# Activity Three: Priority Packing for the Moon

## Educator Notes

In this activity students will be conducting a simulated mission to the Moon. Students will expand their knowledge about basic human needs by thinking about what resources will be necessary on a mission to the Moon. Students will identify resources available at their selected landing site and what science missions should be conducted. Students will also need to prioritize what to pack for living and working at their selected Moon site.

### Learning Objectives

Students will use the engineering design process to

- Evaluate the importance of given objects based on basic human needs and availability of space on a lander in order to be successful on a mission to the Moon.
- Optimize a given volume for packing items for space in the human landing system cargo bay.

### Challenge Overview

Students will engage in a Moon survival scenario, select a Moon science mission based on a chosen landing site, prioritize the items for the mission, and describe how to optimize a packing solution.

### Suggested Pacing

45 to 90 minutes

### National STEM Standards

| Science and Engineering (NGSS) | |
|---|---|
| *Disciplinary Core Ideas*<br>• MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.<br>*Crosscutting Concepts*<br>• Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between quantities as scales change.<br>• Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.<br>*Science and Engineering Practices*<br>• Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. | *Science and Engineering Practices (continued)*<br>• Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.<br>• Engaging in Argument From Evidence: Argumentation is the process by which explanations and solutions are reached.<br>• Obtaining, Evaluating, and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. |
| **Technology (ISTE)** | |
| *Standards for Students*<br>• Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts, and make meaningful learning experiences for themselves and others.<br>• Computational Thinker: Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions. | *Standards for Students (continued)*<br>• Creative Communicator: Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats, and digital media appropriate to their goals. |
| **Mathematics (CCSS)** | |
| *Content Standards by Domain*<br>• CCSS.MATH. CONTENT.7.G.B.6: Solve real-world and mathematical problems involving area, volume, and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.<br>• CCSS.MATH.CONTENT.6.G.A.2: Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths, and show that the volume is the same as would be found by multiplying | the edge lengths of the prism. Apply the formulas $V = l\ w\ h$ and $V = b\ h$ to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems.<br>• CCSS.MATH.CONTENT.6.G.A.4: Represent three-dimensional figures using nets made up of rectangles and triangles and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems. |

## Activity Preparation

The educator should

- Read the introduction and background information and the Educator Notes to become familiar with the challenge.
- Determine teams and roles ahead of time (see the background information at the beginning of this guide for recommendations).
- Print the following:
  - Student Handout (one per student)
  - Lunar Cargo Packing List (one per team) Lunar Cargo Polyominoes sheets (one of each kind per team)

    Note: Polyominoes are equal-sized squares joined together edge to edge to form a plane geometric figure.
- Provide computer access to students so they can visit NASA Moon to Mars resources.

## Materials

- Printouts
- Lunar Map from Activity 1 (Choose Your Landing Site)
- Poster paper
- Writing utensil
- Glue or tape
- Scissors
- Computers for site research OR print out the five Site Information sheets from Activity 1 (Choose Your Landing Site)

**Safety**

Practice safety protocols for scissor use.

## Introduce the Challenge

- Inform students that they will be working in teams to prioritize and pack for a science mission to the Moon.
- Remind students that the landing site they select (or are assigned) will determine what they will be packing for survival and for their science investigation.

| Criteria | Constraints |
|---|---|
| You must maximize space available for packing. (10 × 10 square = 100 units) | You may not exceed the space provided. (10 × 10 square = 100 units) |
| You must include life support resources (unless found at your site) and science equipment for your mission in your payload. (Note: See Brain Booster for 1-day uses for the average human.) | You may not leave out anything from your priority list: food, supplies, life support, science equipment, power equipment, and building equipment. |
| You must have enough basic life support for 7 days on the Moon for each team member astronaut. | You may not assume there are resources at your landing site if they have not been researched. |
| Your final packing solution must reflect the predetermined priority list and maximize your packing area but may be under 100 percent. | Your final packing solution may not go over 100 percent. |

## Facilitate the Challenge

**Ask**

NASA plans on going back to the Moon and will demonstrate how humans will be able to live sustainably on the South Pole region of the Moon. The human landing system will deliver the astronauts to the surface of the Moon at a predetermined site where they can live and work for up to 7 days and conduct specific science missions.

## Landing Humans on the Moon

Look at the map of the lunar South Pole region, with the five predetermined landing sites. Assign teams to a specific landing site and provide them with the corresponding Site Information sheet from Activity One. Ask students to think about what they know about the basic needs of humans. What resources will astronauts need to bring with them, and what science investigations can be conducted?

- What are the basic things that organisms need to live?
- How is being on the Moon different than being on Earth?
- What would astronauts living on the Moon need for survival?
- What supplies will you take for your science mission based on the assigned location?
- How can you prioritize and pack supplies in the cargo bay following design criteria?

