame
40 minutes

Materials
- Four 4 oz. paper cups/per group
- A screw-on bottle cap/per group
- Pie pan/per group
- Clear plastic straws
- Teaspoon
- Baking soda
- Measuring cup
- White vinegar
- Food coloring (4 colors: red, blue, yellow, green)
- Play dough (either bought or homemade) in the same 4 colors as food coloring (see attached homemade play dough recipe)
- Colored pencils
- Drawing paper

Preparation
For each group:

1. Secure the bottle cap to the center of the tin using a loop of tape. Put a teaspoon of baking soda in the cap.
2. Fill 4 tall paper cups each with 1/8 cup of vinegar. Make each cup a different color by adding 3 drops of food coloring (red, blue, yellow, green).
3. Set aside small balls of clay, one of each color.

Adapted from NASA's Lava Layering Activity:
http://lunar.arc.nasa.gov/education/activities/active7.htm

Lava Layers (continued)

Exploration

1. Ask participants what they see when they look at the Moon (a face, light and dark areas). Tell them that the dark areas are the lunar *maria*, or seas. Explain that they are not actual seas or oceans, but layers of lava that have flooded low areas in the past. Tell them that in this activity they will create their own lava flows. They will then take a *core sample* from the thickest part. Explain that geologists take core samples of earth and then analyze the layers. The information they gather can tell them what happened in the past.
2. Divide participants into groups of 3 to 4. Distribute pie tins, cups of colored vinegar and play dough to each group. Tell groups that the bottle cap is their eruption source and the pie tin represents the original land surface.
3. Have groups pour the red-colored vinegar into the source cap and watch the eruption of “lava.” Have group members use red play dough to cover the areas where red “lava” flowed.
4. Have groups repeat step 3 for each color of vinegar and play dough. You may need to add fresh baking soda to the source cap or spoon out excess vinegar as needed.
5. Distribute clear straws, paper and colored pencils to each group. Have each participant push a straw through an area of overlapping clay “lava” layers to get a “core sample.” Have them draw what they see in the vertical section, color their drawings and add these labels: oldest flow, youngest flow.

Wrap-Up

When groups have finished, have participants present their findings. You may want to use the following questions to build understanding.

- After your four eruptions, can you still see the original land surface (pie tin)? Where?
- Do you see lava flows covering or overlapping other flows? Describe it.
- Where is the oldest flow?
- Where is the youngest flow?
- Did your lava flows always follow the same path? How were the lava paths different?
- What do you think controls the direction of lava flows?
- If you had not seen the eruptions, how would you know that there are many different layers of lava? Can you give two reasons?

Build the Orbiter

In this activity, participants will build a model of NASA's Lunar Reconnaissance Orbiter (LRO), built from edible or non-edible materials. They will learn about the instruments the spacecraft will carry and how these instruments will help us better understand the Moon, and plan for a future lunar outpost.

Age Level
8-14

Time Frame
60 minutes

Materials
- Picture of the LRO for each group or for individuals to share
- Building materials (choose one):
    - Non-edible materials: medium size cardboard boxes, an assortment of smaller boxes (cereal boxes, milk containers, round boxes, etc), tin cans, flat pieces of cardboard, straws, foil cupcake holders, tin foil, glue, tape, silver electrician's tape, film canisters, pipe cleaners, magic markers.
    - Edible materials: candy, cookies, and crackers of varying shapes and sizes, including: pinwheel cookies (module), cupcakes (module), graham crackers (solar panels), sugar wafers (solar panels), gumdrops, candy corn, peppermints, after dinner mints, licorice sticks, hard candy, graham crackers, sugar wafers, pirouette cookies, pretzels, oyster crackers, marshmallows, snack mix, cereal.

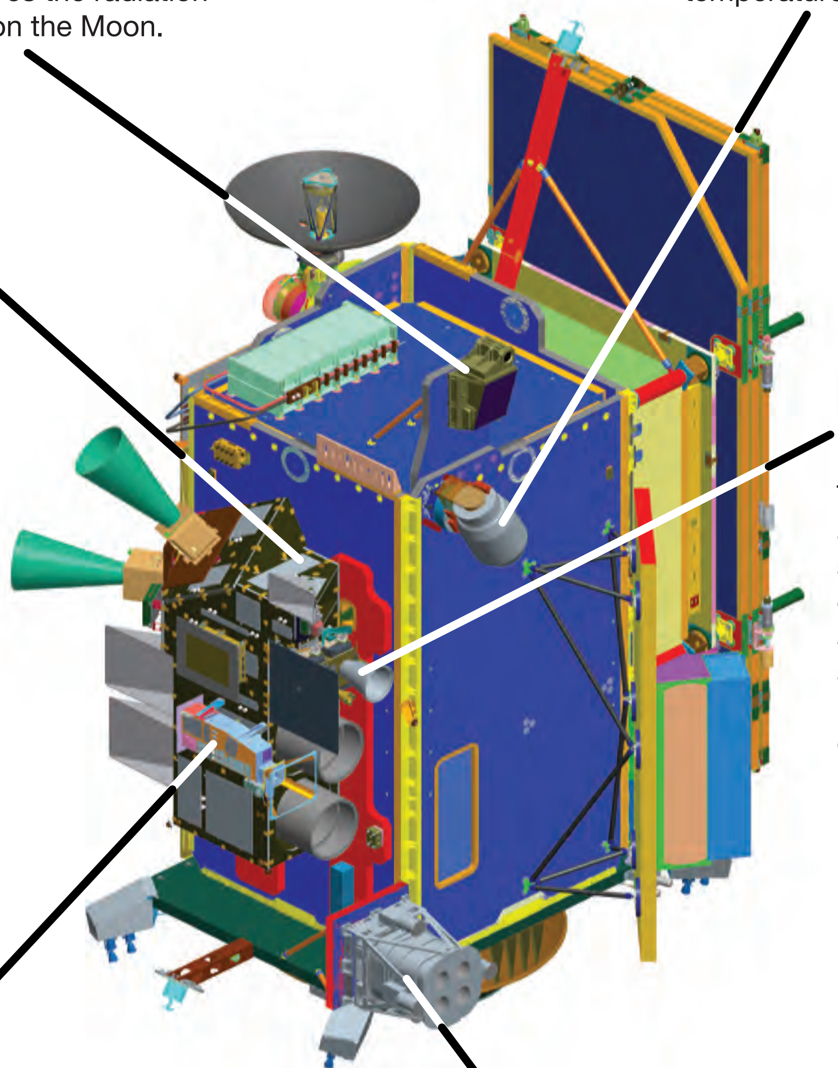
Exploration
1. Discuss with participants what kind of information the LRO will collect and how that information will be used. Point out that different NASA groups will design, assemble, and test the instruments for the LRO spacecraft. The NASA groups have to communicate with each other and with the technicians who will be putting the spacecraft together. They have to ensure that the instruments are the right weight, fit correctly together in the space available, and will collect measurements properly.
2. Display the pictures of the LRO spacecraft. Point out and name the various instruments. Tell participants that they will work in teams to build their own model of the LRO and then present it to the entire group.
3. Have the participants work in small groups. Distribute a picture of the LRO spacecraft and an instrument information sheet to each group.
4. Have groups look at the orbiter and identify and read about each instrument. Have them discuss how they might go about building their LRO. Have them choose the materials they will need and work together to construct the orbiter.

Wrap-Up
Have each group present their completed orbiter. Call on different members of the group to point out the various instruments and to describe their functions.

Adapted from LPI's Building an LRO Activity:
http://www.lpi.usra.edu/education/explore/moon/lro.shtml

Lunar Reconnaissance Orbiter

This diagram shows the LRO spacecraft that will orbit around the Moon. There are six instruments on board, each with a specific job.



CRATER

Cosmic Ray Telescope for the Effects of Radiation

This instrument measures the radiation levels on the Moon.

DLRE

Diviner Lunar Radiometer Experiment

This instrument takes the temperature of the lunar surface.

LROC

Lunar Reconnaissance Orbiter Camera

This is a special camera that takes close-up pictures of the surface of the Moon in order to look for safe places that future missions could land. It is also looking for places that sunlight doesn't reach or places where the sun is almost always shining.

LOLA

Lunar Orbiter Laser Altimeter

This instrument will make a detailed map of the surface of the Moon that is good enough to allow for safe landings on the lunar surface. It is also looking for ice crystals on the surface of the Moon that might be hidden in dark shadows.

LAMP

Lyman Orbiter Laser Altimeter

This camera looks for ultraviolet light—a kind of light that our eyes cannot see—in order to locate places on the Moon that are always in shadow. It is looking for water-ice that might be hidden in the darkness of these areas.

LEND

Lunar Exploration Neutron Detector

This instrument measures how many neutrons, or tiny particles with no electric charge, come from the Moon's surface. Neutrons are made when cosmic rays from space hit the lunar surface.

The Moon Tune

This song activity will introduce participants to how the Moon formed and changed through time, NASA missions that will search for water and other resources on the Moon, and the future of lunar outposts.

Age Level
7-12

Time Frame
20 minutes

Materials
- The Moon Tune lyrics
- Field Trip to the Moon DVD (this optional music track is located in the LRO/LCROSS menu)

Exploration
Note: The song is sung to the tune of "You are my Sunshine." Older participants may want to make up their own tune in different musical styles (such as hip-hop, country, jazz, etc).

1. Have participants divide into groups. Distribute "The Moon Tune." Explain that each group will be called on to sing several stanzas. Sing the first stanza of the song, pausing at the "/" symbol to make sure participants are familiar with the tune.
2. Designate which stanzas each group will sing. Then, sing the song along with the groups! You may want to use the optional music track on the DVD as accompaniment to your singing.

Adapted from LPI's LRO Moon Tune Activity:
http://www.lpi.usra.edu/education/explore/moon/moon_tune.shtml

The Moon Tune (continued)

Wrap-Up

Conclude the activity by using the following questions to guide a discussion. Encourage participants to find answers in the lyrics.

1. **How did our Moon form?**
(Answers will include: A large, planet-sized body struck Earth, vaporizing the impactor and hurtling pieces of the impactor and Earth's outer surface into orbit around Earth. Those pieces eventually clumped together — accreted — to form our Moon.)
2. **How do craters on the Moon form?**
(Answers will include: Craters are formed when asteroids or comets strike the Moon. Most of the larger craters formed early in the Moon's history, until about 3.9 billion years ago; however the Moon and other planetary bodies still are hit by asteroids and comets occasionally.)
3. **What important resource may comets deliver to the Moon when they strike?**
(Answers will include: Ice; comets contain water ice.)
4. **Why would ice from comets not melt?**
(Answers will include: If it is in the deep craters, or in polar regions, where the Sun's heat does not reach it, it could stay frozen.)
5. **How did the Moon's dark patches form?**
(Answers will include: Some craters were later filled by lava that cooled to form smooth, dark areas on the Moon. These dark areas are called *mare*, or seas, but they never contained water.)
6. **What is the Lunar Reconnaissance Orbiter? How long will it orbit the Moon?**
(Answers will include: The LRO is a NASA spacecraft that will orbit and study the Moon for about a year.)
7. **What kinds of information will the LRO collect for scientists?**
(Answers will include: Measurements of temperature and radiation from the Sun, maps of resources like types of rocks and water ice, maps and pictures of the lunar surface and its features.)
8. **Why does NASA want to collect more information about the Moon?**
(Answers will include: NASA plans to send humans to the Moon for extended stays at lunar outposts around 2018. LRO will provide important information about where certain resources — like water ice and elements in rocks — exist, where the surface is safe for landing and building, and where scientific questions about the Moon's formation and changes can best be studied. All of these activities will prepare future astronauts to explore Mars and beyond.)

The Moon Tune

Note: The song is sung to the tune of "You are my Sunshine."

**The LRO is / NASA's new mission
To orbit 'round the Moon one year,
And take cool pictures / of all the craters
In search of water with hi-tech gear.**

**Some lunar craters / were made by comets,
Those balls of dirt and ice in space.
They hit the Moon and / they made some big holes,
That made the Moon have a crater face.**

**And if these craters / are deep enough holes
Some of their ice may still be there.
And when you melt ice / you will get water,
And it's the water about which we care.**

**The Moon has many / other cool features.
It has some mountains, rocks, and seas,
Except the "seas" are / not filled with water,
They're filled with hard lava rock, you see?**

**Now let me tell you / the cool true story
Of how our Moon first came to be.
It was part of Earth / then it got knocked off
By a planet-sized rock and set free.**

**It wasn't knocked off / into just one piece,
But into lots of rocks in space.
Then they accreted / that's stuck together,
To form our Moon that extraordinary place!**

**And with the data / that we collect there,
We will return again some year.
Two thousand eighteen / is what we hope for,
And on that day then all Earthlings will cheer!**

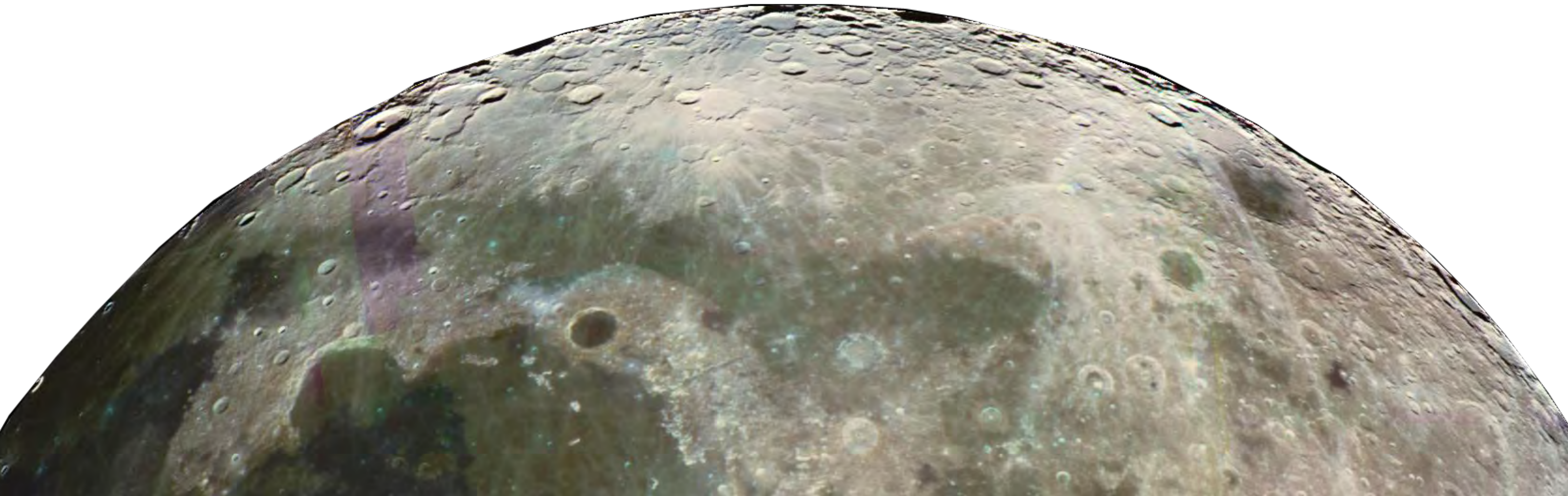
**In LRO the / "L" stands for "lunar,"
Which is another word for "Moon."
"R" means "reconnaissance" / that is a big word
For getting info to get us there soon!**

**What does the "O" mean? / It stands for "orbiter"
Which means to circle 'round and 'round.
The LRO will / just stay in orbit
And, no, it never will ever touch down.**

**The type of data / it will collect there,
Will be about Moon temps and ice,
And radiation / and surface features.
To have this data will sure be nice!**

**There is one thing that / the Moon does not have,
And that's an atmosphere with air.
But we'll extract it / from rocks and water,
Which will help us build bases up there!**

**And all this data / will help us know how
To someday build a lunar base,
To launch some rockets / and other spacecraft,
To Mars and other cool places in space!**



Impact Craters

In this activity, participants will explore what happens when a meteorite, asteroid, or other object hits the Moon. They will explore what features the impacts create by dropping balls of different sizes and weights from different heights.

Age Level
5-14

Time Frame
45 minutes

Materials
- NASA photographs of craters on the Moon and Mars
- One large tub or box, such as a large dishpan
- A large bag of flour (enough to fill the box 1-2 inches deep)
- Fine cocoa powder or sand
- Sieve
- Two same-size balls of different weights, such as a marble, gumball, or mothball; two same-weight balls of different sizes, such as a rubber ball and golf ball
- Yard stick
- Small rulers
- Tooth picks
- 3x5 index card to smooth the surface of the powder
- Newspaper
- Data chart for each participant

Preparation
1. Fill the pan with flour to a depth of 1-2 inches (2.5-5 centimeters). Tap the pan to settle the flour and smooth the surface.
2. Using the sieve sprinkle a fine layer of cocoa or sand evenly and completely over the flour.
3. Sprinkle another layer of white flour on top of the cocoa or sand.
4. Spread newspaper on the floor and place the pan on top of the newspaper.

Adapted from NASA's Make a Crater Activity:
http://lunar.arc.nasa.gov/education/activities/active15a.htm

Impact Craters (continued)

Exploration

Note: You may want to simplify the activity according to the age and ability of your participants. As you conduct the activity, use the questions in the Wrap-up section to guide their understanding.

1. Display the NASA photographs of craters on the Moon and Mars. Call on volunteers to identify the parts of a crater (most craters have deep central depressions, raised rims, and a blanket of ejected material, ejecta, surrounding them). Ask what factors might affect a crater's appearance (the nature of the surface, and the speed, size, and mass of the object making the impact). Tell participants they are going to explore how craters are made.
2. Distribute a data sheet to each participant, and have them record data for each test. Have them gather around the box, standing several feet away from it. Begin with the balls that are similar in size, but different weights. Before a ball is dropped have a volunteer ready with the yardstick to measure each height. Have another volunteer take one of the balls and drop it from three different heights. Call on other volunteers to measure the diameter of each crater, its depth (using a toothpick), and the distance the ejecta traveled after the impact (from the edge of the crater). Repeat the test using the other ball that is similar in size.
3. If necessary, smooth out the top layer and sprinkle more cocoa or sand and then flour. Then repeat the above procedure with the balls that are similar in weight, but different sizes.
4. After testing, have participants analyze and discuss their data. You may want to use the following questions to guide their understanding:
   - How did crater size change when balls of different mass (i.e., weight) were dropped from the same height?
   - How would you state the general relationship between a ball's mass and the crater size?
   - How did the size of the balls affect the crater sizes?
   - How would you state the general relationship between a ball's size and the crater size?
   - How did the different speeds of the balls affect the crater sizes?
   - How would you state the general relationship between a ball's speed and the crater size?

