National Aeronautics and
Space Administration

NASA STEM FORWARD TO THE MOON

EDUCATORS GUIDE

ACKNOWLEDGEMENTS

The Moon 2024 Education Guide is published by NASA's Office of STEM Engagement to accompany the STEM Education segment of the Apollo Anniversary broadcast aired on NASA TV July 19, 2019. While it may be used in both formal and informal educational settings, the target audience for the chosen activities are middle school students in informal educational settings or families in the home setting.

The guide tells the story of NASA's plans to go forward to the Moon by the year 2024 through hands-on STEM activities. It is outlined to immerse students in the ideas, concepts and experiences that make mission planning, operations, exploration and sustainability on the Moon possible.

Many educators and specialized personnel have contributed to the content, revisions and packaging of this document. Their support is greatly appreciated.

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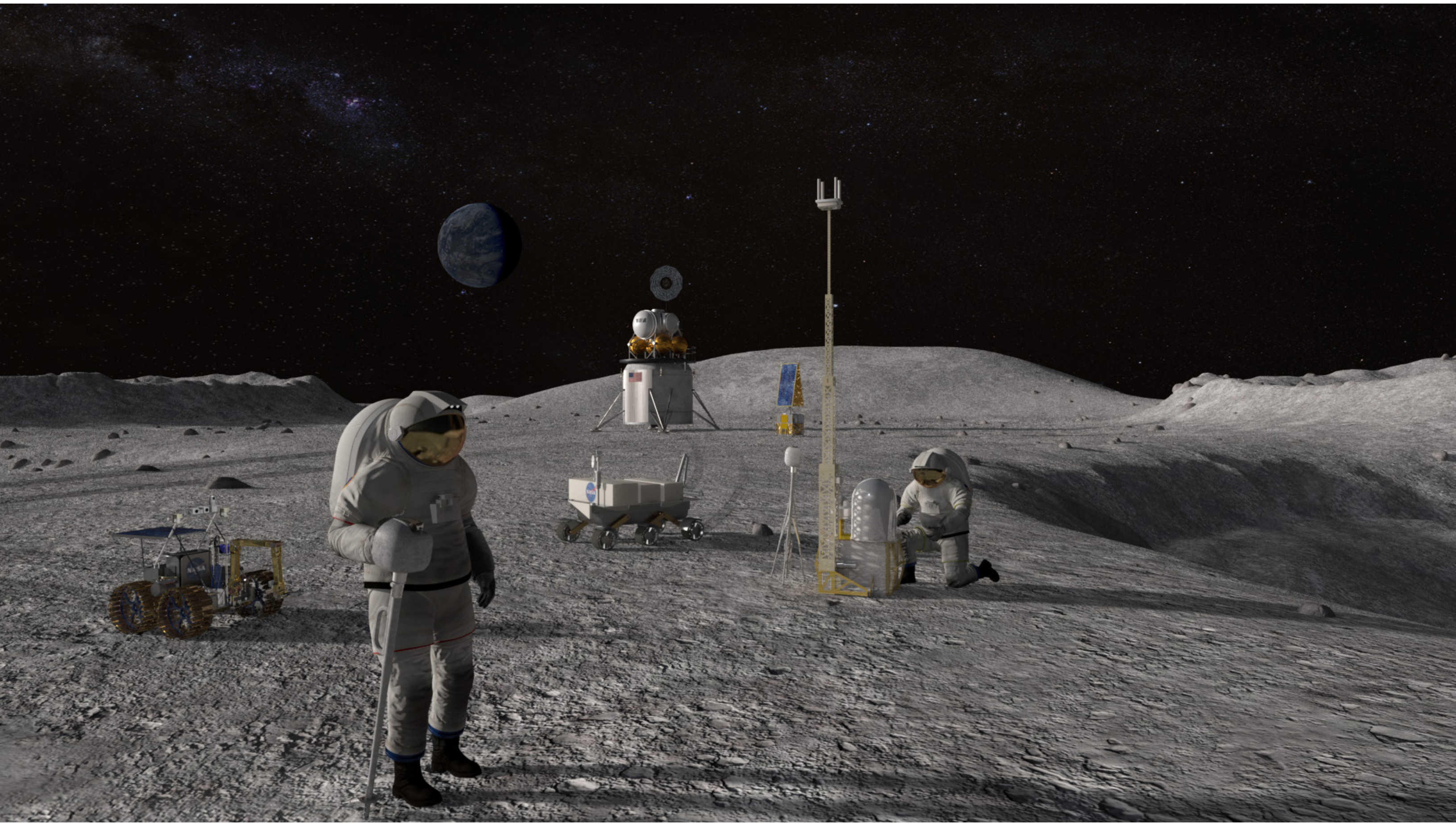
TABLE OF CONTENTS