### Imagine

Survival Scenario (read to students):

> The year is 2025 and you are part of a four-member team traveling toward the Moon. As your spacecraft enters lunar orbit, you spot the base camp. It is located on a crater rim near the lunar South Pole, in near-constant sunlight. This location is not far from supplies of water ice that can be found in the cold, permanently shadowed part of the crater. As your spacecraft descends toward the lunar surface, you suddenly notice that there is a problem with the thrusters. You land safely, but off course, about 25 kilometers (approximately 15 miles) from the base camp. As you look across the charcoal-gray, dusty surface of the Moon, you realize your survival depends on reaching the base camp, finding a way to protect yourself until someone can reach your team, or meeting a rescue party somewhere between your landing site and the habitat. You know the Moon has basically no atmosphere or magnetosphere to protect you from space radiation. The environment is unlike any found on Earth. The regolith, or lunar soil, is a mixture of materials that includes sharp, glassy particles. The gravity field on the Moon is only one-sixth as strong as Earth's. More than 80 percent of the Moon is made up of heavily cratered highlands. Temperatures vary widely on the Moon. It can be as cold as 193 °C (–315 °F) at night at its poles and as hot as 111 °C (232 °F) during the day at its equator. Survival will depend on your mode of transportation and your ability to navigate. Your basic needs for food, shelter, water, and air must be considered. With the Moon's lower gravity, 25 kilometers (approximately 15 miles) is not too far to walk, but you are limited in what you can carry. You can only take seven items with you. What should you take with you and why?
>
> Of the 12 items available, strategize with your team and prioritize the 7 items your team will carry during your journey to the lunar base camp. Your survival depends on your ability to work with other team members to determine not only the value of these items, but how to use them as well.
>
> 1. Box of matches
> 2. Oxygen
> 3. Food
> 4. Water
> 5. Lights with solar-powered rechargeable batteries
> 6. Magnetic compass
> 7. Solar powered receiver–transmitter
> 8. Life raft
> 9. First aid kit

### Share With Students

#### Brain Booster

On Earth, the average American uses about 132 liters (roughly equal to 35 gallons) of water every day. In contrast, the average astronaut on the International Space Station (ISS) uses 11 liters (3 gallons) of water. Water is heavy (1 kilogram per liter), so attempts are made to minimize the amount of water carried on board a spacecraft. An astronaut on the ISS uses about 0.83 kilograms (1.83 pounds) of food per meal each day. The average person (both on the ISS and on Earth) needs about 0.84 kilograms of oxygen per day.

Learn more:
https://www.nasa.gov/content/life-support-systems

#### On Location

NASA's Planetary Missions Program Office, which is located at Marshall Space Flight Center, helps humanity answer profound questions about the nature of the solar system and our place in it. On a certain night of the year, this office hosts an International Observe the Moon Night. This is a worldwide event that encourages observation, appreciation, and understanding of our Moon and its connection to NASA exploration and discovery.

Check out the website to participate in a town near you:
https://moon.nasa.gov/observe-the-moon-night/about/overview/

10. Map of Moon's surface
11. 15 meters (approximately 50 feet) of nylon rope
12. Signal mirror

Once the teams have agreed on their seven essential items, facilitate a whole-team discussion on the reasoning behind each student's choices. Be open to all answers if students have reasonable justifications for their order and reasoning. This activity helps to verify students' understanding of the conditions on the Moon. This can also lead to identifying student misconceptions about the Moon's environment. (Winning student/team has the most points for correct order; see the following priority table and scoring information.)

NASA's Suggested Priority Items

| Item | Priority Level | Explanation |
|---|---|---|
| **Oxygen** | High | Oxygen to breathe is the most important survival need, since the Moon has virtually no atmosphere. |
| **Water** | High | Water is another basic survival need for the astronauts. Because there is no liquid water on the Moon, the astronauts will need the water they brought with them to survive. |
| **Food** | High | Although the food concentrate must have water added to be useful, it is lightweight and easy to carry, meeting a third basic need for survival. |
| **Solar-powered receiver–transmitter** | High | As people from the lunar outpost are looking for you, you should try to reach them. Maintaining communication with your outpost is essential. |
| **First aid kit** | High | A first aid kit takes up little space and may be important to have in case of illness or injury. |
| **Map of Moon's surface** | High | With no other directional tools available, a map of the Moon's surface is necessary. |
| **Life raft** | Medium | The life raft makes a great sled for carrying the oxygen and water. |
| **15 meters (about 50 feet) of nylon rope** | Medium | The rope makes dragging the life raft easier or may come in handy when crossing difficult terrain. |
| **Lights with solar-powered rechargeable batteries** | Medium | The lights are helpful if you travel across large shadowed areas. Some areas in the polar regions are permanently dark. |
| **Signal mirror** | Medium | The signal mirror is used as a form of communication if the radio is not working. |
| **Box of matches** | Low | With little oxygen on the Moon, the matches are useless. |
| **Magnetic compass** | Low | The compass is virtually useless because there is no Moon-wide magnetic field. |

***Scoring***

For each of the student/teams' seven items, add the number of points (3 – High Priority, 2 – Medium Priority, 1 – Low Priority) from the NASA ranking, then add up all the points.

- 20 or more: Excellent – Future Moon Explorers!
- 19: Good
- 18: Average
- 17: Poor – Suggests use of Earthbound logic
- 16 or fewer: Very poor – Need to go back to Basic Astronaut Moon Survival Training!

**Plan**

- Take out the Lunar Cargo Packing List. Have student teams prioritize six items for a mission to their landing site. This is the first step to prioritize the cargo they will bring to the Moon.