Wrap-Up

Call on volunteers to share what conclusions they can draw from the analysis of their data. Encourage them to cover these points:

- The higher the ball's starting point, the greater its velocity at impact.
- The greater an object's velocity, the larger its impact crater.
- When dropped from a given height, the greater the mass, the larger the crater.
- When dropped from a given height, the greater the volume, the larger the crater.

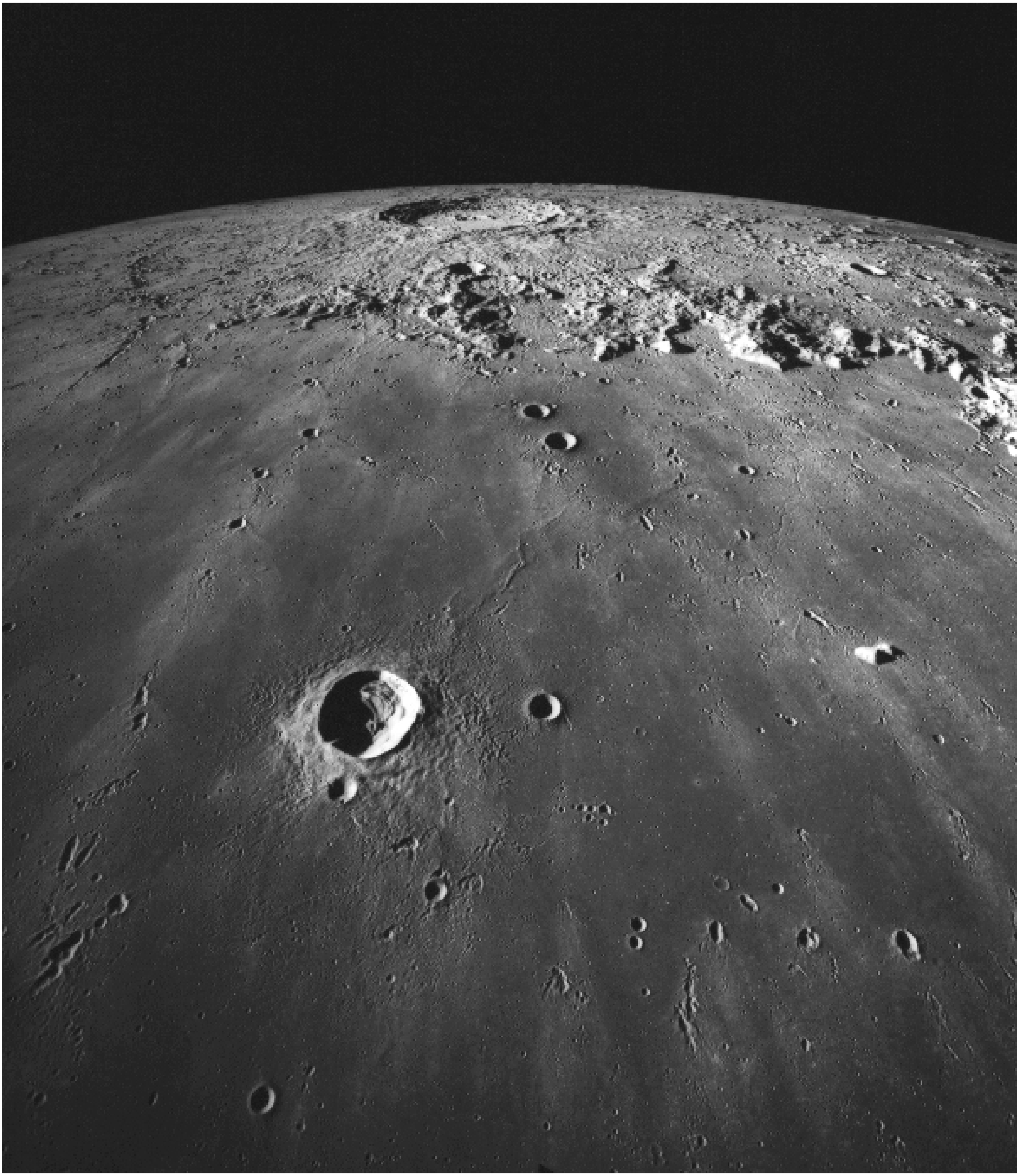
Impact Craters Data Sheet

Record your findings in these charts.

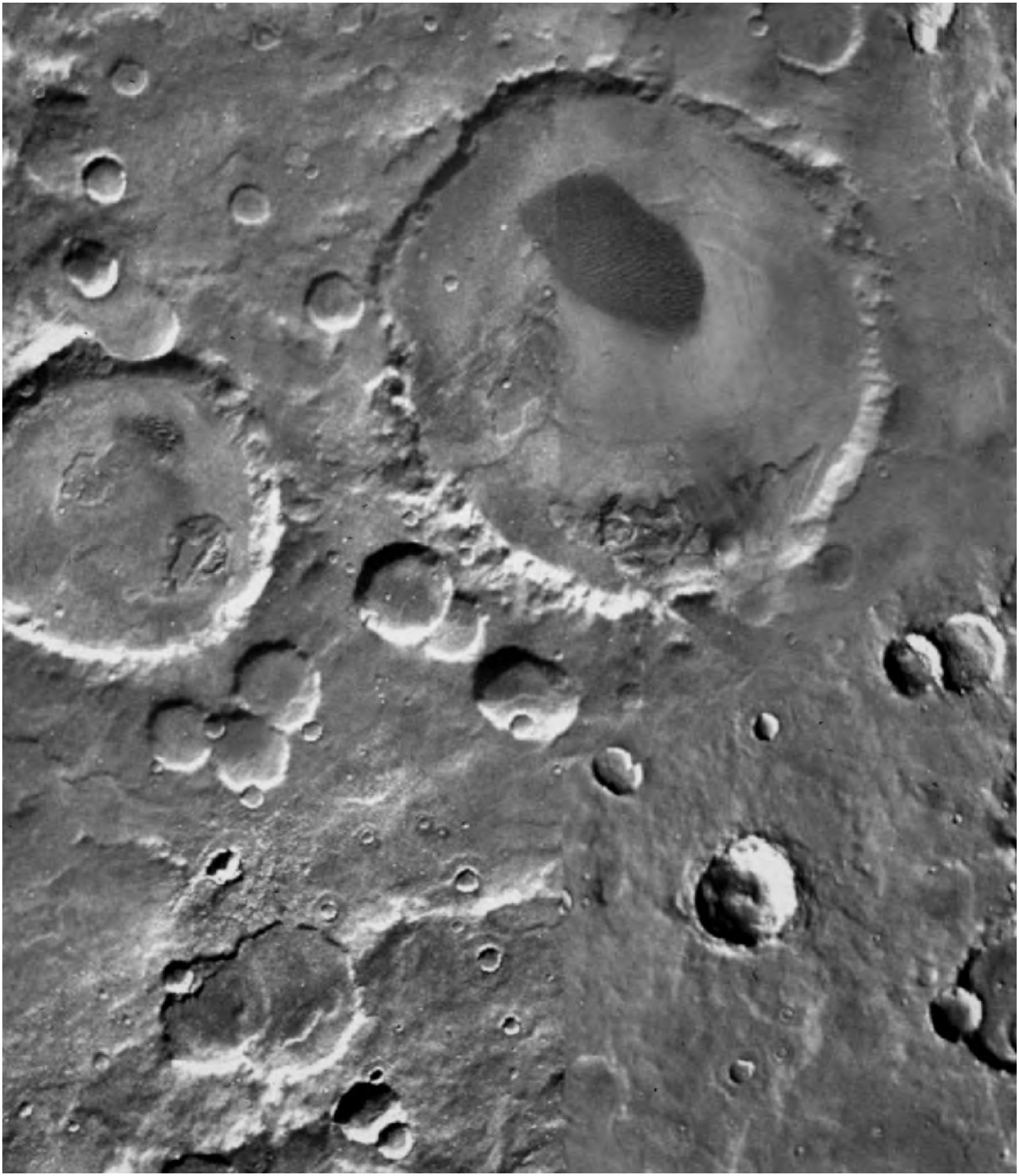
Balls of same size but different weight		HEIGHT of drop	WIDTH of crater	DEPTH of crater	DISTANCE ejecta traveled
TEST 1	Ball 1				
TEST 2	Ball 1				
TEST 3	Ball 1				
TEST 4	Ball 2				
TEST 5	Ball 2				
TEST 6	Ball 2				

Balls of same weight but different size		HEIGHT of drop	WIDTH of crater	DEPTH of crater	DISTANCE ejecta traveled
TEST 1	Ball 1				
TEST 2	Ball 1				
TEST 3	Ball 1				
TEST 4	Ball 2				
TEST 5	Ball 2				
TEST 6	Ball 2				

Craters on the Moon



Craters on Mars



Moon Landforms

In this activity, participants will identify landforms on the surface of the Moon using photographs taken from the Apollo spacecraft.

Age Level
9-14

Time Frame
40 minutes

Materials
- Landform Identification Answer Key

For each group:
- Landform Information Sheet
- NASA photographs of the lunar surface
- Landform Identification Sheet

Introduction
Share with participants that in late 2008 NASA will be sending a spacecraft — the Lunar Reconnaissance Orbiter (LRO) — to orbit the Moon. This spacecraft will collect science information that will help scientists and engineers determine the best place to build a future lunar outpost.

Exploration
1. Talk with participants about some of the common landforms they know. You can ask:
    - Imagine you were going on a trip to a place you'd never been before. Would you need to know what the land looked like? Why?
    - Now imagine you were going to the Moon. Why would you need to know what the surface of the Moon is like?
2. Tell participants that they are going to use some NASA photographs to identify Moon landforms. Invite them to describe what they see when they look at the Moon (light and dark areas). Call on volunteers to name the light and dark areas. If necessary, explain that the light areas are the lunar highlands and that the darker plains are called the lunar maria (which is Latin for "sea").
3. Display a photograph of the Moon (or if you have a large group, distribute a few of the photographs for participants to share). Have participants identify the highlands and the maria (numbered 1 and 2).

Adapted from NASA's Lunar Landform Identification Activity:
http://lunar.arc.nasa.gov/education/activities/active13a.htm

Moon Landforms (continued)

4. Distribute Landform Information Sheet and ask volunteers to read aloud how these regions formed. Direct them to the lines called rays indicated by number 3. Have a volunteer read aloud the description of a ray. Have participants identify other rays in the Moon photograph.

5. Divide participants into groups of 3–4. Distribute photographs and an Identification Sheet to each group. Tell groups their task will be to identify the lunar landforms in the photos using the Landform Information Sheet. They will then record their findings on the Identification Sheet. They can begin by filling in the identification sheet for landforms 1, 2, and 3 that they previously identified on the first photograph. Have groups begin the task. Point out that some landforms may appear in more than one photo. While groups are completing the task, circulate among them and provide assistance, if necessary.

Wrap-Up

Give each group time to present their findings. If there are discrepancies in identification, call on groups to explain how they arrived at their answers. Use discussion questions to wrap up the activity:

- Were some landforms easier to identify than others?
- Did shadows help make some landforms easier to see?
- Imagine you were asked to choose a landing site for a lunar vehicle. Which landform would you choose to land on or near? Why?

Landform Information Sheet

central crater uplift
Mountain in the center of large (greater than 40 kilometer in diameter) impact craters.

cinder cone
A low, broad, dark, cone-shaped hill formed by an explosive volcanic eruption.

crater ejecta
Material thrown out from and deposited around an impact crater.

dome
A low, circular, rounded hill which is suspected to be a volcanic landform.

highlands
The highlands appear as bright areas of the Moon. The highlands are comprised of countless overlapping craters (ranging from 1 meter to over 1000 meters) that formed when meteorites crashed into the Moon.

impact crater
A roughly circular hole created when something, such as a meteorite, struck the Moon's surface.

lava flow
A break out of magma from underground onto the surface.

maria
Areas that formed when lava flows filled in low places. The low places are mostly inside huge basins which were formed by large meteor impacts. The maria cover 16% of the Moon's surface.

multi-ringed basin
Huge impact crater surrounded by circular mountain chains.

ray
Bright streak of material blasted out from an impact crater.

rille
A channel in the lunar maria formed by an open lava channel or a collapsed lava tube.

terraced crater walls
Steep walls of an impact crater with "stair steps" created by slumping due to gravity and landslides.

wrinkle ridge
A long, narrow, wrinkly, hilly section in the maria.

Landforms Identification Sheet

Make a checkmark for each landform you identify in the photos.

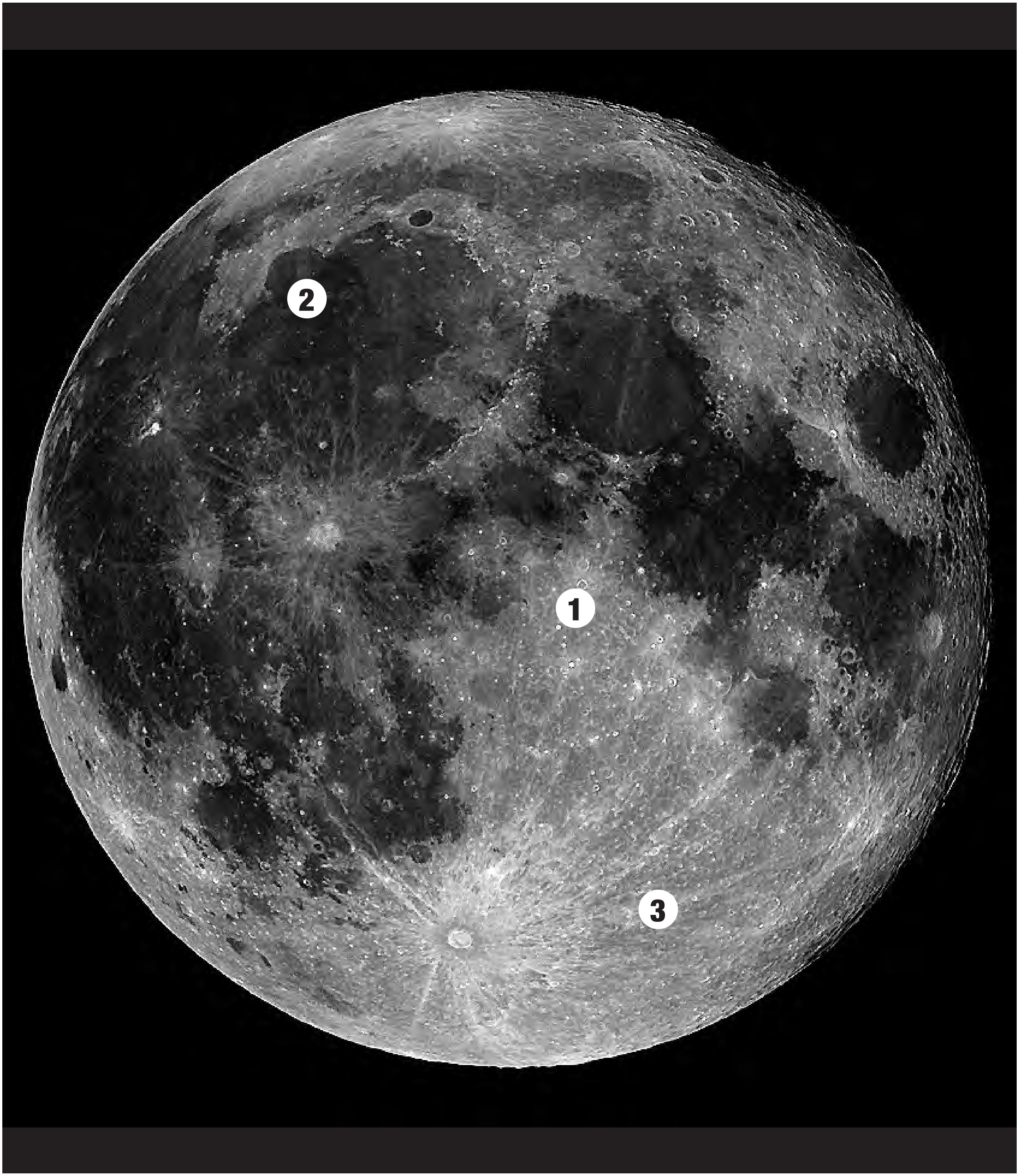
LANDFORM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
central crater uplift																				
cinder cone																				
crater ejecta																				
dome																				
highlands																				
impact crater																				
lava flow																				
maria																				
multi-ringed basin																				
ray																				
rille																				
terraced crater walls																				
wrinkle ridge																				