- Have each team draw a 10- by 10-inch square on a large sheet of paper. This space represents the (500-kilogram-unit) cargo bay of their human landing system, which will transport the basic needs and science cargo for the mission. Have each team cut out the six sets of shapes on the Lunar Cargo Polyominoes worksheets. Polyominoes are equal-sized squares joined together edge to edge to form a plane geometric figure.
- These shapes represent cargo that needs to be packed into the human landing system. The percentage shown on each item represents the *percentage of volume* it will occupy in the cargo bay.

### Create

- Based on their team's original priority list, students will fit the shapes in the cargo bay, beginning with the supplies they will need the most of. For example, if food is their number one priority, there should be a greater *percentage* of food packed in the cargo bay.
- Teams should try to pack the cargo so there are no empty spaces. Be sure students use only the shapes given and do not cut them to make them fit in the cargo bay.

### Test

- Have students follow the second step on the Lunar Cargo Packing List worksheet to calculate the percentages of each type of packed cargo. A fully packed cargo bay will equal 100 percent.
- Have students compare their final decision with their original priority list.

### Improve

- If necessary, instruct students to repack the cargo bay until the priority list has been followed and space has been used to its maximum capacity.

### Share

Engage students with the following discussion questions:

- What are the advantages and disadvantages of your team's site?
- What resources are available to the astronauts at your landing site?
- Did you obey all the criteria and constraints in this activity?
- Think about how density, mass, and balance can affect human spaceflight. How could your team pack the payload based on density, mass, and balance? Discuss various packing solutions.
- Does your final packing decision reflect your original priority list?
- Do you have enough evidence that NASA would agree with the priority packing your team has chosen?

Note: Depending on the time remaining, teams can also present their final packed cargo bay and the reasons they chose the cargo they did, based on the science mission and landing site the team selected or was assigned. Remember, there is not a "perfect" answer if teams can justify and defend their final packing solution. There are a variety of ways that student teams can present their findings and conclusions. Suggestions for presentations include a Q&A session, a Moon Realty presentation, or a team presentation using jigsaw.

Have students justify their packing plans:

- Defend your choices in the items your team picked.
- What is a "high-priority" item and what determines it being a high priority?
- Why did you not select certain items?
- Did your final packing solution match your priority list?

Optional: Share student results on social media using #NextGenSTEM. Be sure to include the module and activity name.

## Extensions

- Provide printed directions to help students who may need additional structure for the inquiry.
- Educators can make this activity more realistic and switch from 2D to 3D by using polyominoes, a math manipulative. Another 3D option would be to have students fill a shoebox with “cargo” items, like building blocks of various sizes.
- Allow students to “dive deeper” into the science missions. Refer to NASA web links and information provided in the background section.

## Pick Your Science Mission (Extension Activity)

- Student teams decide on a mission for a particular location and identify items needed for that science mission. If jigsaw grouping is being used, have the Activity One expert choose the location. If not, have teams randomly select a site on the South Pole from Activity One.
  - If you had complete control, what would you place in your lander for your mission? Justify your decision. Do not forget basic Moon survival needs (food, water, and shelter with an energy source).
  - Research what actual scientists would be doing and their science equipment needs.
- Moon Mission Objectives:
  - Study of planetary processes
  - Understanding volatile cycles
  - Interpreting the impact history of the Earth–Moon system
  - Revealing the record of the ancient Sun
  - Observing the universe from a unique location
  - Conducting experimental science in the lunar environment
  - Investigating and mitigating exploration risks to humans
- Allow students to make a new priority packing list for packing specific science equipment based a new landing site.

## References

Field Trip to the Moon
https://www.nasa.gov/pdf/305948main_FTM_LRO_Informal_Guide.pdf

Survival! Exploration: Then and Now
https://www.nasa.gov/pdf/166504main_Survival.pdf

## Resources

NASA Trek Link (Moon Map)
https://trek.nasa.gov/moon/#v=0.1&x=0&y=0&z=1&p=urn%3Aogc%3Adef%3Acrs%3AEPSG%3A%3A104903&d=&locale=&b=moon&e=-224.99999580294752%2C-106.52343551295796%2C224.99999580294752%2C106.52343551295796

Explore Space Exploration: Build a Moon Base
https://www.lpi.usra.edu/education/explore/beyondEarth/activities/buildAcolony.shtml

# Activity Three: Priority Packing for the Moon

## Student Handout

### Your Challenge

You will be assigned a landing site on the South Pole of the Moon using NASA topographic maps and data. You will engage in a Moon survival scenario, prioritize items for a Moon mission, and describe how to optimize a packing solution for all your supplies.

| Criteria | Constraints |
|---|---|
| You must maximize space available for packing. (10 × 10 square = 100 units) | You may not exceed the space provided. (10 × 10 square = 100 units) |
| You must include life support resources (unless found at your site) and science equipment for your mission in your payload. (Note: Research necessary here to identify the average 1-day uses for the average human.) | You may not leave out anything from your priority list: food, supplies, life support, science equipment, power equipment, and building equipment. |
| You must have enough basic life support for 7 days on the Moon for each team member astronaut. | You may not assume there are resources at your landing site if they have not been researched. |
| Your final packing solution must reflect the predetermined priority list and maximize your packing area but may be under 100 percent. | Your final packing solution may not go over 100 percent. |

### Ask

NASA has a mission to explore the South Pole region of the Moon.

- What would astronauts living on the Moon need to survive?
- What supplies will you take for your science mission based on the selected location?
- How will you prioritize and pack supplies in the cargo bay following design criteria?

### Imagine

The year is 2025 and you are part of a four-member team traveling toward the Moon. As your spacecraft enters lunar orbit, you spot the base camp. It is located on a crater rim near the lunar South Pole, in near-constant sunlight. This location is not far from supplies of water ice that can be found in the cold, permanently shadowed part of the crater. As your spacecraft descends toward the lunar surface, you suddenly notice that there is a problem with the thrusters. You land safely, but off course, about 25 kilometers (approximately 15 miles) from the base camp. As you look across the charcoal-gray, dusty surface of the Moon, you realize your survival depends on reaching the base camp, finding a way to protect yourself until someone can reach your team, or meeting a rescue party somewhere between your landing site and the habitat. You know the Moon has basically no atmosphere or magnetosphere to protect you from space radiation. The environment is unlike any found on Earth. The regolith, or lunar soil, is a mixture of materials that includes sharp, glassy particles. The gravity field on the Moon is only one-sixth as strong as Earth's. More than 80 percent of the Moon is made up of heavily cratered highlands. Temperatures vary widely on the Moon. It can be as cold as 193 °C (–315 °F) at night at its poles and as hot as 111 °C (232 °F) during the day at its equator. Survival will depend on your mode of transportation and your ability to navigate. Your basic needs for food, shelter, water, and air must be considered. With the Moon's lower gravity, 25 kilometers (approximately 15 miles) is not too far to walk, but you are limited in what you can carry. You can only take seven items with you. What should you take with you and why?

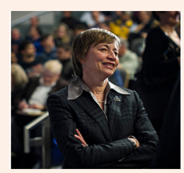
### Fun Fact

You are part of the Artemis Generation. Artemis was the Greek Goddess of the Moon and the twin sister of Apollo. Through the Artemis missions, NASA plans to put the first woman and first person of color on the Moon. We have not been back to the Moon since 1972. During the Apollo program of the 1960s and 1970s, NASA sent nine missions to the Moon. Six of them landed astronauts safely on the surface, the only times humans have visited another world.

Learn more: https://www.nasa.gov/specials/artemis/

### Career Corner

Dr. Maria Zuber led NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission to explore the Moon.



Maria Zuber

A geophysicist, Maria is an expert on planetary and space science. She has more than half a dozen NASA missions under her belt and decades of experience unraveling mysteries from Mercury to Mars and beyond. Maria was the first woman to lead a robotic planetary mission for NASA. She also was the first woman to lead a science department at the Massachusetts Institute of Technology (MIT).

Learn more: https://solarsystem.nasa.gov/people/2200/maria-zuber/

Of the 12 items available, strategize with your team and prioritize the 7 items your team will carry during your journey to the lunar base camp. Your survival depends on your ability to work with other team members to determine not only the value of these items, but how to use them as well.

1. Box of matches
2. Oxygen
3. Food
4. Water
5. Lights with solar-powered rechargeable batteries
6. Magnetic compass
7. Solar powered receiver–transmitter
8. Life raft
9. First aid kit
10. Map of Moon's surface
11. 15 meters (approximately 50 feet) of nylon rope
12. Signal mirror

### Plan

- Take out the Lunar Cargo Packing List and have your team decide on a priority list for packing for the Moon. Prioritize the cargo that you will bring to the Moon.
- Draw a 10- by 10-inch square on a large sheet of paper. This space represents the (500-kilogram-unit) cargo bay of your human landing system, which will transport the basic needs and science cargo for the mission. Cut out the six sets of shapes on the Lunar Cargo Polyominoes sheets. Polyominoes are equal-sized squares joined together edge to edge to form a plane geometric figure.
- These shapes represent cargo that you can pack into your human landing system. The number on each shape represents the *percentage of volume* it will occupy in the cargo bay.

### Create

- Based on the team's original priority list, fit the shapes in the cargo bay beginning with the supplies you will need the most of. For example, if food is the team's number-one priority, there should be a greater percentage of food packed in the cargo bay.
- 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.

### Test

- Now calculate the percentages of each type of packed cargo. A fully packed cargo bay will equal 100 percent.
- Compare your team's final decision with your original priority list.

### Improve

- Repack the cargo bay until the priority list has been followed and space has been used to its maximum capacity.

### Share

Think about and answer as a team:

- What are the advantages/disadvantages of your site?
- What resources are available to the astronauts at your landing site?
- Did you obey all the criteria and constraints in this activity?
- Think about how density, mass, and balance can affect human spaceflight. How would your team pack the payload based on density, mass, and balance? Discuss various packing solutions.

- How did your team's final cargo bay packing solution compare to your original priority list?
- Do you have enough evidence that NASA would agree with the priority packing your team has chosen?