Landforms Identification Sheet

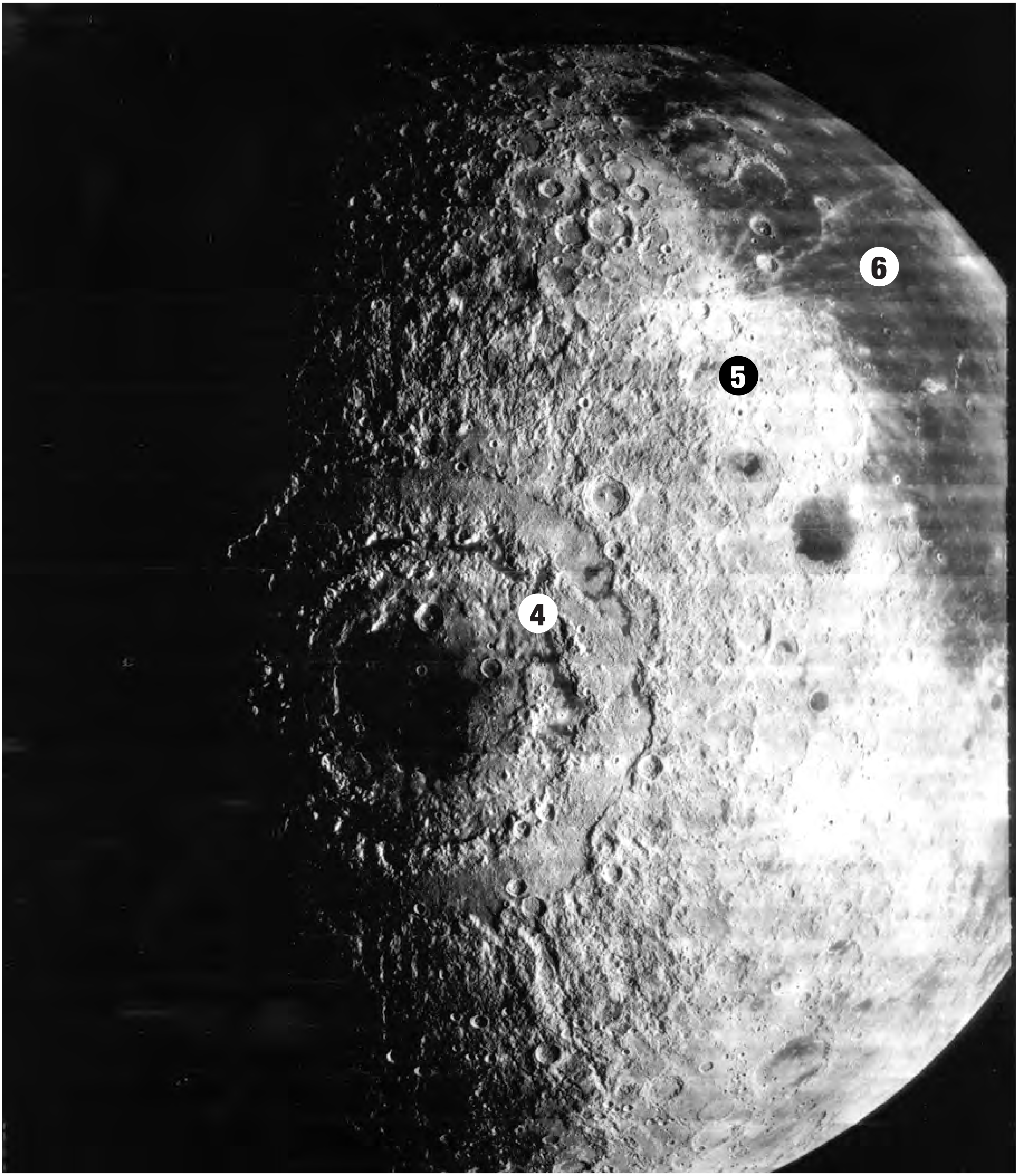
ANSWER KEY

LANDFORM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
central crater uplift													●							●
cinder cone										●										
crater ejecta											●									
dome																●				
highlands	●				●															
impact crater								●	●											
lava flow														●						
maria		●				●														
multi-ringed basin				●																
ray			●															●		
rille							●										●			
terraced crater walls												●							●	
wrinkle ridge															●					

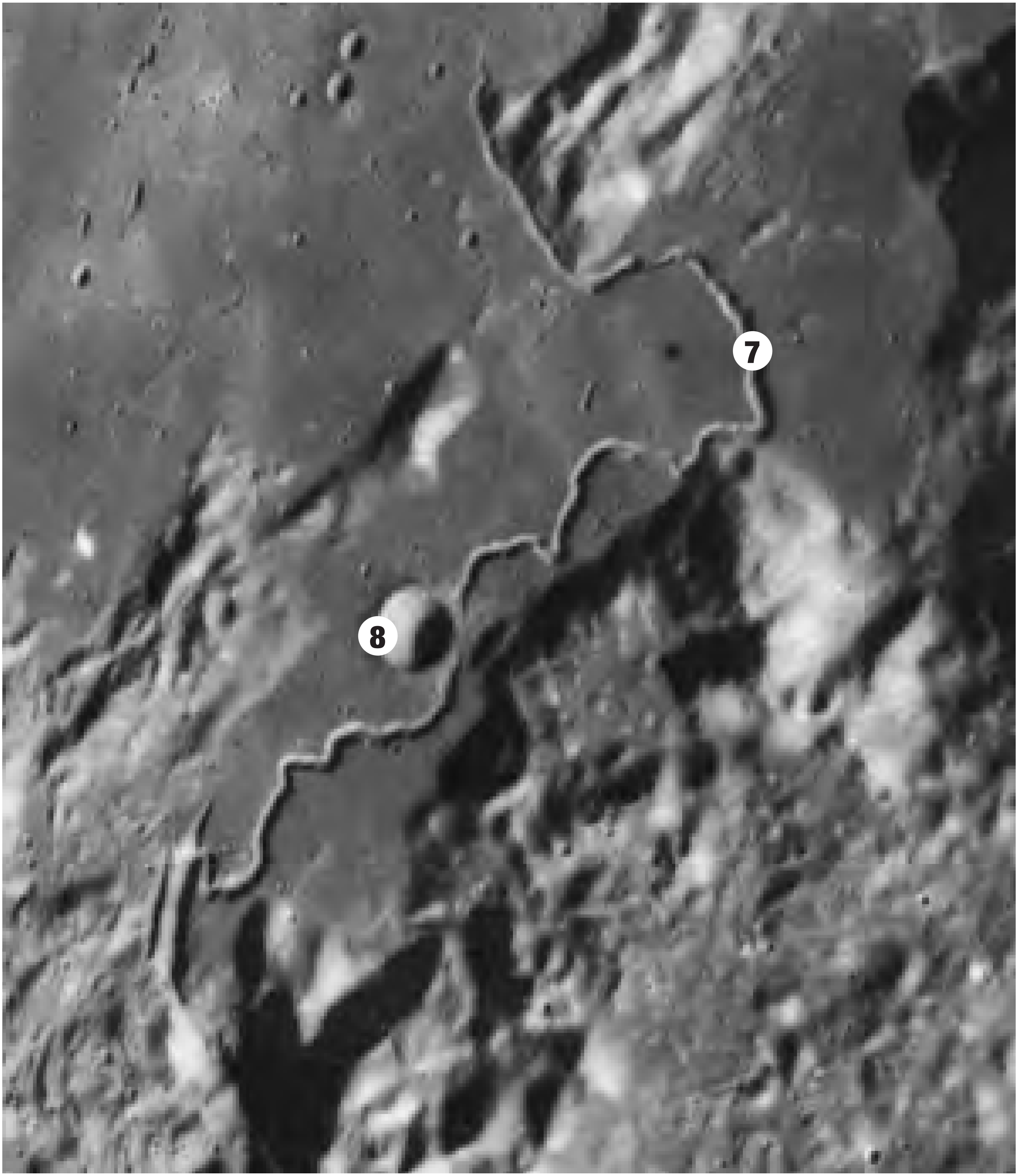
The Moon



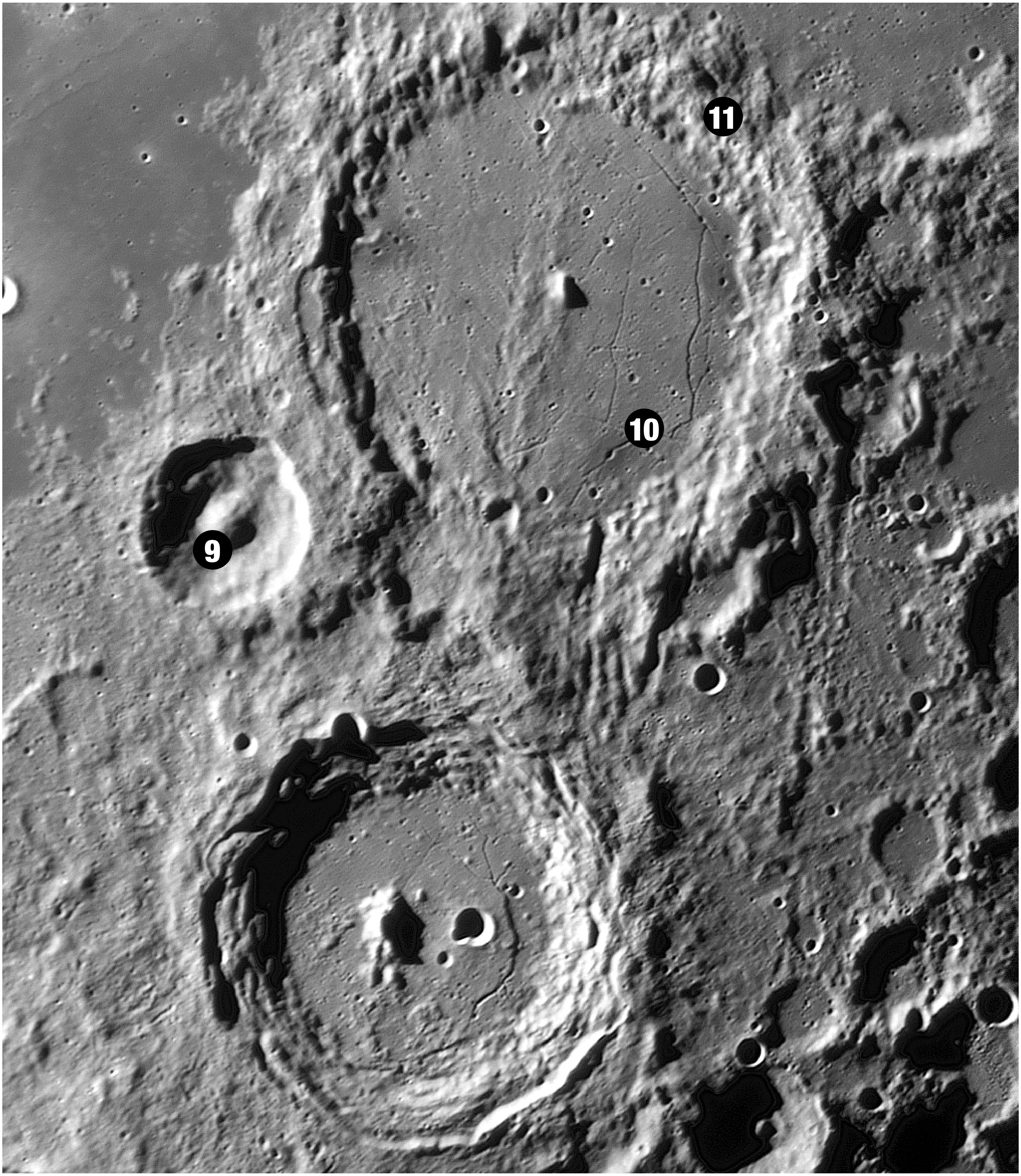
Orientale



Apollo 15 Landing Site



Alphonsis



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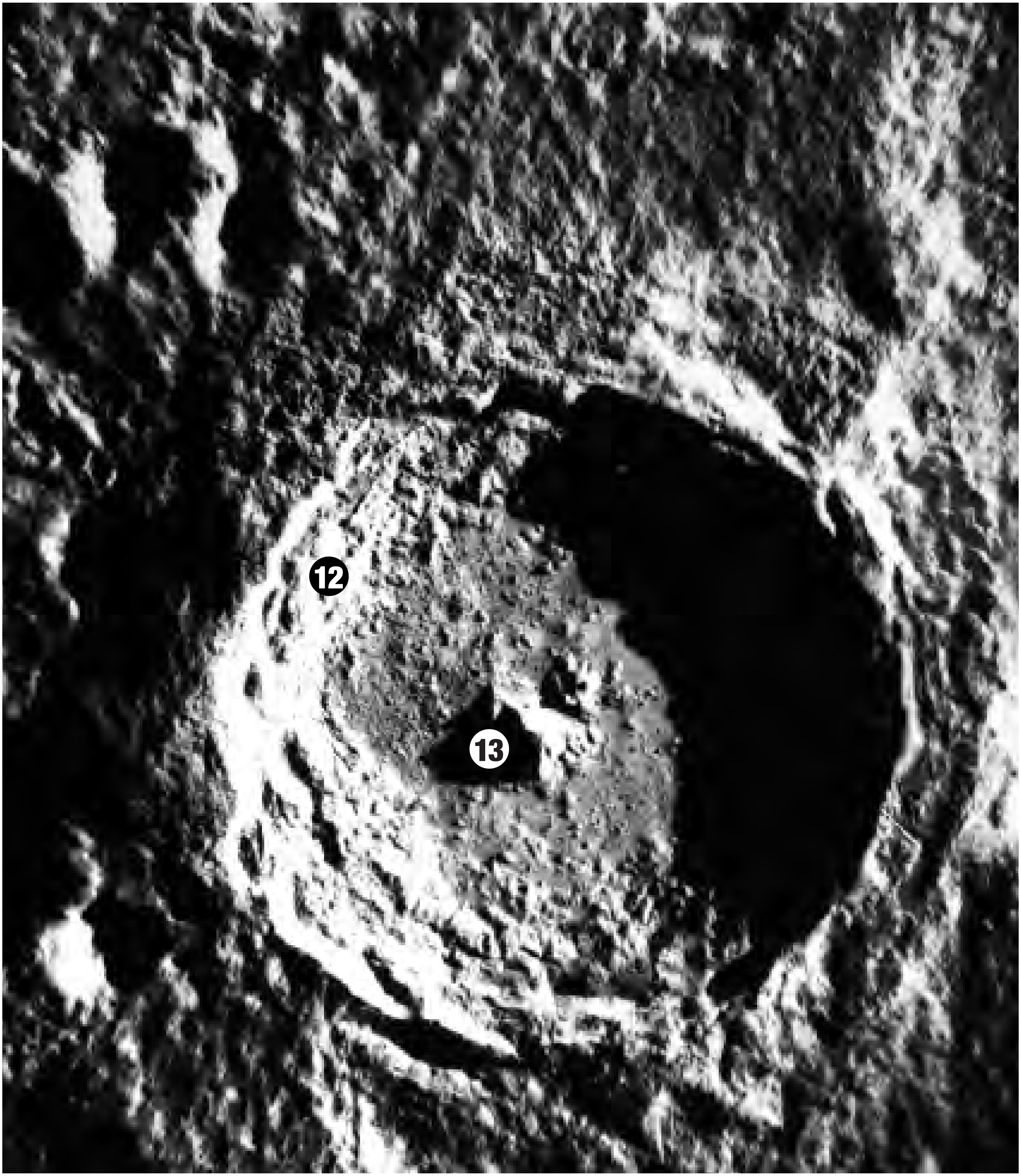
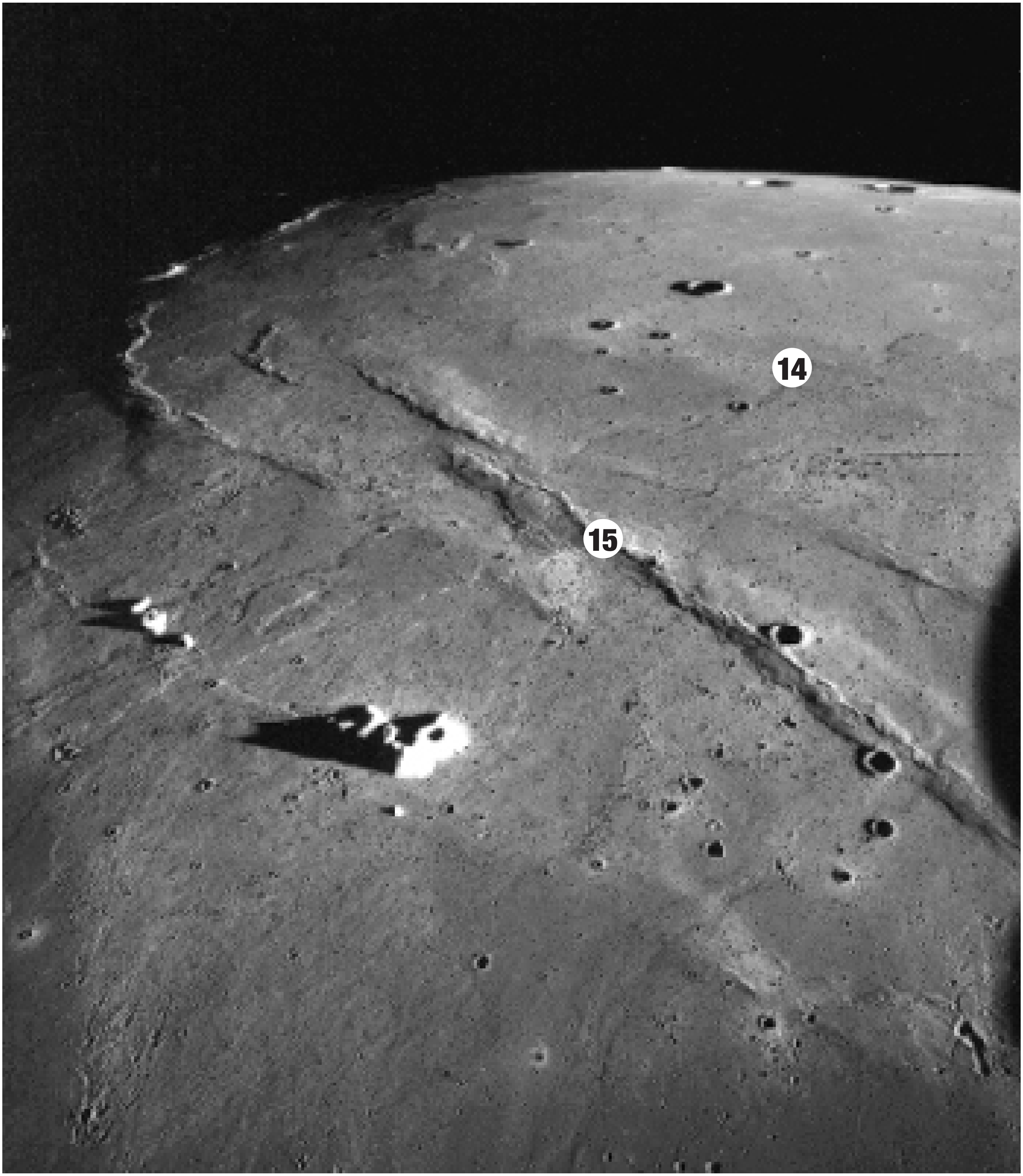
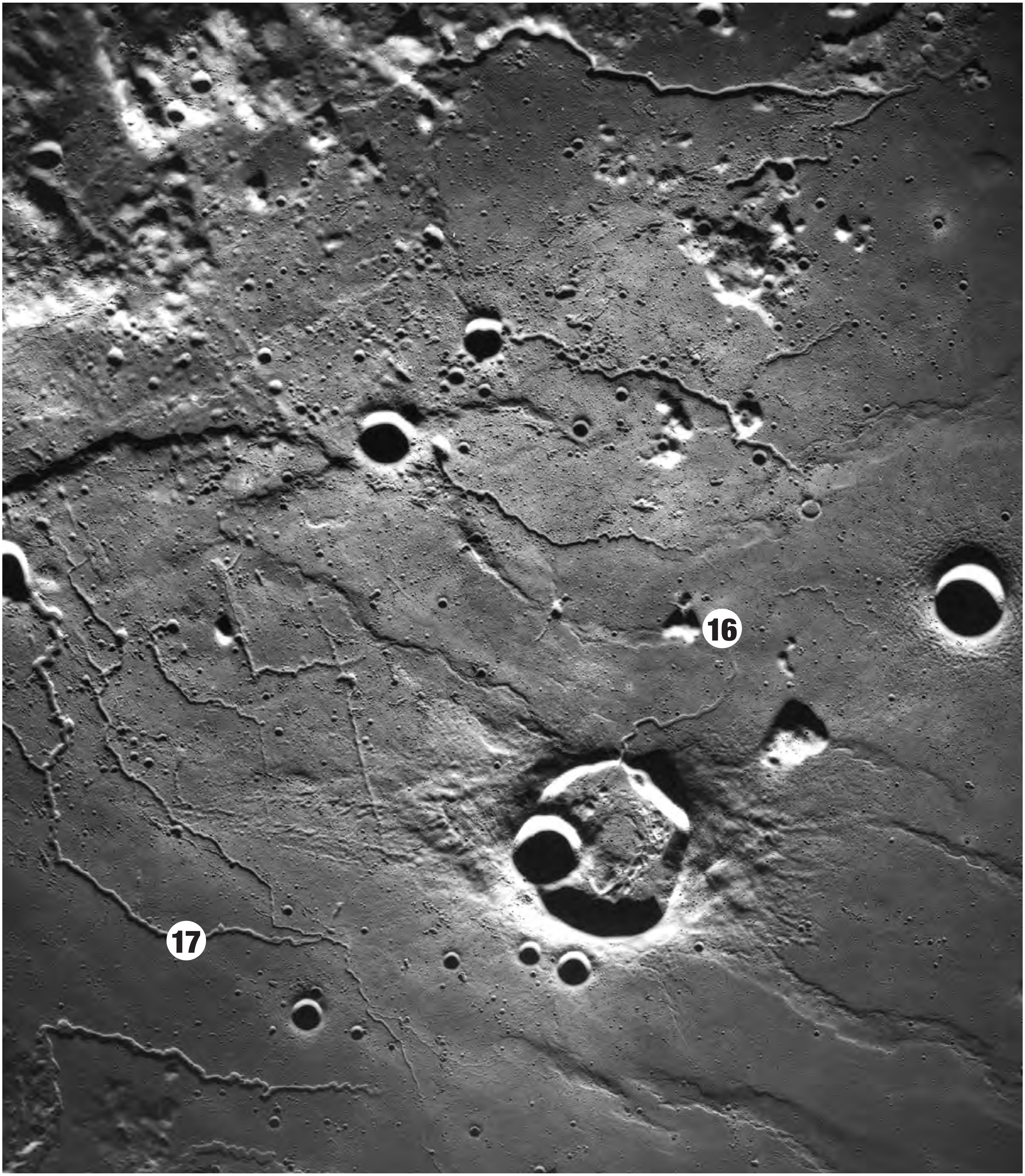