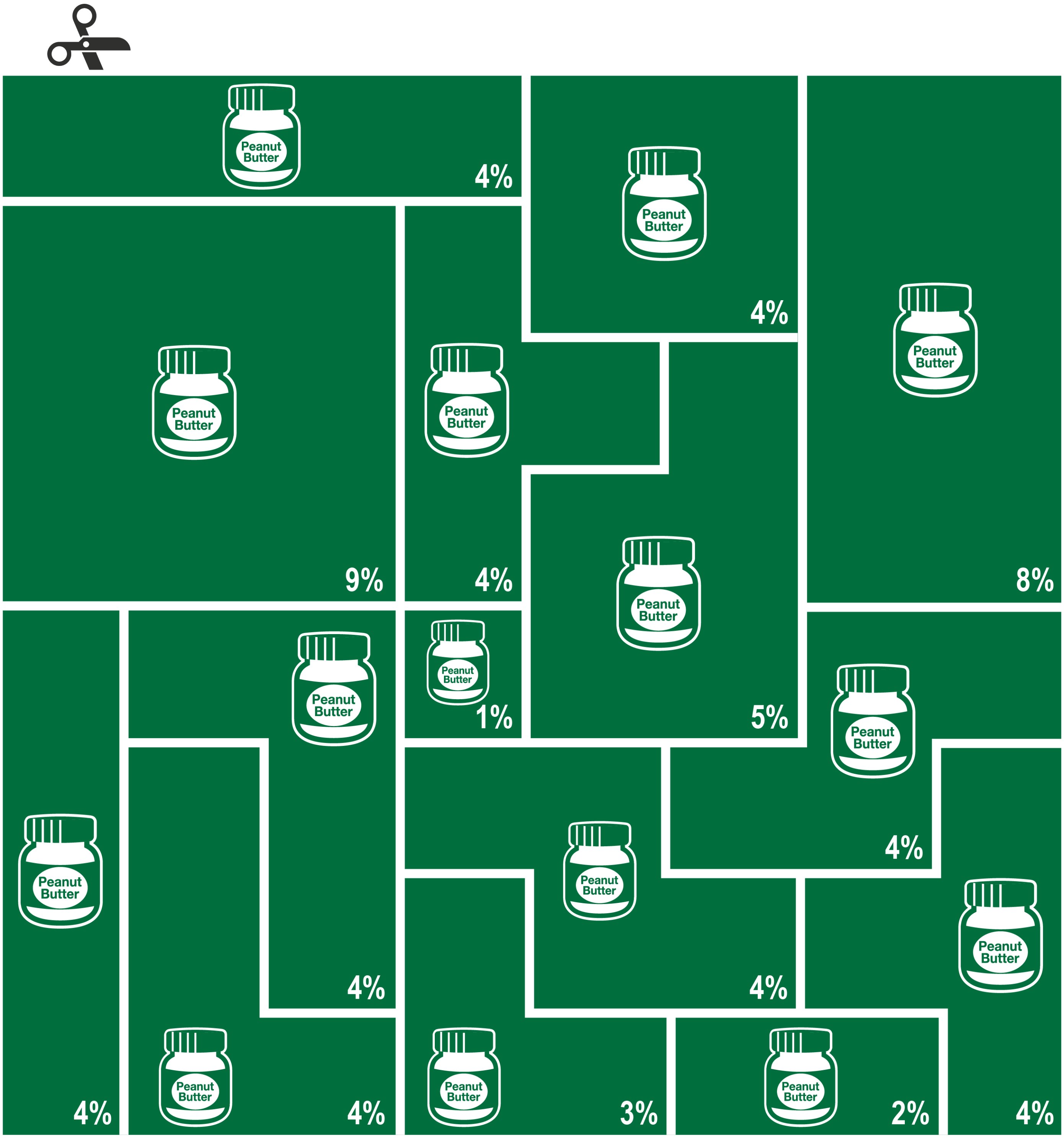
# Lunar Cargo Packing List

| Priority | Type of Cargo | Percentage of Packed Cargo |
|---|---|---|
| | **Food**<br>Examples: Dried, frozen, canned, and packaged foods, such as tortillas and peanut butter | |
| | **Supplies**<br>Examples: Spacesuits, clothing, medical supplies, and toiletries | |
| | **Life Support**<br>Examples: Oxygen, water, air filters, water purification system | |
| | **Science Equipment**<br>Examples: Shovels, pickaxes, drills, robots, and rotary wire brushes | |
| | **Power Equipment**<br>Examples: Generators, wires, electrical cords, outlets, light bulbs, and solar cells | |
| | **Building Equipment**<br>Examples: Power tools, construction materials, bricks, and metal structures | |