Mare Imbrium



Oceans of Storms



Copernicus

LUNAR BASE ACTIVITIES

Team Investigations

This set of activities engages participants in our exploration of 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. Some of the teams (Ecosystem, Habitat, Medical) have more steps to complete than the other teams, so you may want to assign more participants to these teams.

Ecosystem Investigation http://corecatalog.nasa.gov/item.cfm?num=300.0-86D

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 http://corecatalog.nasa.gov/item.cfm?num=300.0-86A

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 http://corecatalog.nasa.gov/item.cfm?num=300.0-86C

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 http://corecatalog.nasa.gov/item.cfm?num=300.0-86E

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 http://corecatalog.nasa.gov/item.cfm?num=300.0-86B

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

Two and a half hours 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 www.nasa.gov/education/core
- 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.

Team Investigations

1 Phase One: Introducing and Viewing the DVD (40 minutes)

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 your group 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 them a chance to vote on a group answer.

3. **Introduce Field Trip to the Moon and view the Introduction and Feature Presentation** (25 minutes)
   Explain to group 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?

Team Investigations (continued)

2 Phase Two: Investigation Task 1 (45 minutes)

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 your group 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 group will have planned a habitable and sustainable lunar station.

2. **Divide the group into teams** (5 minutes)
   Divide the group into six teams and assign a different investigation to each team. Select a member 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 teams that the toolbox contains the resources and materials that are needed to complete the tasks.

3. **Task 1: Teamwork** (25 minutes)
   Distribute the Task 1 cards to each Communications Officer. Have the Communications Officers stand and read their first task to the entire group, 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 teams 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 group. As they work on their tasks, check on each team's progress, providing assistance as necessary. You can use the Questions to Help Guide Team Investigations.

4. **Task 1: Reporting and discussion** (10 minutes)
   After the first task is completed, have the Communications Officers share their teams' progress with the rest of the group. Tell teams 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** (optional break time)
   The articles will enhance their 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. They can read the articles on their own or together as a team.

Team Investigations (continued)

3 Phase Three: Investigation Task 2 (30 minutes)

1. **Task 2: Teamwork** (30 minutes)
   Distribute the Task 2 cards to each Communications Officer. Have the officer from each team read the task to the group. Make sure teams 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. As teams work, check on their progress, providing assistance as necessary.

4 Phase Four: Bringing It All Together (35 minutes)

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 wall.) Have each team present their final project. Allow time for any questions the group may have.

2. **Final discussion** (10 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?

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 www.nasa.gov/education/core
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)

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)

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)

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)

Questions to Help Guide Team Investigations

As 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 chose the best site.

Questions to Help Guide Team 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 Help Guide Team 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?

Ecosystem Investigation — TASK CARD 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.

Ecosystem Investigation — TASK CARD 2

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.

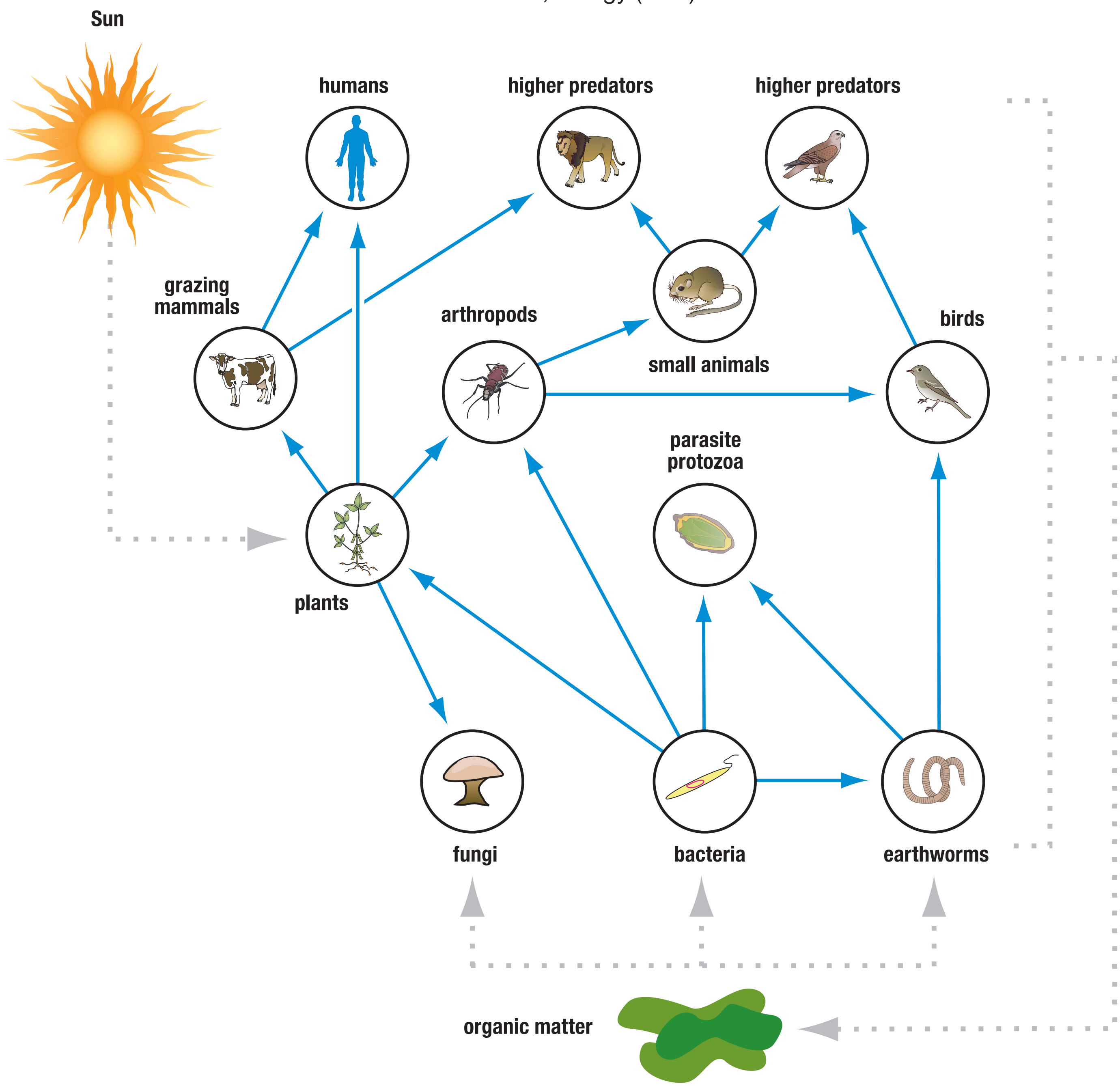
5\. Your ecosystem will fit into the lunar habitat designed by the Habitat Team.

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.

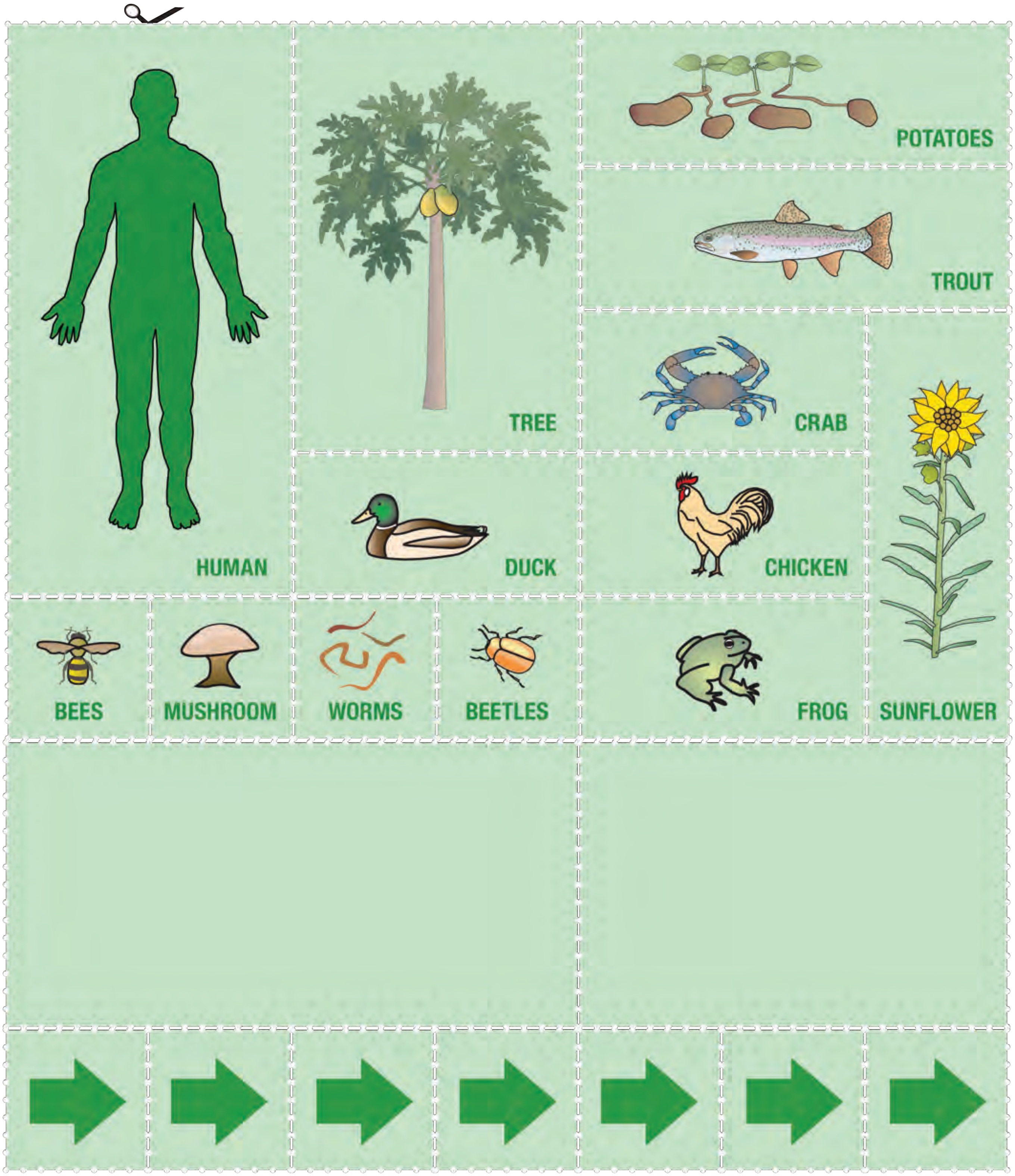
Decomposers

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

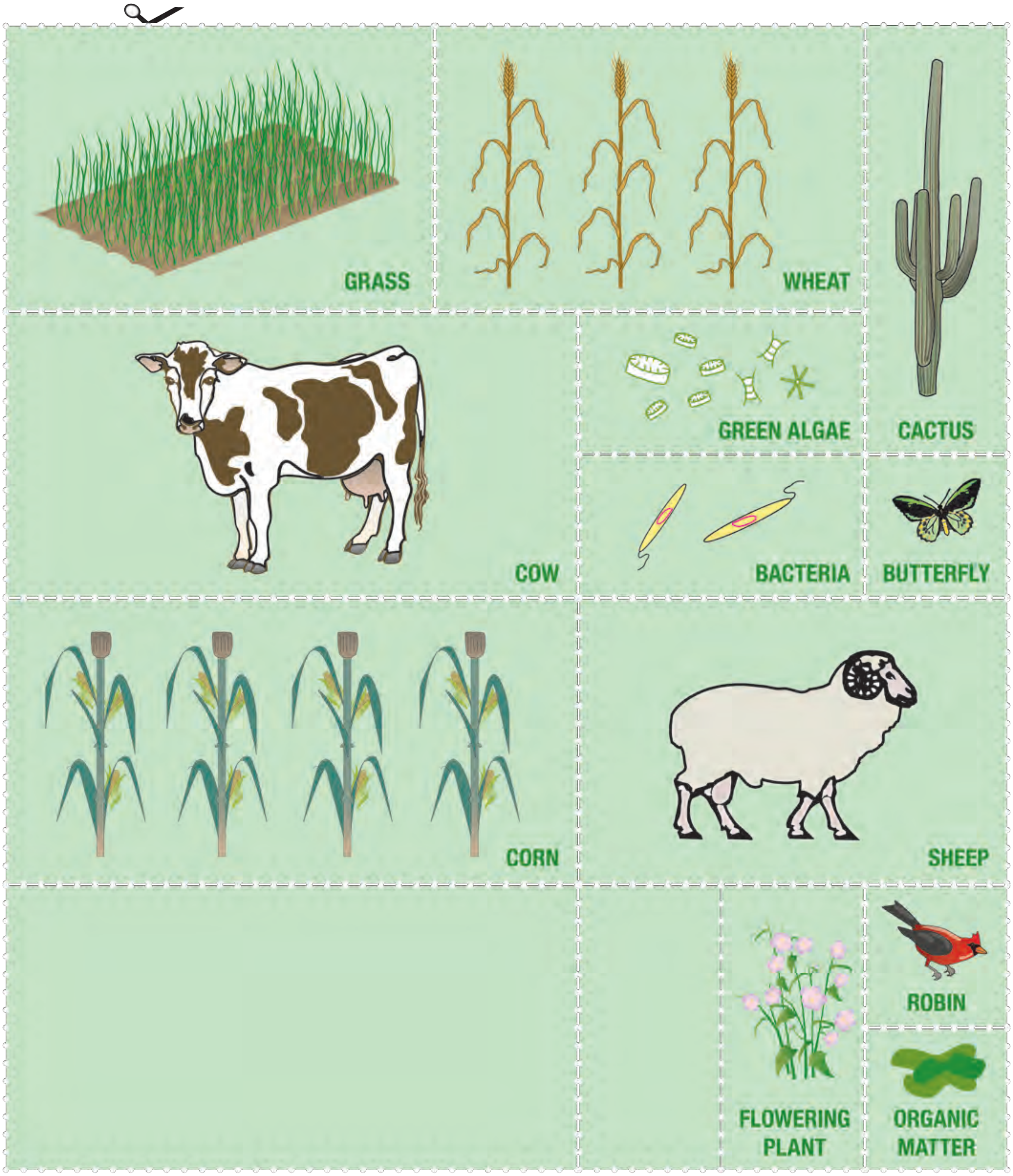
Cut out the organism cards along the dotted lines. Use the blank cards to add organisms of your choice.