| Total Percentage |
|---|
| |

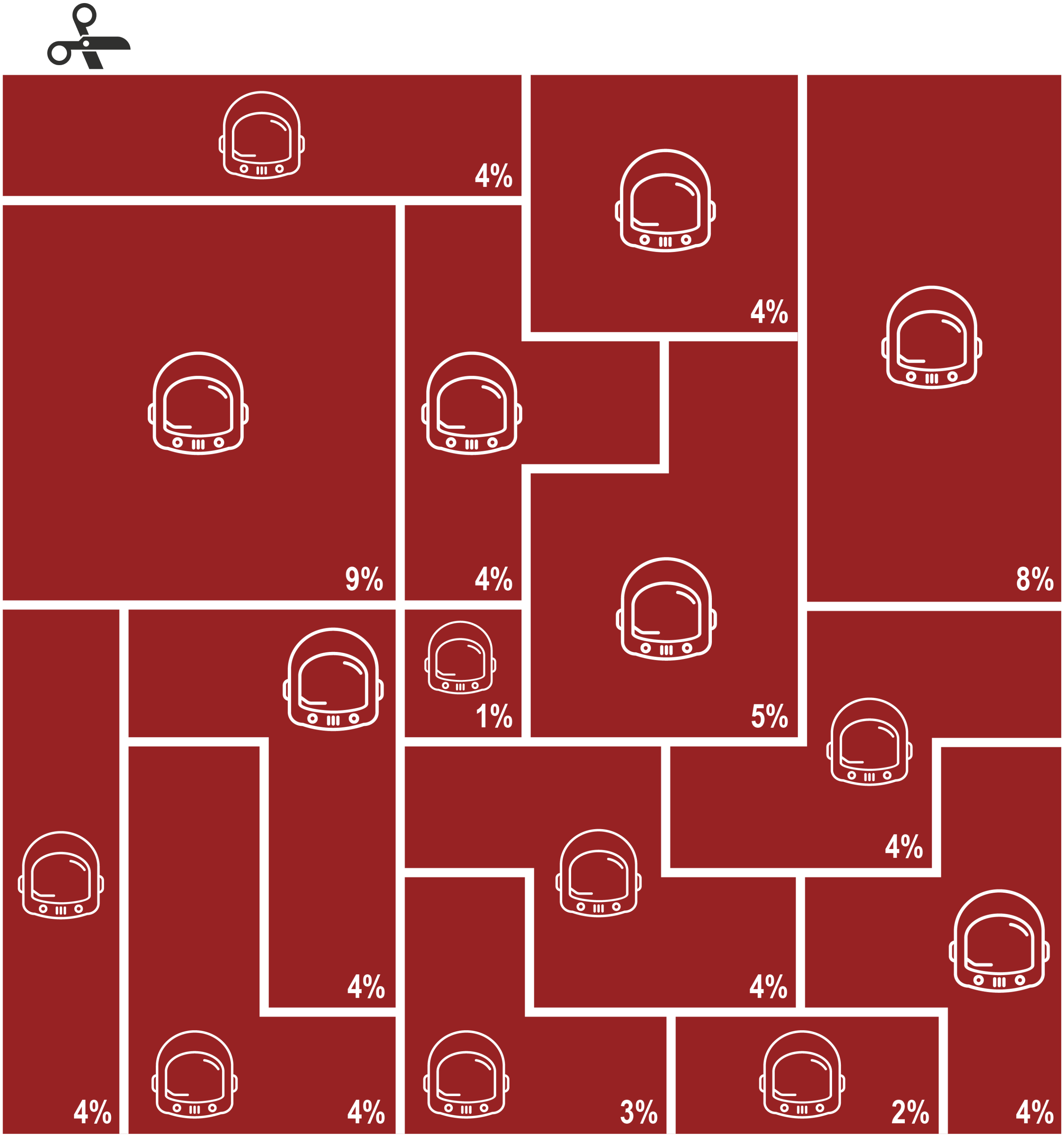
# Lunar Cargo: Food Polyominoes

Instructions: Cut out the cargo shapes along the lines. These shapes represent one of the six kinds of cargo that need to be packed for the Moon. (Refer to the Lunar Cargo Packing List worksheet.)