Organism Cards

Instructions

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



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.

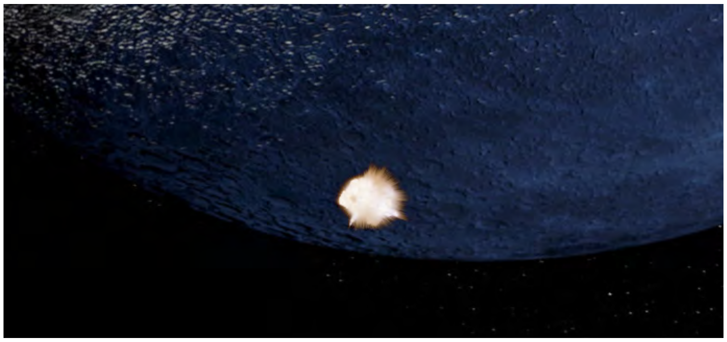
The name of the mission is LCROSS, short for Lunar CRater Observation and Sensing Satellite. LCROSS is a secondary payload: It will hitch a ride to the Moon on board the same rocket as the Lunar Reconnaissance Orbiter (LRO) satellite, due to launch from the Kennedy Space Center in October 2008.

"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_2O. 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

Geology Investigation — TASK CARD 1

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.

Geology Investigation — TASK CARD 2

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.

Geology DATA CARD

Metals and Minerals

SILICATES

Chemical Formula: SiO_2

Silicates can be used to manufacture:

- glass
- solar cells
- computer chips
- oxygen

Geology DATA CARD

Metals and Minerals

ALUMINUM OXIDE

Chemical Formula: Al_2O_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.

Geology DATA CARD

Metals and Minerals

TITANIUM OXIDE

Chemical Formula: 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.

Geology DATA CARD

Metals and Minerals

IRON (II) OXIDE

Chemical Formula: FeO

Iron can be used to manufacture:

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

Note:
Iron is a dense, strong metal.

Geology DATA CARD

Metals and Minerals

SOLID WATER (ICE)

Chemical Formula: H_2O

Water can provide:

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

Geology DATA CARD

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)

Geology DATA CARD

Metals and Minerals

SODIUM OXIDE

Chemical Formula: Na_2O

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

Geology DATA CARD

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.

Geology DATA CARD

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!

Geology DATA CARD

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!

Geology DATA CARD

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!

Geology DATA CARD

Metals and Minerals

CALCIUM OXIDE

Chemical Formula: CaO

Calcium can be used to manufacture:

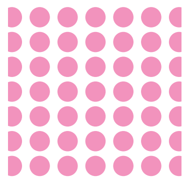
- heat-resistant shielding
- construction material (base structures, concrete)
- oxygen
- supplements for healthy bones

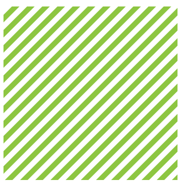
Key of Lunar Metals and Minerals

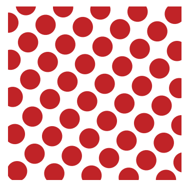
Instructions

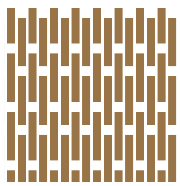
Use this key to identify the metals and minerals available at your landing site.

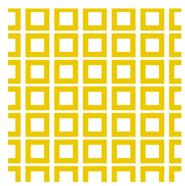

Silicates

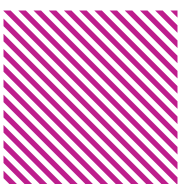

Sodium Oxide

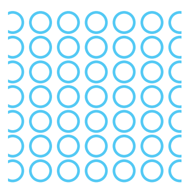

Aluminum

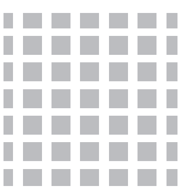

Diamond (Carbon)

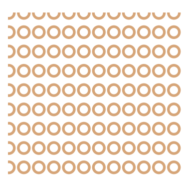

Titanium Oxide


Gold

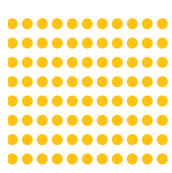

Ferrous Oxide (Iron)


Silver


Solid Water (Ice)

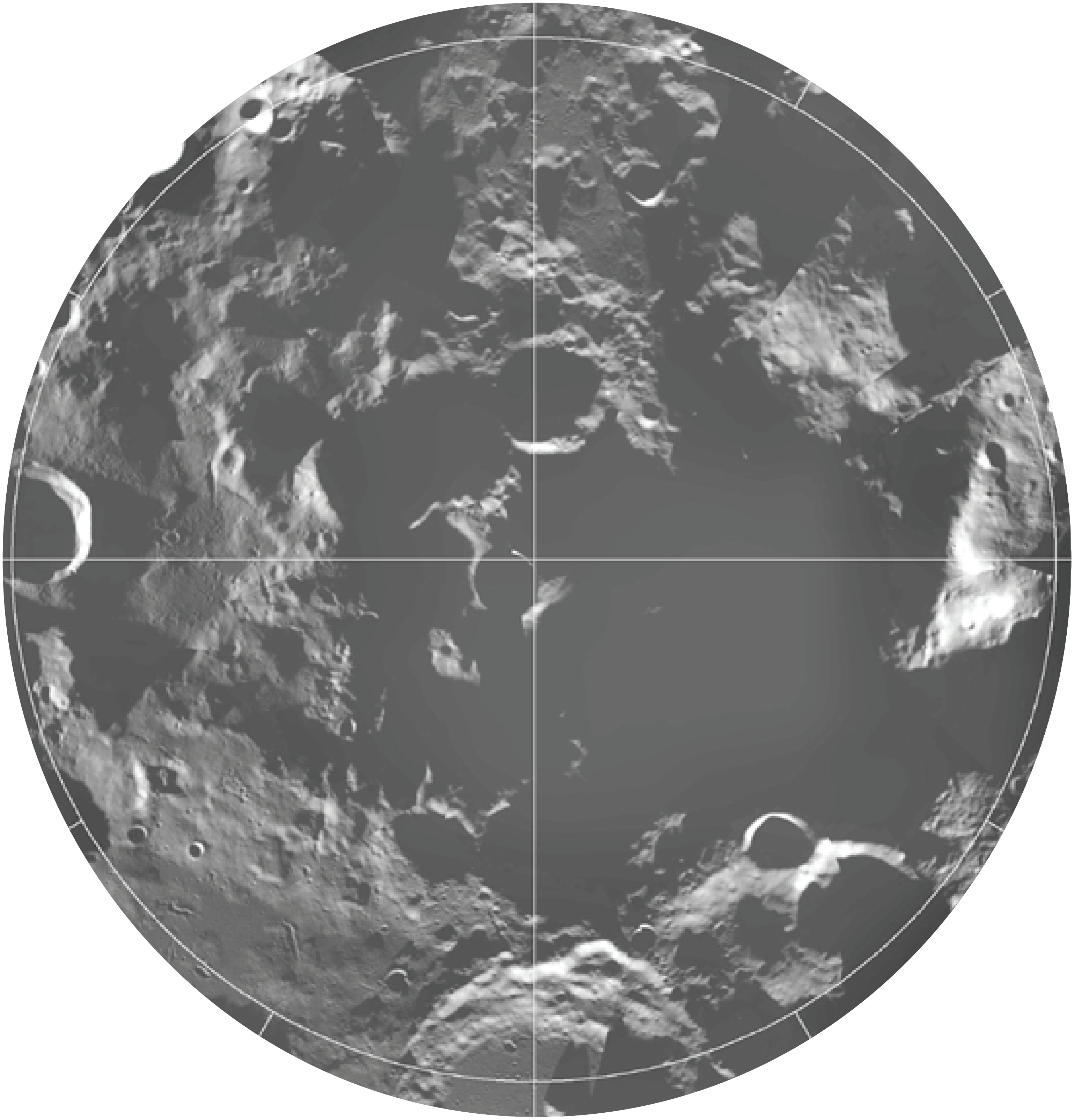

Platinum


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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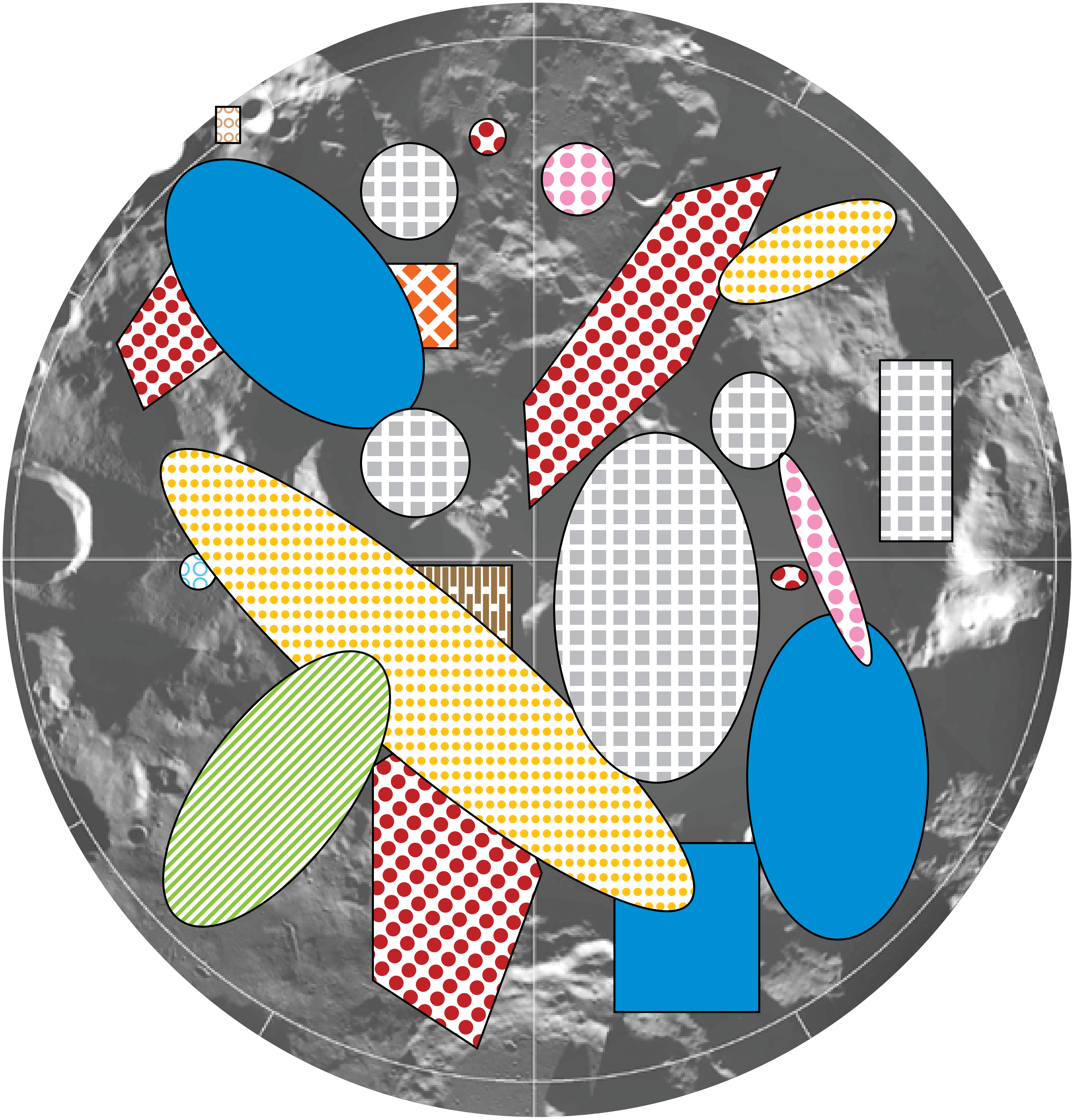
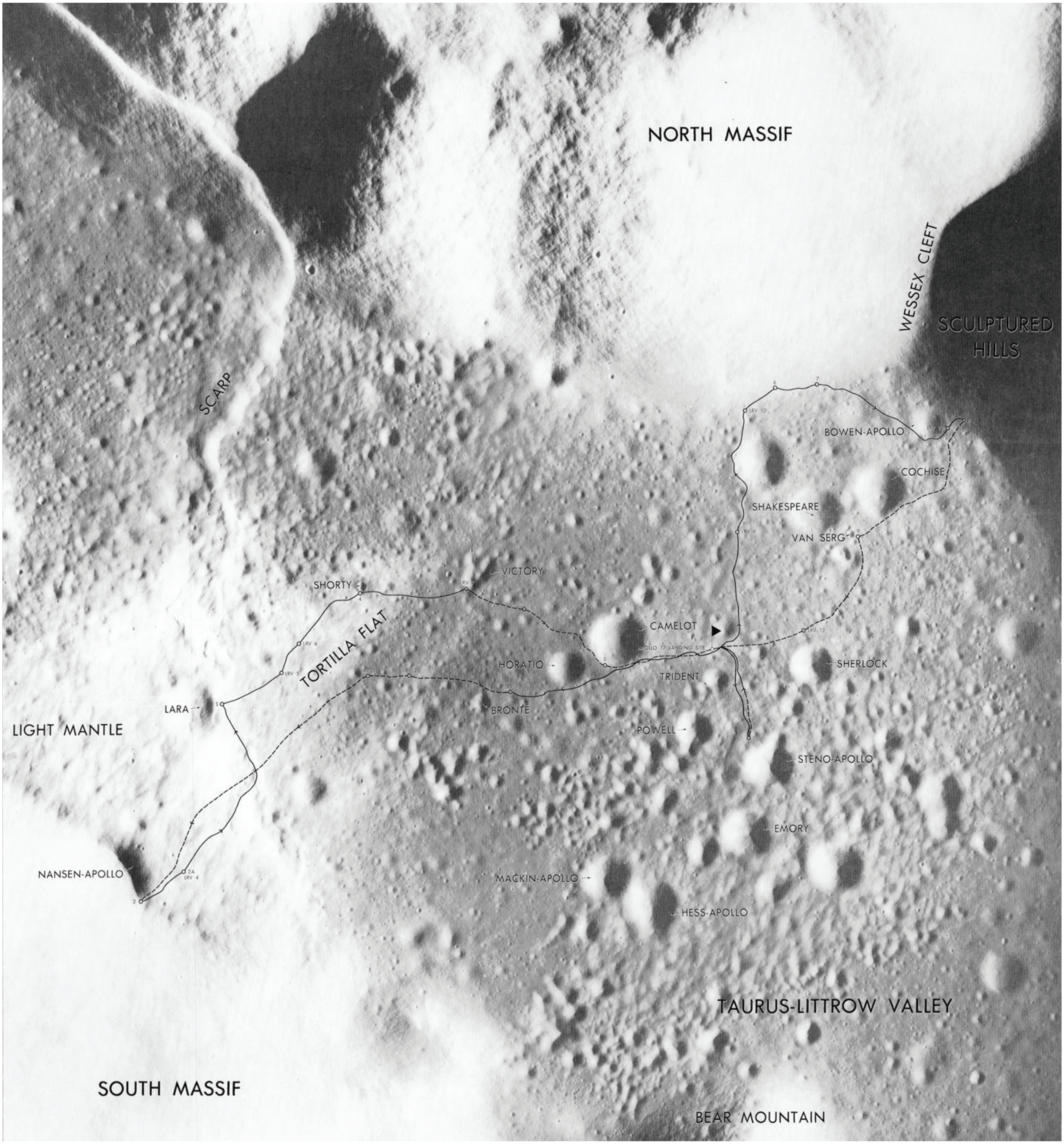


Valley of Taurus-Littrow

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

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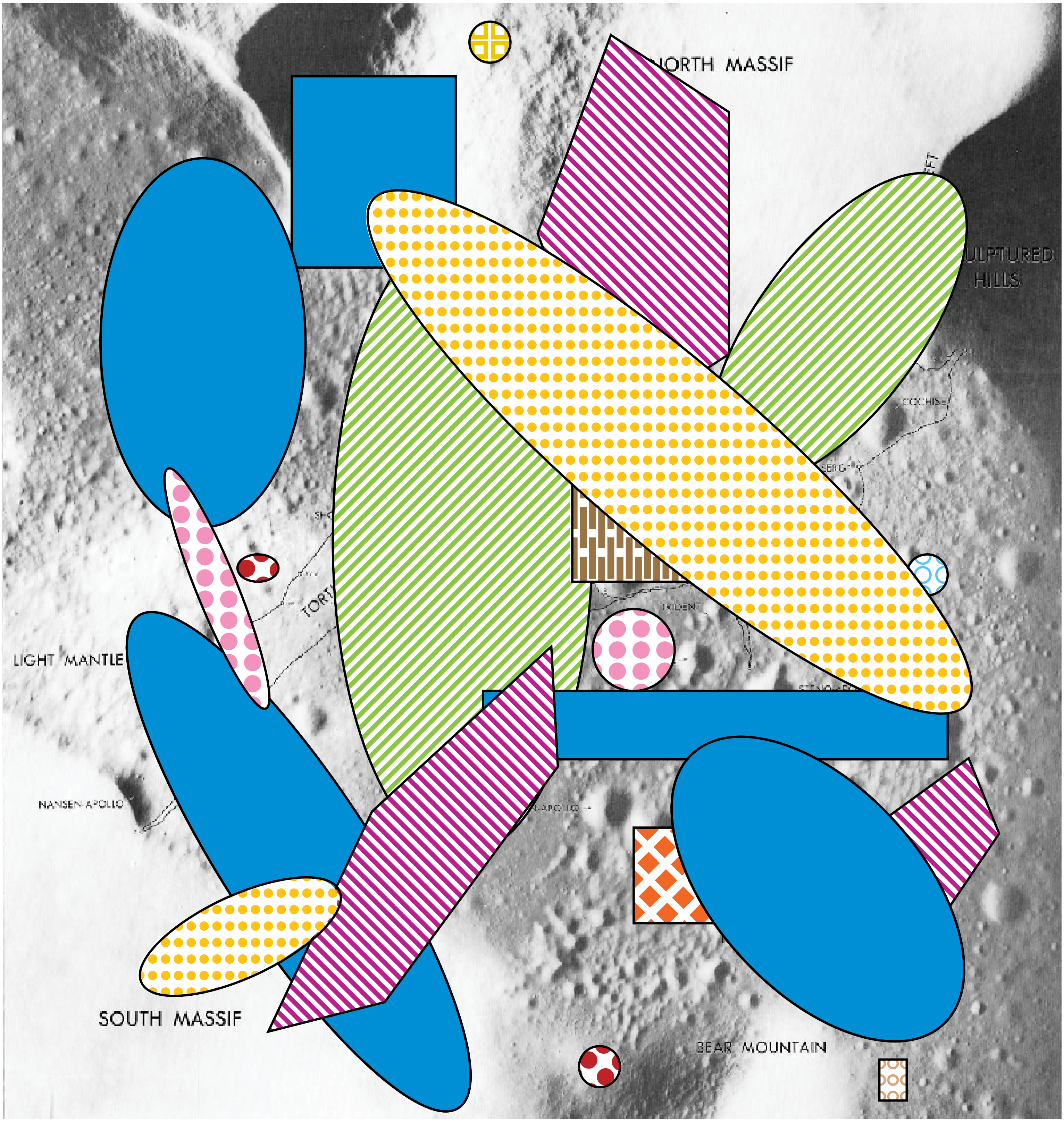
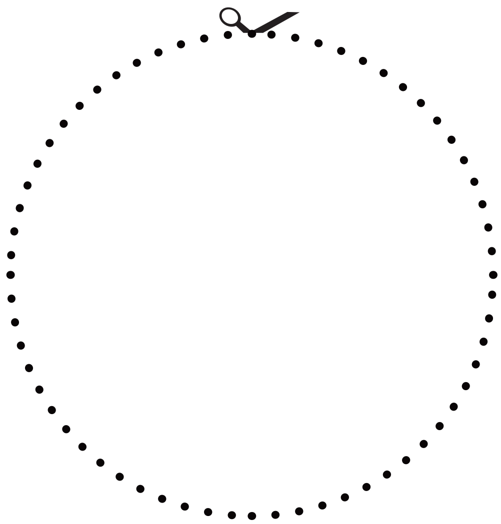


Mining Area

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

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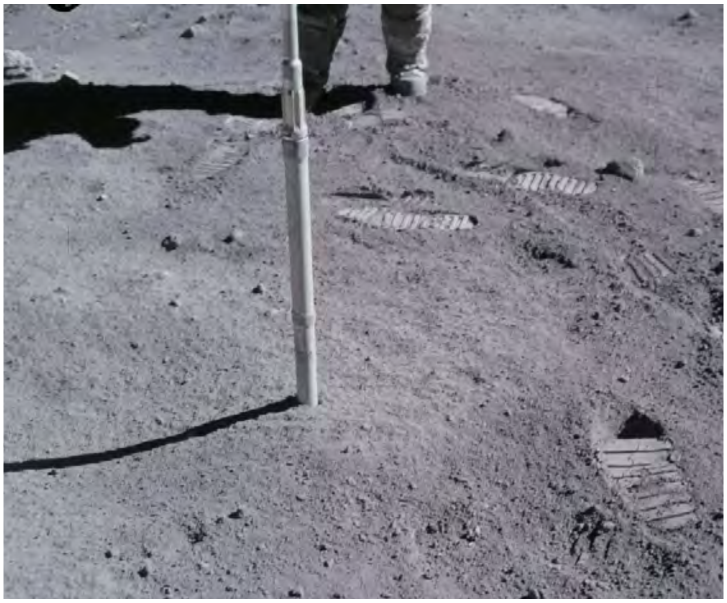


Apollo 16 astronaut Charlie Duke (feet shown) drives a core sample tube into the lunar regolith.

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 periodic 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.

NASA article from:
http://science.nasa.gov/headlines/y2007/26jan_harshwitness.htm

Habitat Investigation TASK CARD 1

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.

Habitat Investigation TASK CARD 2

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 an 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.

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

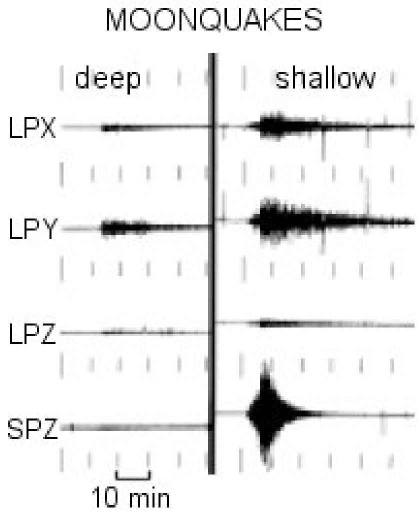
NASA astronauts may need quake-proof housing.

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.”



Representative lunar seismograms from the Apollo 16 station.

NASA article from:
http://science.nasa.gov/headlines/y2006/15mar_moonquakes.htm

Engineering Investigation — TASK CARD 1

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.

Engineering Investigation — TASK CARD 2

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.

Engineering DATA CARD

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.

Engineering DATA CARD

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.

Engineering DATA CARD

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.

Engineering DATA CARD

Energy Source
GEOTHERMAL 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.

Engineering DATA CARD

Energy Source

SOLAR ENERGY

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

Engineering DATA CARD

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.

Engineering DATA CARD

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.

Engineering DATA CARD

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.

Engineering DATA CARD

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.

Engineering DATA CARD

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.

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 (SiO_2), "like beach sand," says Cardiff. Also plentiful are oxides of calcium (CaO), iron (FeO), and magnesium (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."

BREATHING MOON ROCKS

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

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

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

D.L. Grimmett 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?

NASA article from:
http://science.nasa.gov/headlines/y2006/05may_moonrocks.htm

Navigation Investigation TASK CARD 1

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.

Navigation Investigation TASK CARD 2

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

What to Do

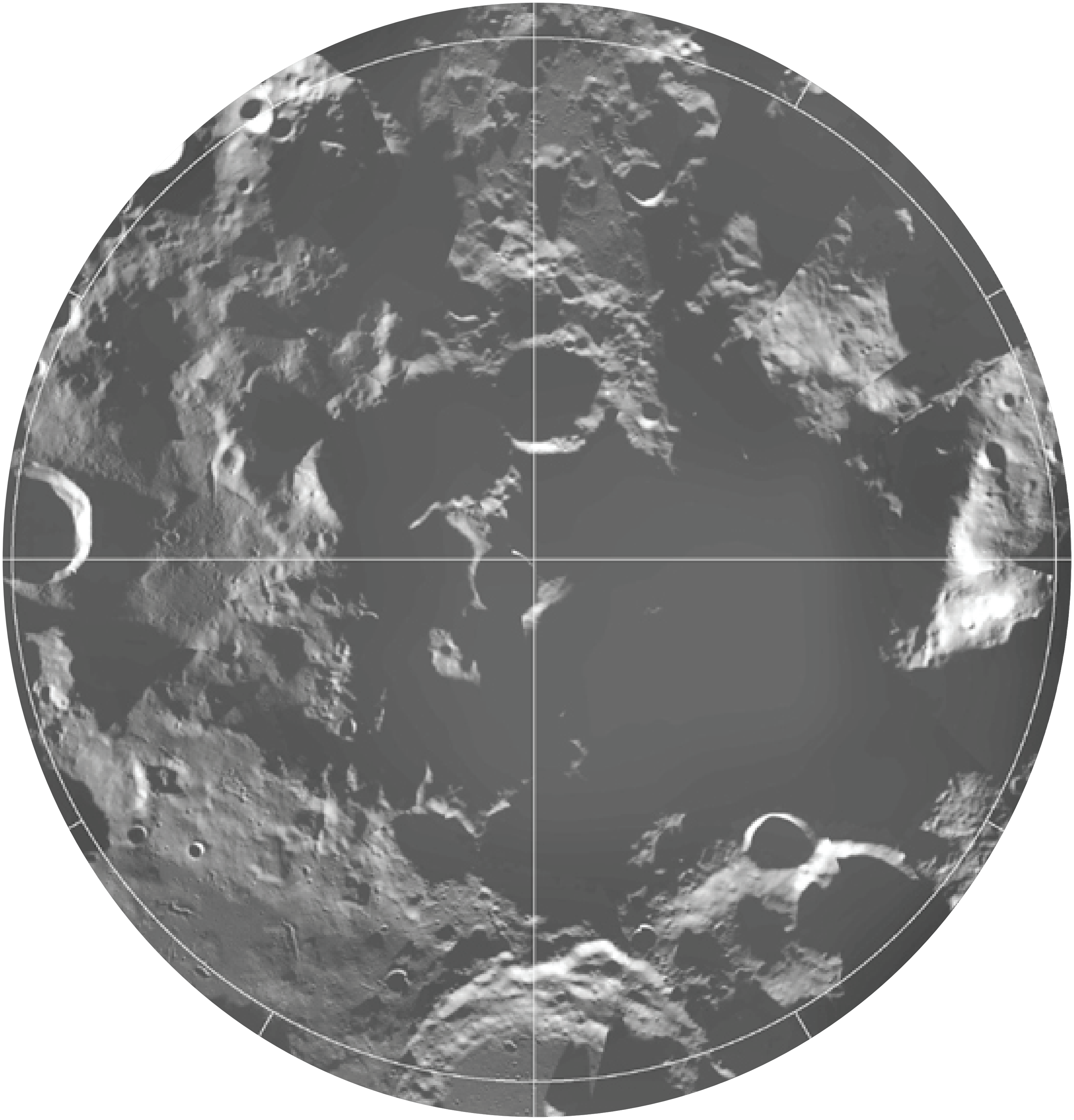
1. Take out the Cargo Packing List. Follow the first step to prioritize the cargo that you will bring to the Moon.
2. Draw a 10” x 10” square on a large sheet of paper. This space represents the cargo bay of your rocket.
3. Cut out the six sets of shapes on the Cargo worksheets. These shapes represent 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.

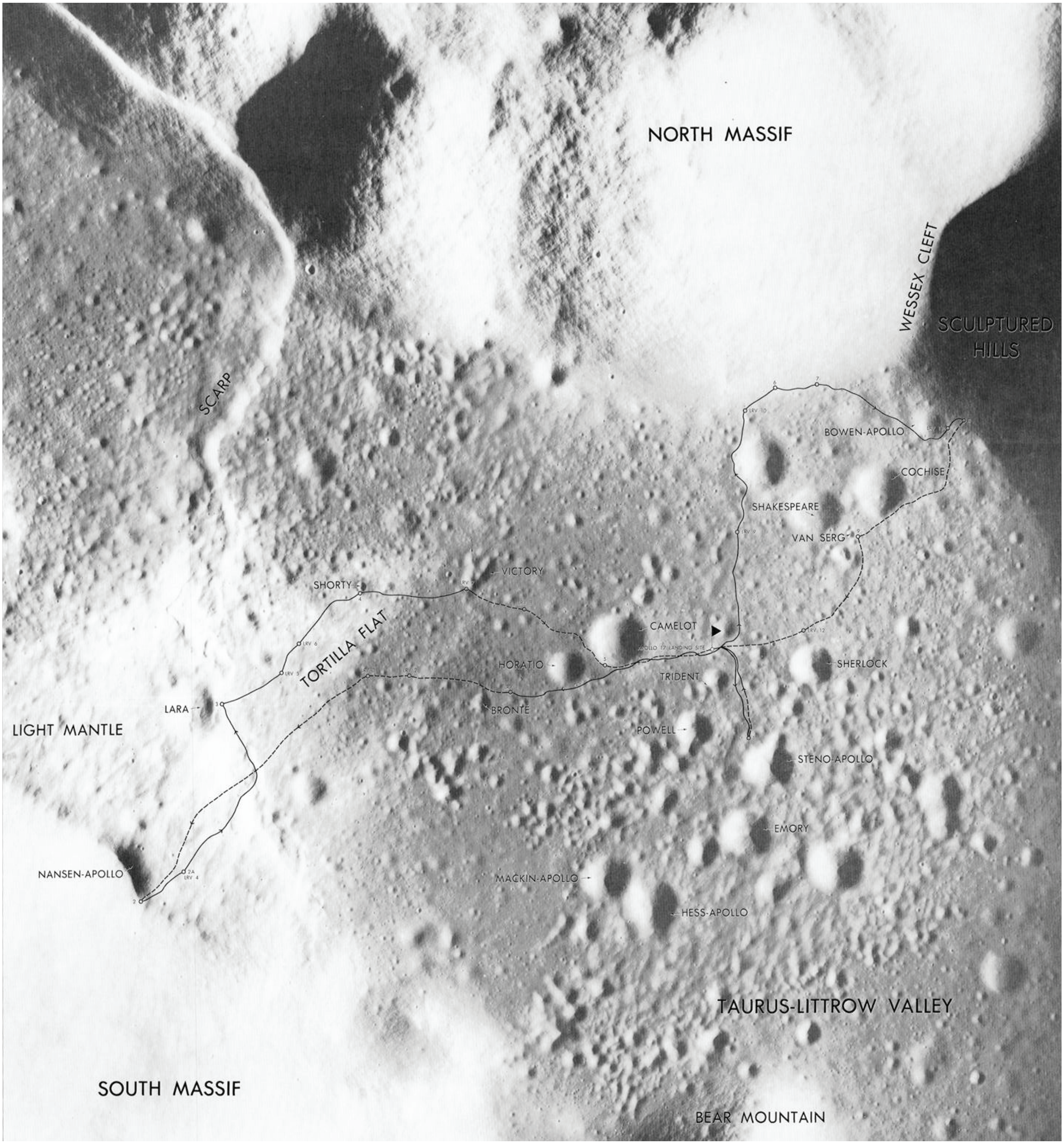
South Pole

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.



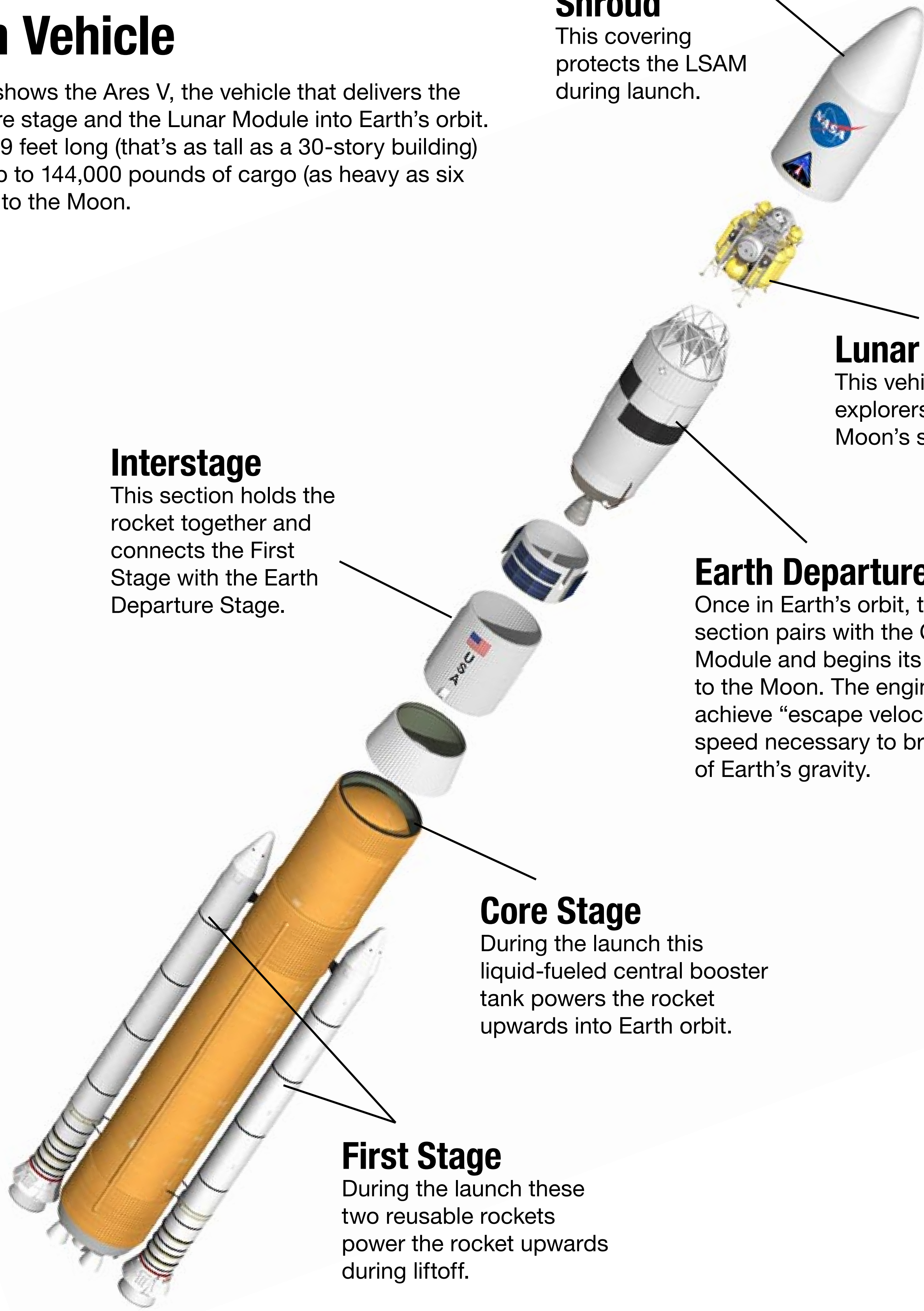
Valley of Taurus-Littrow

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.



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 six 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.