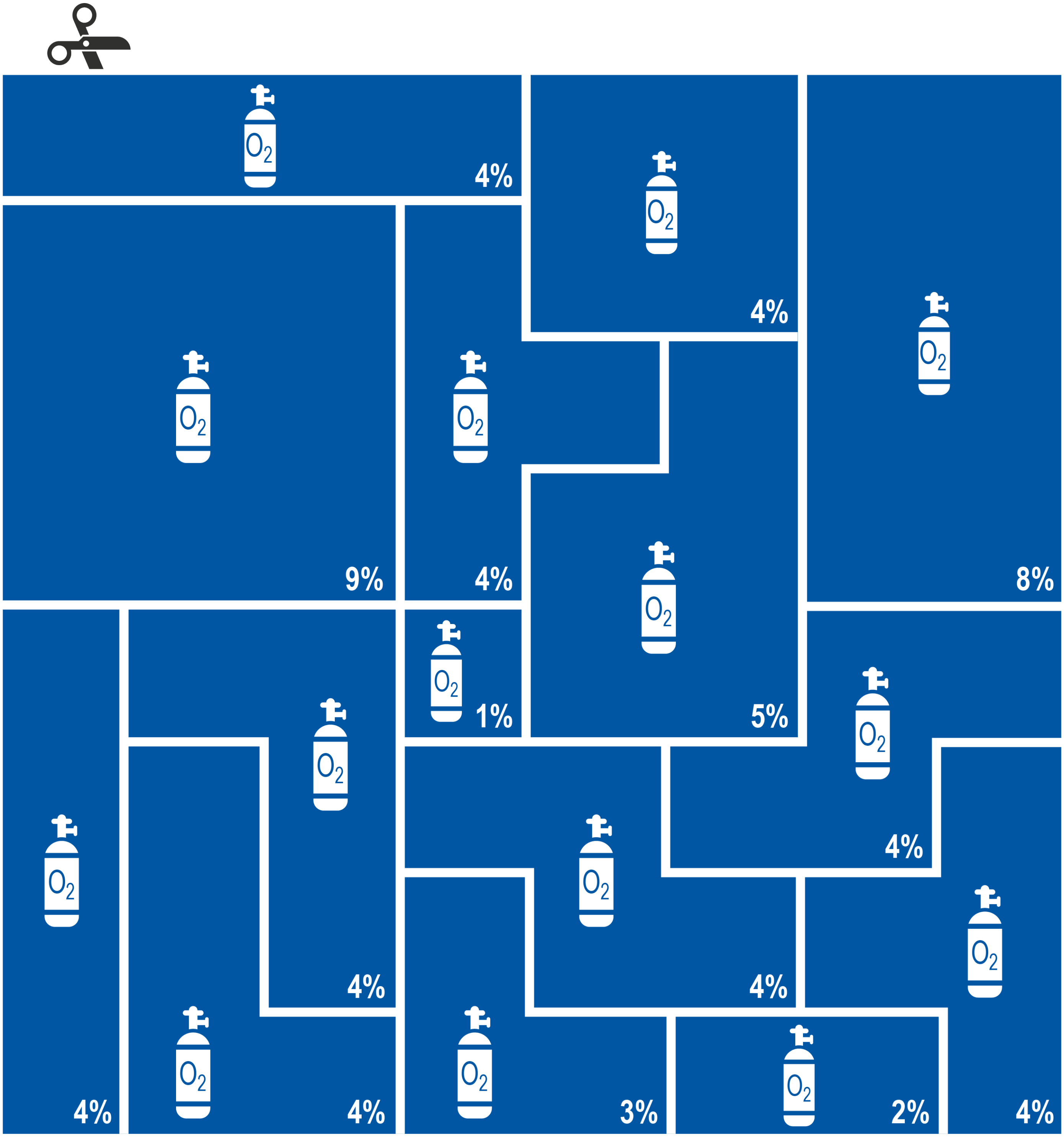
# Lunar Cargo: Supplies Polyominoes

Instructions: Cut out the cargo shapes along the lines. These shapes represent one of the six kinds of cargo that need to be packed for the Moon. (Refer to the Lunar Cargo Packing List worksheet.)



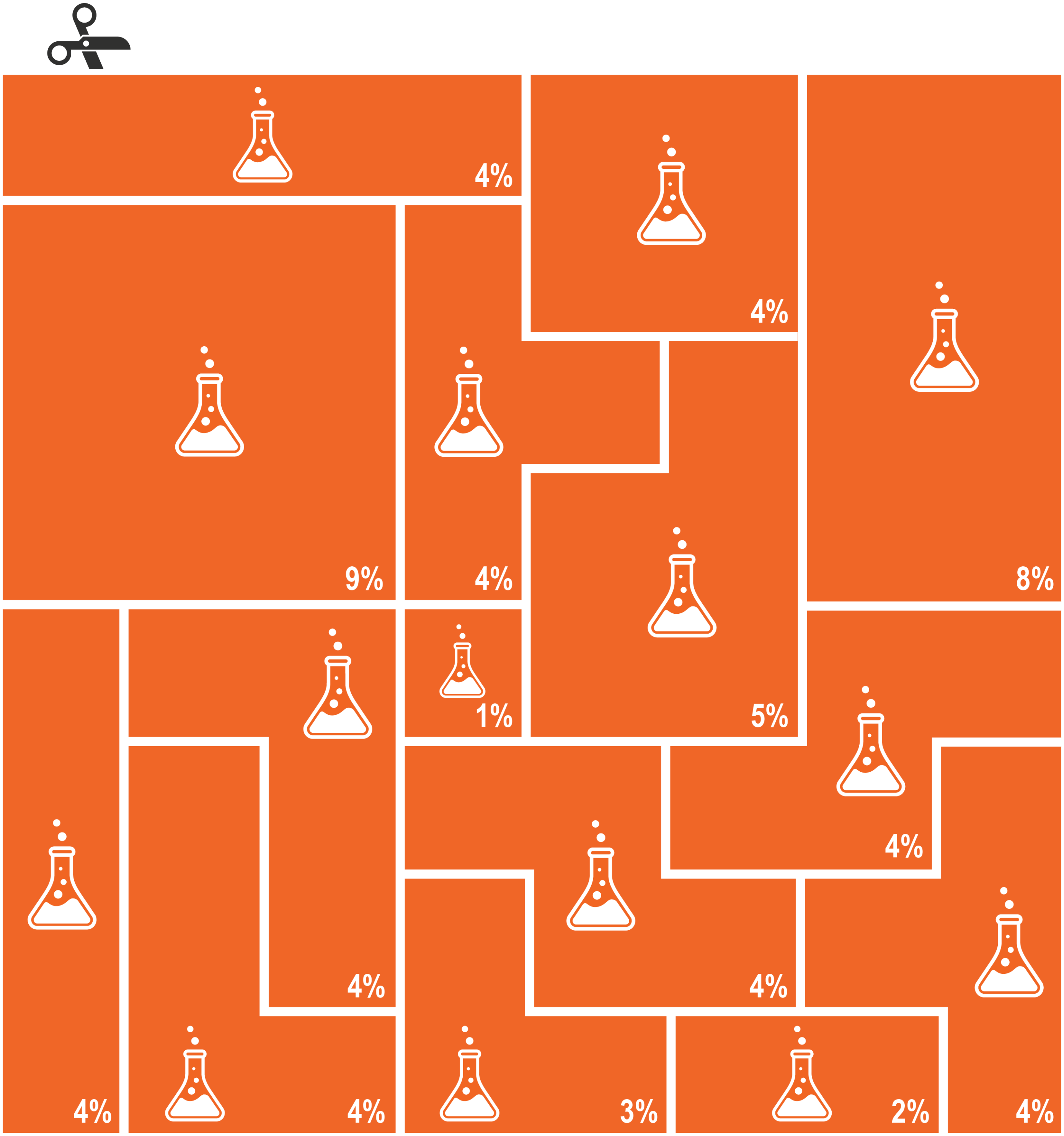
# Lunar Cargo: Life Support Polyominoes

Instructions: Cut out the cargo shapes along the lines. These shapes represent one of the six kinds of cargo that need to be packed for the Moon. (Refer to the Lunar Cargo Packing List worksheet.)