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

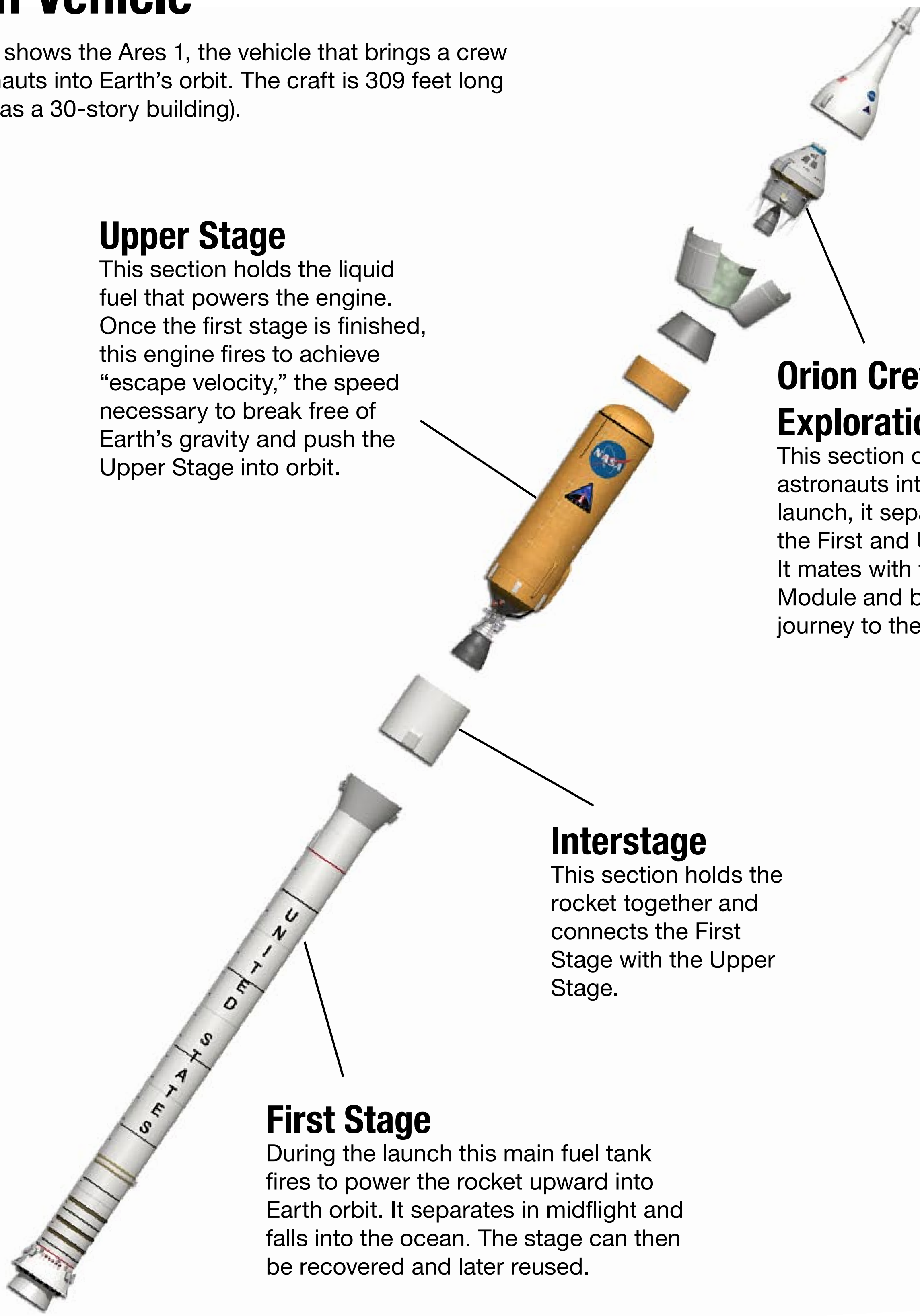
Earth Departure Stage
Once in Earth's orbit, this section pairs with the Crew Module and begins its journey to the Moon. The engine fires to achieve "escape velocity," the speed necessary to break free of Earth's gravity.

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 Ares 1, the vehicle that brings a crew of four astronauts into Earth's orbit. The craft is 309 feet long (that's as tall as a 30-story building).



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

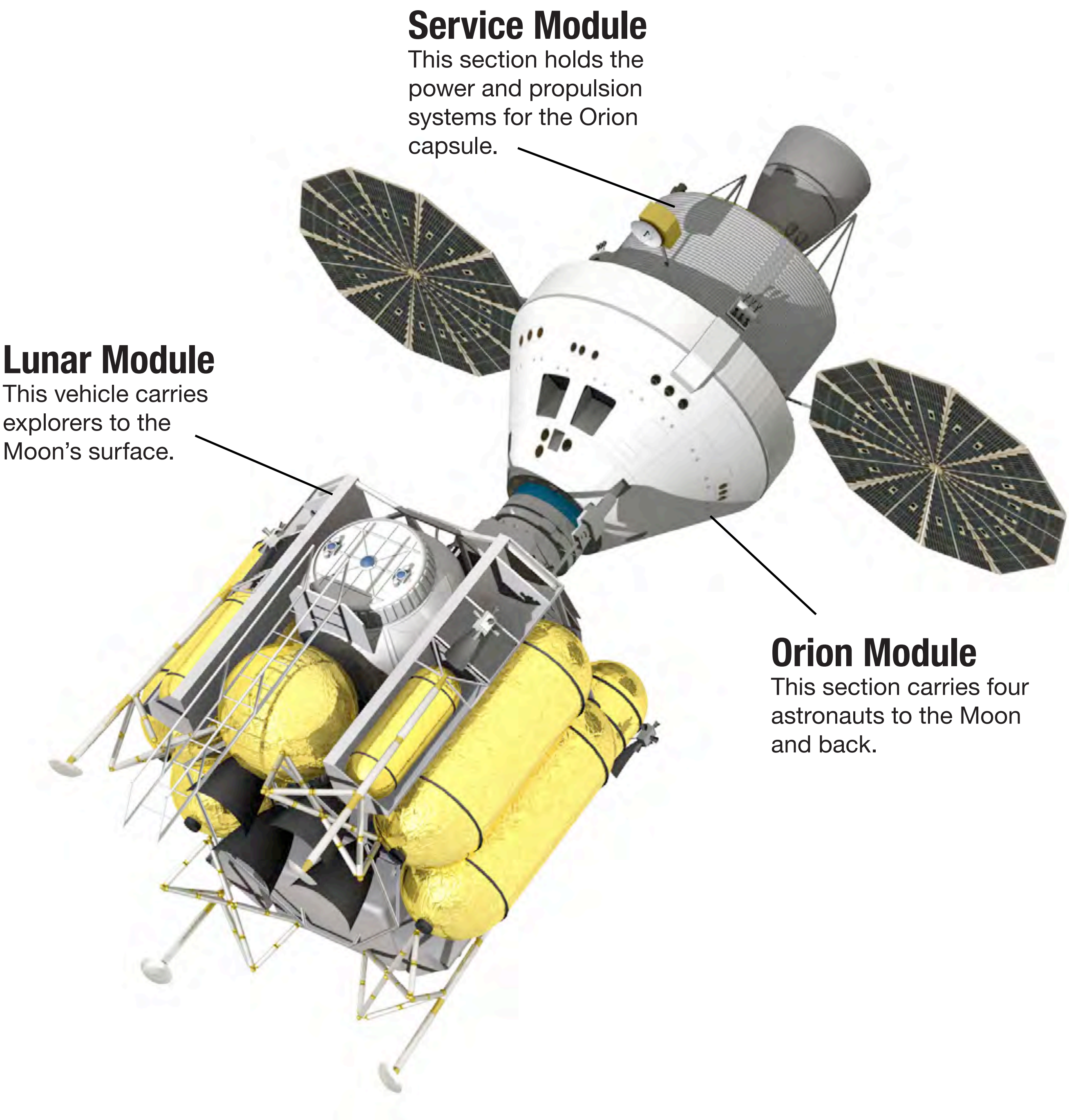
This section holds the rocket together and connects the First Stage with the Upper Stage.

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.

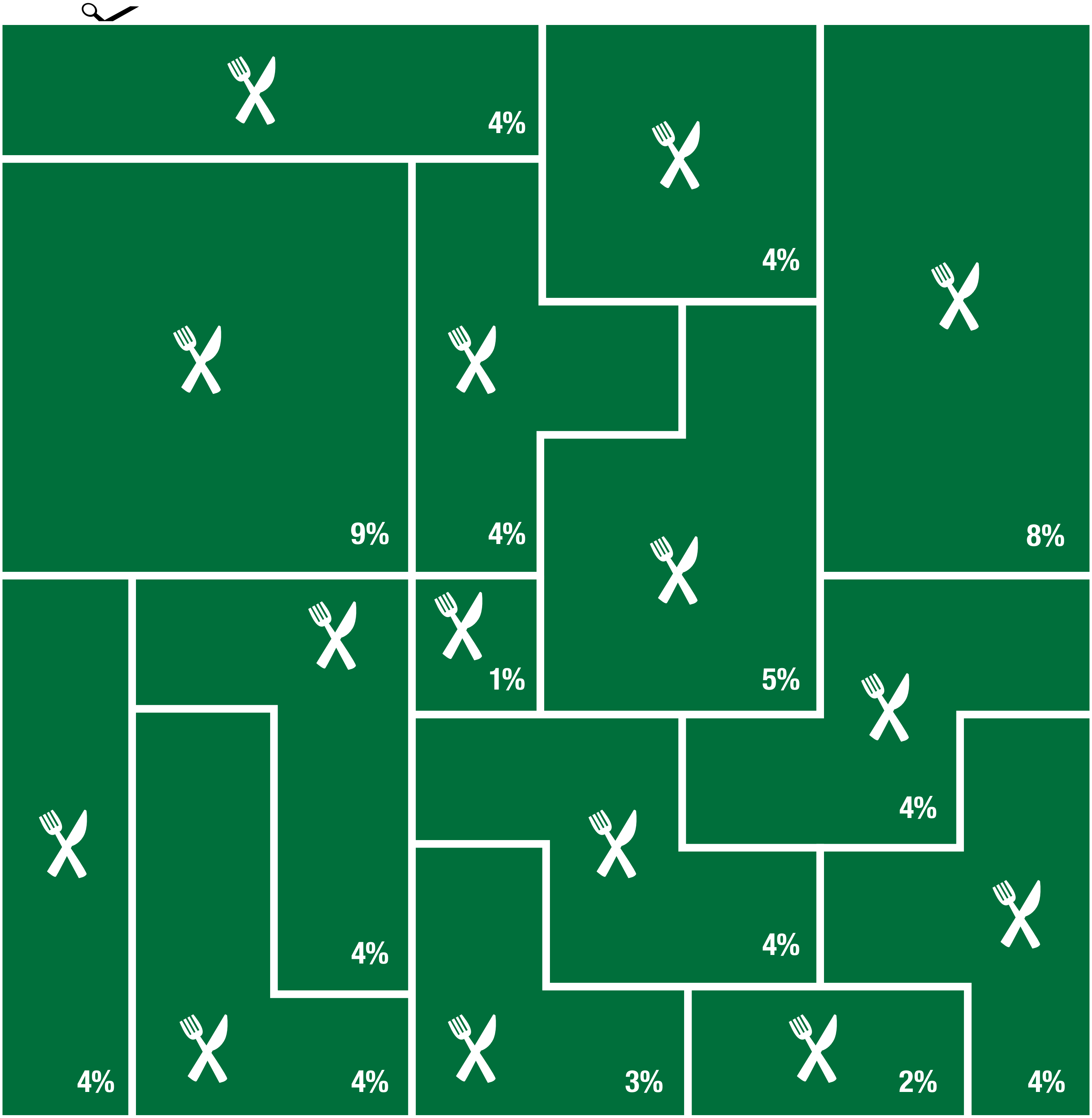
PRIORITY	TYPE OF CARGO	% PACKED CARGO
	Food Examples: dried, frozen, and canned foods such as tortillas and peanut butter	
	Supplies Examples: space suits, clothing, medical supplies, toiletries	
	Life Support Examples: oxygen, water, air filters, water purification system	
	Mining Equipment Examples: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

TOTAL %

Food Cargo

Instructions

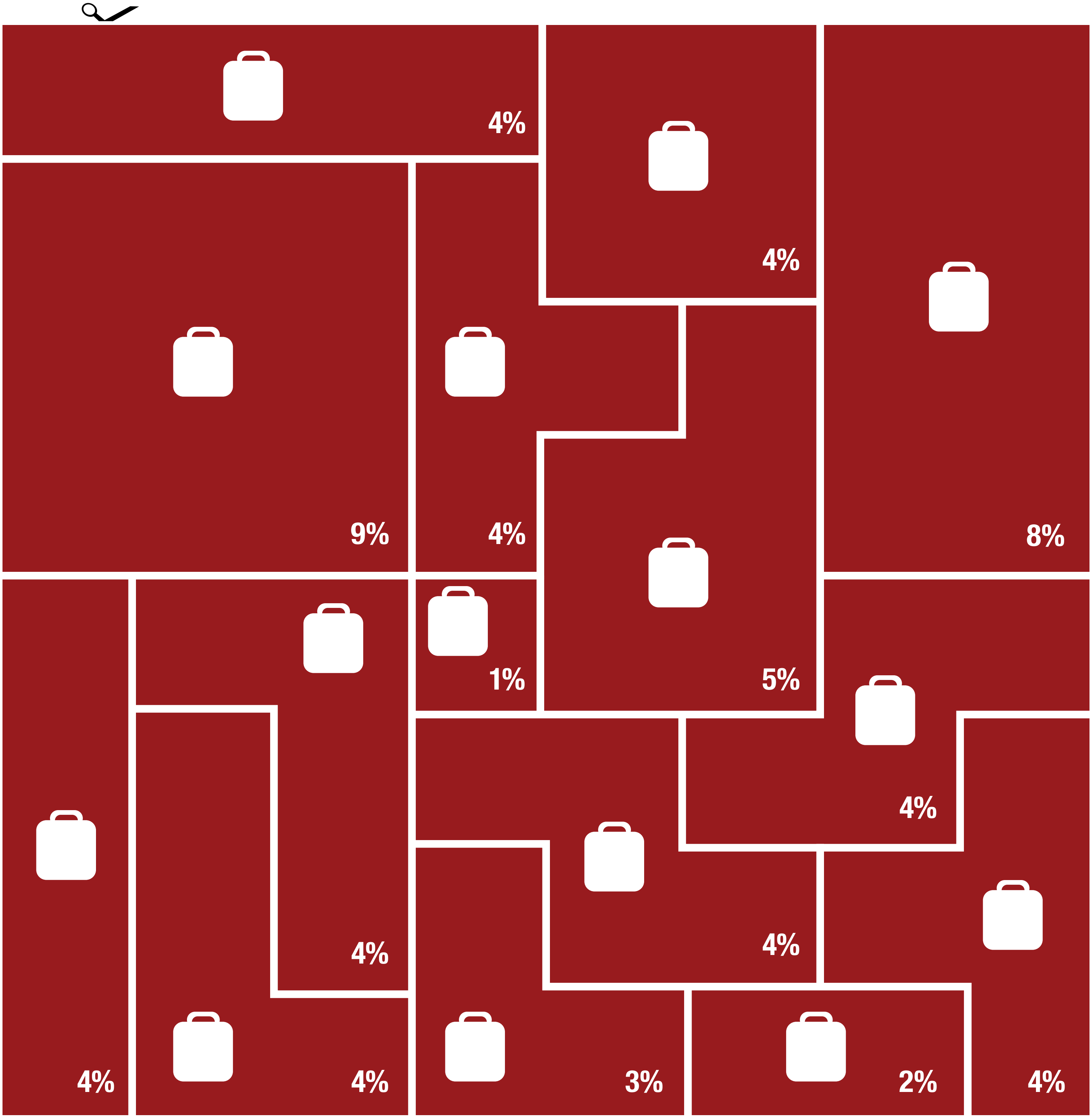
Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



Supplies Cargo

Instructions

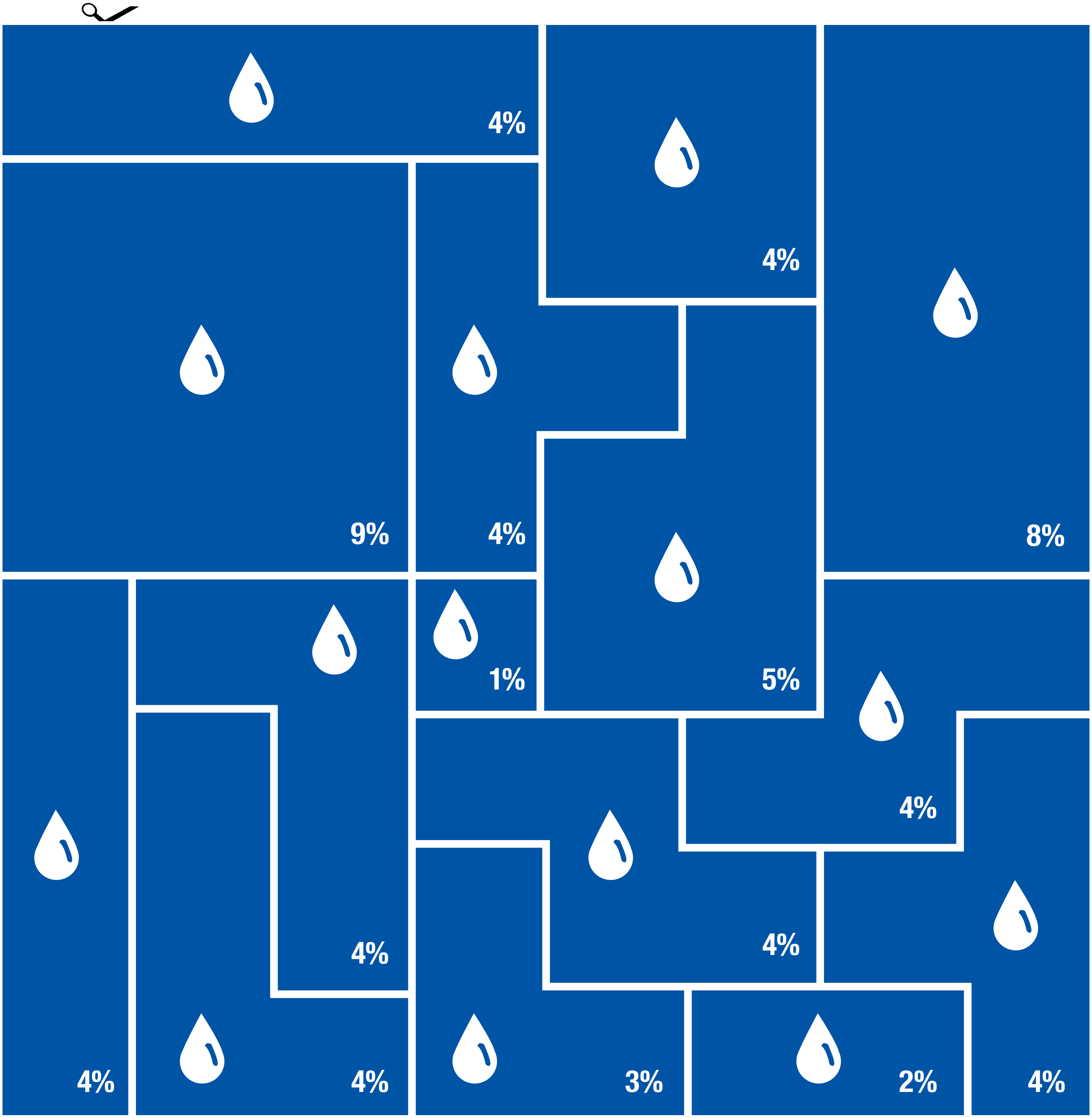
Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



Life Support Cargo

Instructions

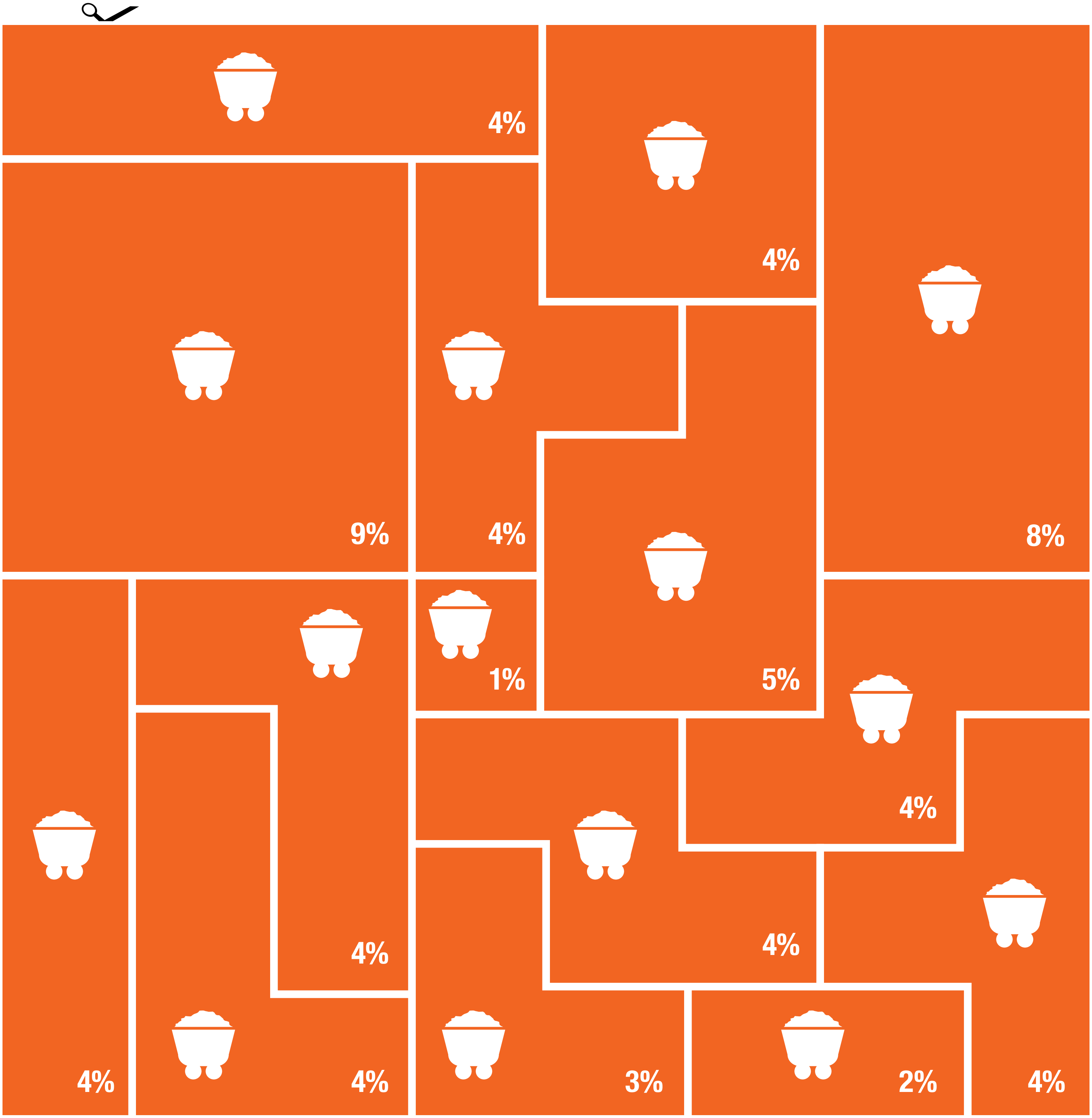
Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



Mining Equipment Cargo

Instructions

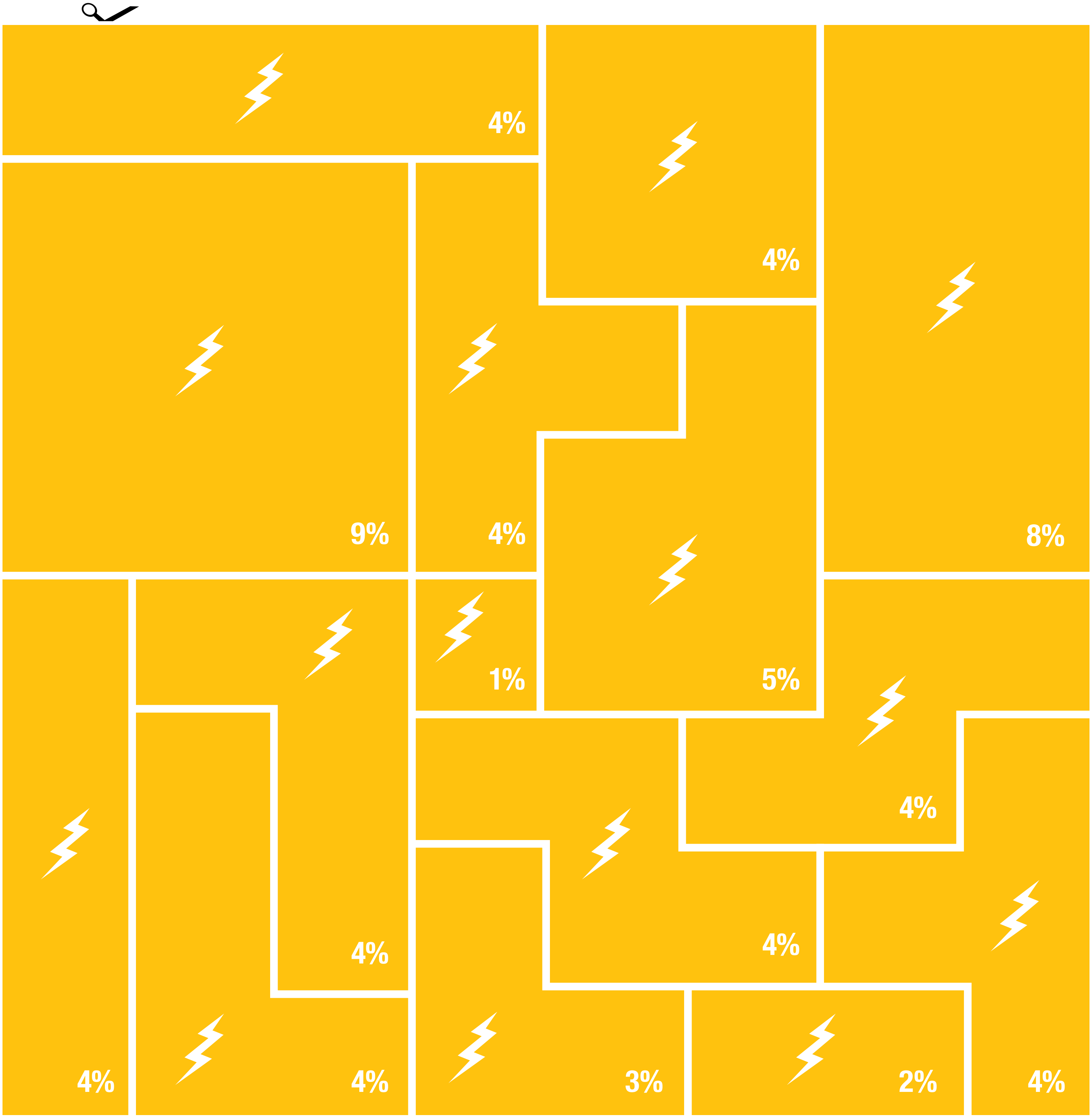
Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



Power Equipment Cargo

Instructions

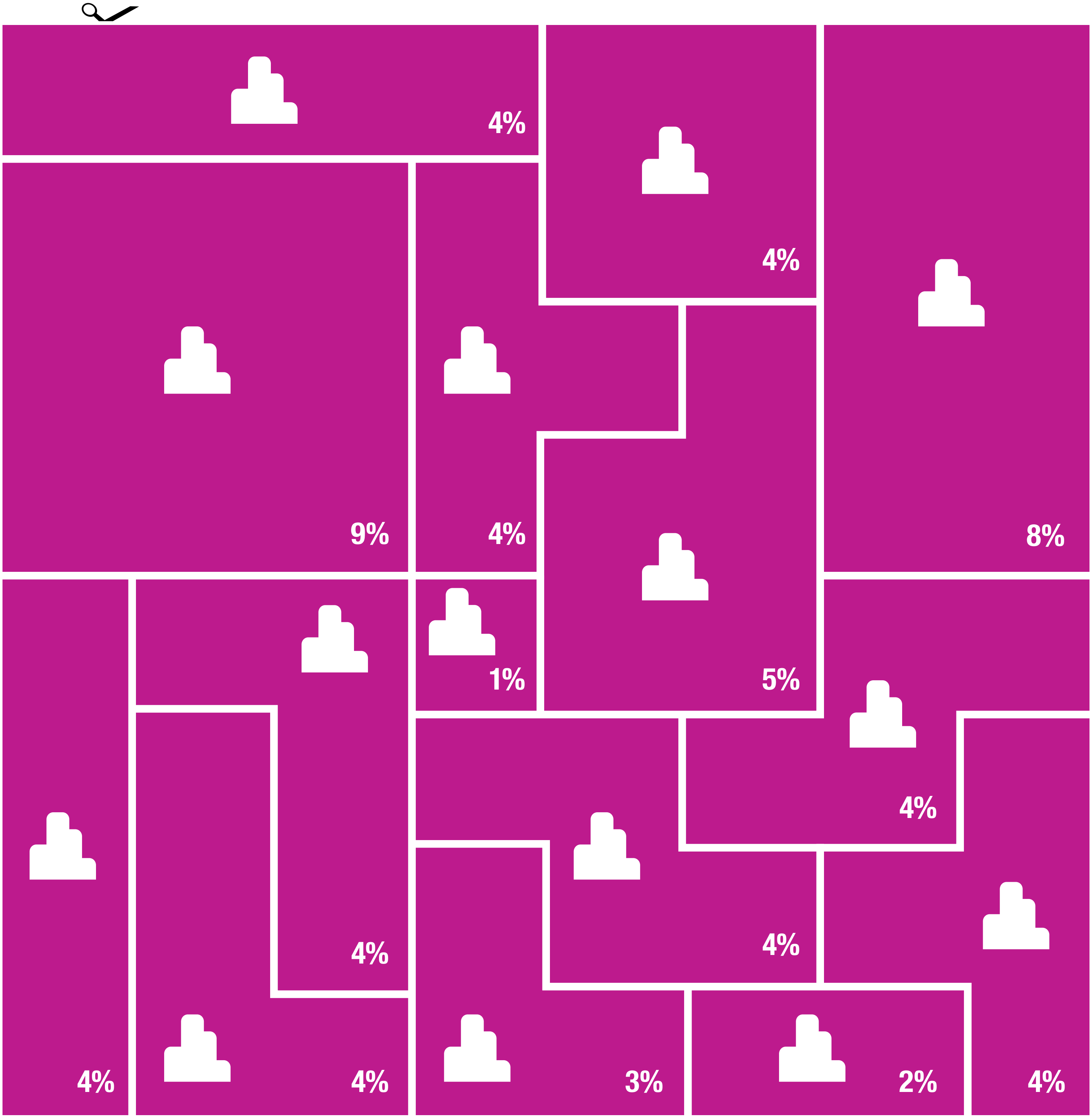
Cut out the cargo shapes along the dotted lines. These shapes represent six kinds of cargo that needs to be shipped to the Moon. (Refer to the Cargo Packing List worksheet).



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 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.

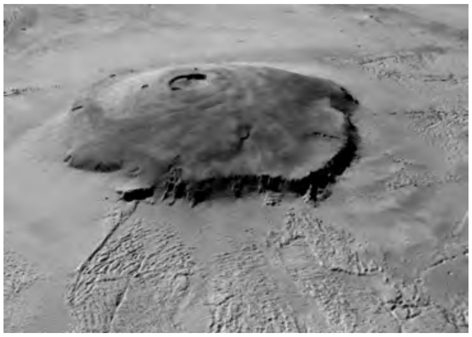
According to NASA's Vision for Space Exploration, astronauts will return to the Moon as early as 2015. This is a key step en route to Mars and beyond. On the Moon, which is practically in Earth's backyard, astronauts can learn how to live on an alien world before attempting longer voyages to other planets.

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.

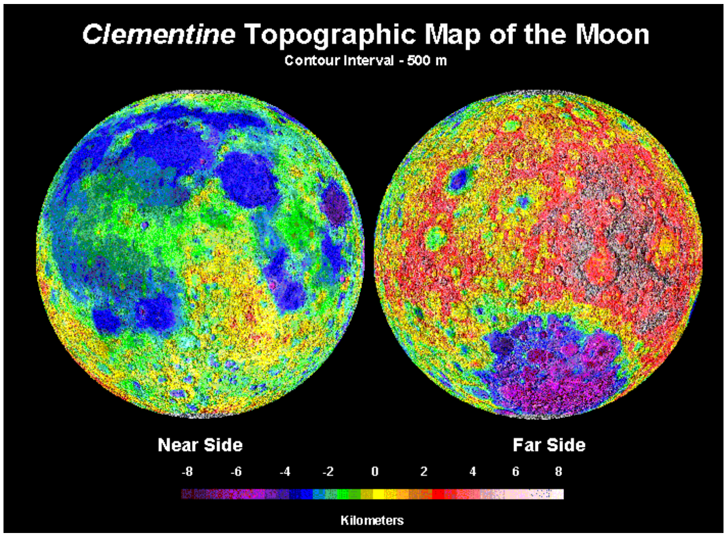
"In a sense, the Moon is an ideal object for making these kinds of observations because it has no atmosphere to interfere with the propagation of the laser pulses," says Smith, who is the principal investigator for LOLA.

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 moondust? LOLA has your bearings.

Misplaced a crater? Unimaginable.

NASA article from:
http://science.nasa.gov/headlines/y2005/24may_lola.htm

Medical Investigation

TASK CARD 1

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.

Medical Investigation

TASK CARD 2

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.

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

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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).

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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).

Medical DATA CARD

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.

Medical DATA CARD

Additional First Aid Items

THERMOMETER

- Used to measure body temperature.

Medical DATA CARD

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.

Medical DATA CARD

Additional First Aid Items

EPINEPHRINE

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

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

Additional First Aid Items

TYLENOL

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

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

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.

Medical DATA CARD

Additional First Aid Items

EMERGENCY BLANKET

- Used to maintain body heat.

Medical DATA CARD

Additional First Aid Items

STERILE WATER

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

Medical DATA CARD

Additional First Aid Items

HEAT AND COLD PACKS

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

Medical DATA CARD

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?

Medical DATA CARD

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?

Medical DATA CARD

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?

Medical DATA CARD

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?

Medical DATA CARD

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 blistery. The technician states that he felt really tired and nauseous. As soon as he sat down, he 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?

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.

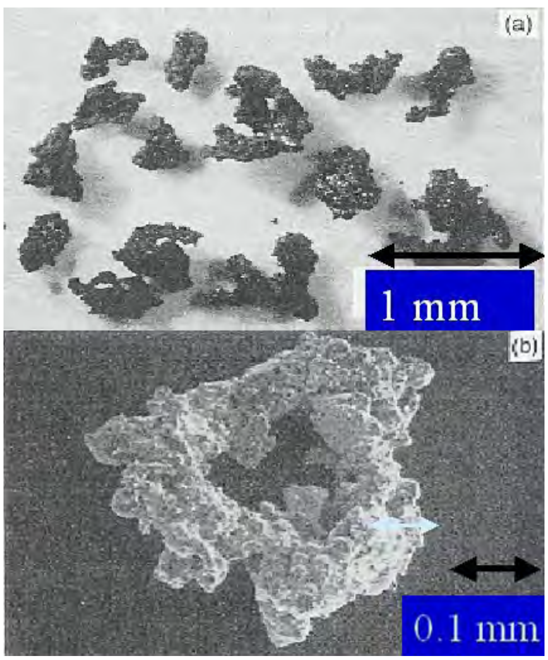
Lunar dust is, like quartz, a compound of silicon and (to our current knowledge) is not poisonous. But like the quartz dust in the Hawk's Nest Tunnel, it is extremely fine and abrasive, almost like powdered glass. Astronauts on several Apollo missions found that it clung to everything and was almost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

DON'T BREATHE THE MOON DUST

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 airborn, 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.

"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 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.

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

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