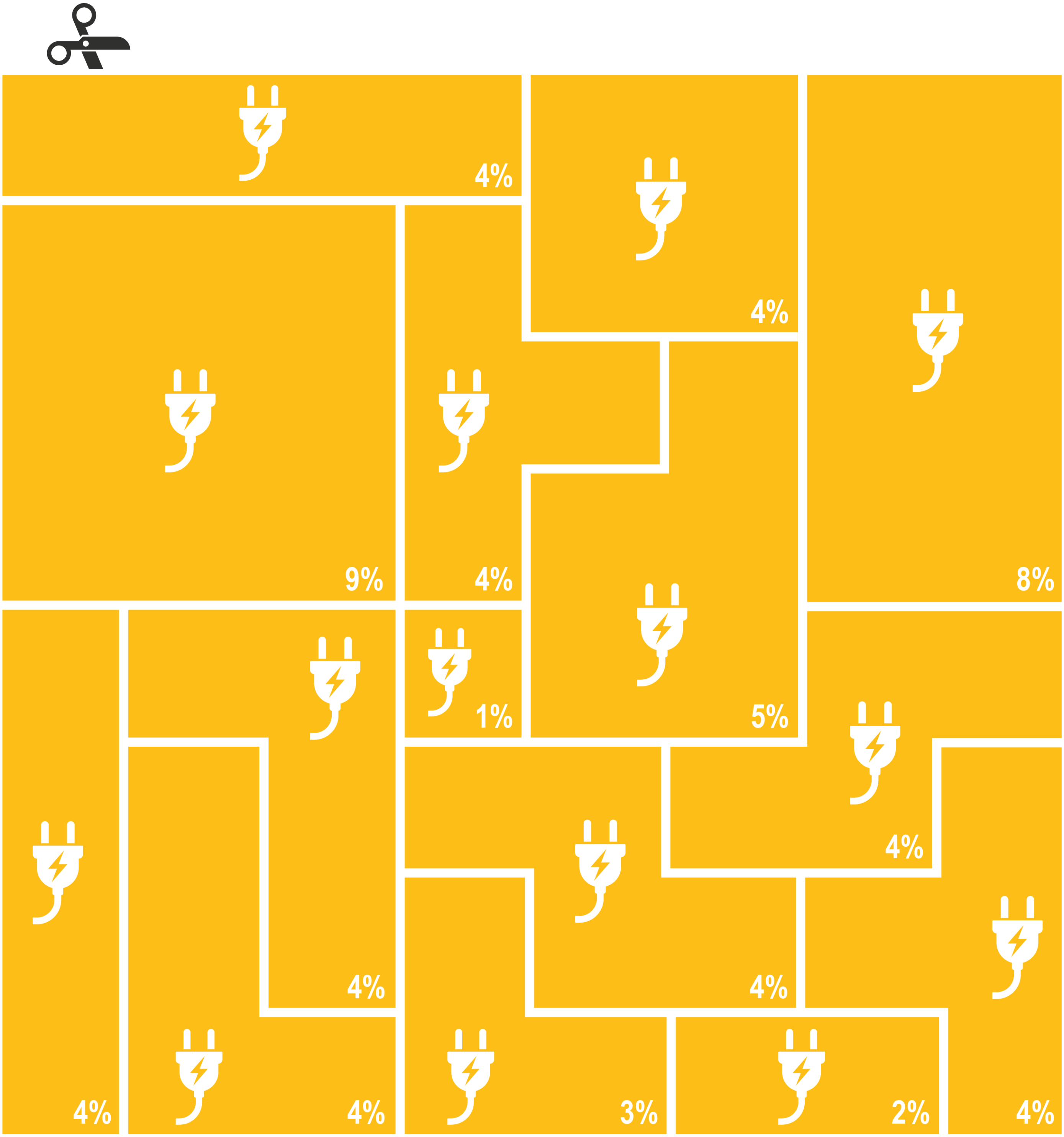
# Lunar Cargo: Science Equipment Polyominoes

Instructions: Cut out the cargo shapes along the lines. These shapes represent one of the six kinds of cargo that need to be packed for the Moon. (Refer to the Lunar Cargo Packing List worksheet.)



# Lunar Cargo: Power Equipment Polyominoes

Instructions: Cut out the cargo shapes along the lines. These shapes represent one of the six kinds of cargo that need to be packed for the Moon. (Refer to the Lunar Cargo Packing List worksheet.)



# Lunar Cargo: Building Equipment Polyominoes

Instructions: Cut out the cargo shapes along the lines. These shapes represent one of the six kinds of cargo that need to be packed for the Moon. (Refer to the Lunar Cargo Packing List worksheet.)