OVERVIEW

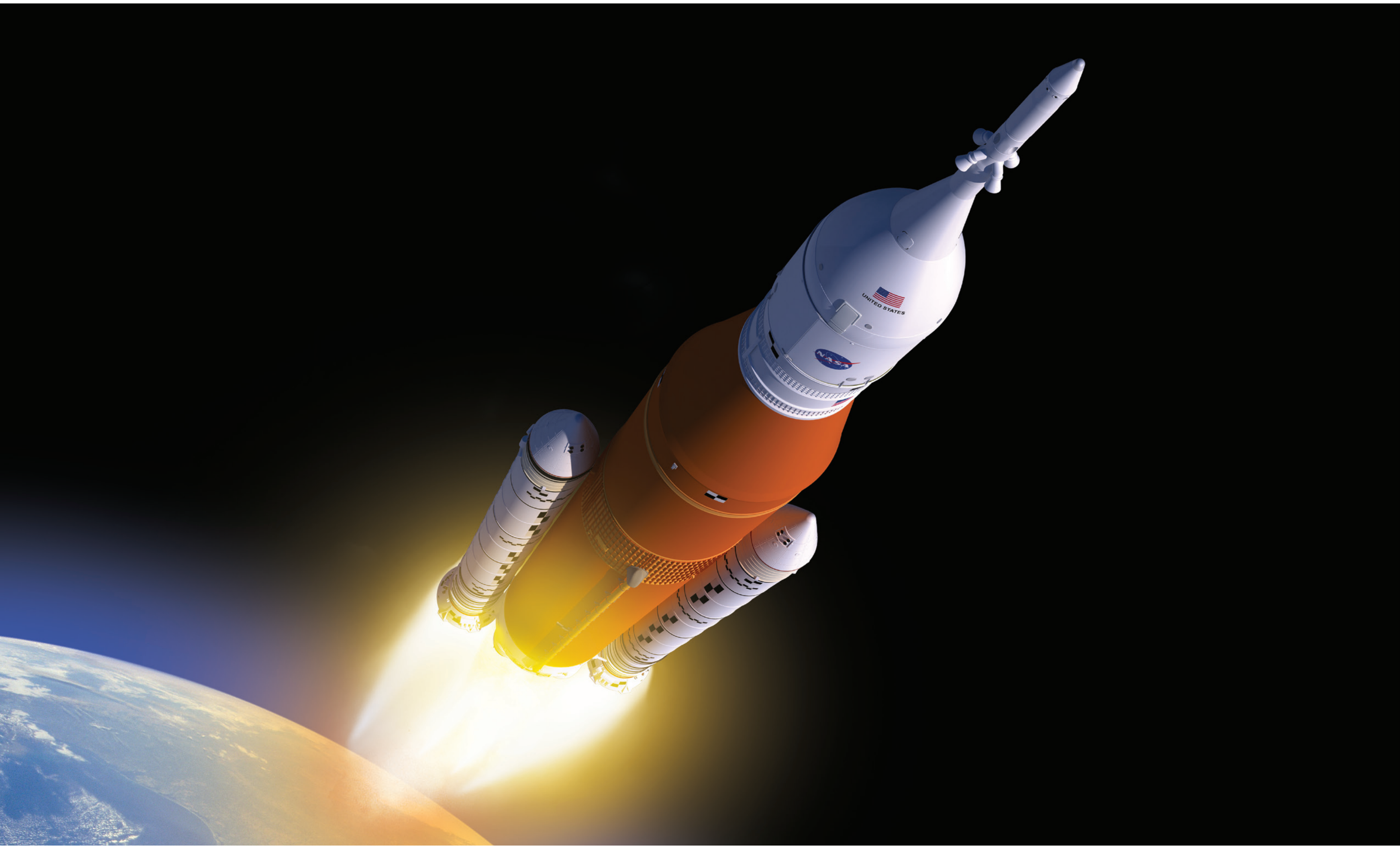
NASA has been given its most ambitious and challenging mission in half a century: to rapidly accelerate its human lunar program and land the first woman and the next man on the surface of the Moon in 2024. This program is named Artemis, after the Greek goddess of the Moon. Artemis is the twin of Apollo, the historic NASA program that first landed humankind on the Moon 50 years ago. Artemis will establish a long-term presence in lunar orbit and on the surface of the Moon. The goal of Artemis is continuous exploration of the lunar surface through a sustainable human presence on the Moon.

This is not an easy task. Even though some of the hardware, such as the Space Launch System (SLS) and Orion, have been in development and are nearing completion, there are several critical technologies, including spacesuits, Gateway modules and a lunar lander, that must be engineered, designed and built at a rapid pace. While NASA and its commercial partners are at work developing this hardware, you can participate as well. These activities simulate some of the same challenges faced by NASA astronauts, engineers, and scientists. It is your mission to solve these challenges throughout the lunar mission, from demonstrating the distance of the Moon from Earth, to launching a rocket and keeping astronauts healthy after landing on the Moon, We are counting on you!



LEAVING EARTH

Planning and preparing for a mission to the Moon can be quite the challenge. Do you know just how far away the Moon actually is? The 384,400 kilometer trip to the Moon will take three days each way! NASA's first mission to launch its Space Launch System (SLS) and Orion Crew Module to the Moon will be called Artemis 1 and it is scheduled for 2020. This will be an uncrewed mission to test the performance and critical systems of both the rocket and spacecraft. The first crewed launch, Artemis 2, will follow in 2022. The crew of Artemis 2 will travel in the Orion Crew Module around the Moon and become the first humans to leave low-Earth orbit since 1972. In 2024, Artemis 3 will travel to the Moon, carrying the first woman and next man to the lunar surface.



Related Videos:

SLS No Small Steps

Build and Launch a Foam Rocket

EARTH, ISS, MOON DEMONSTRATION

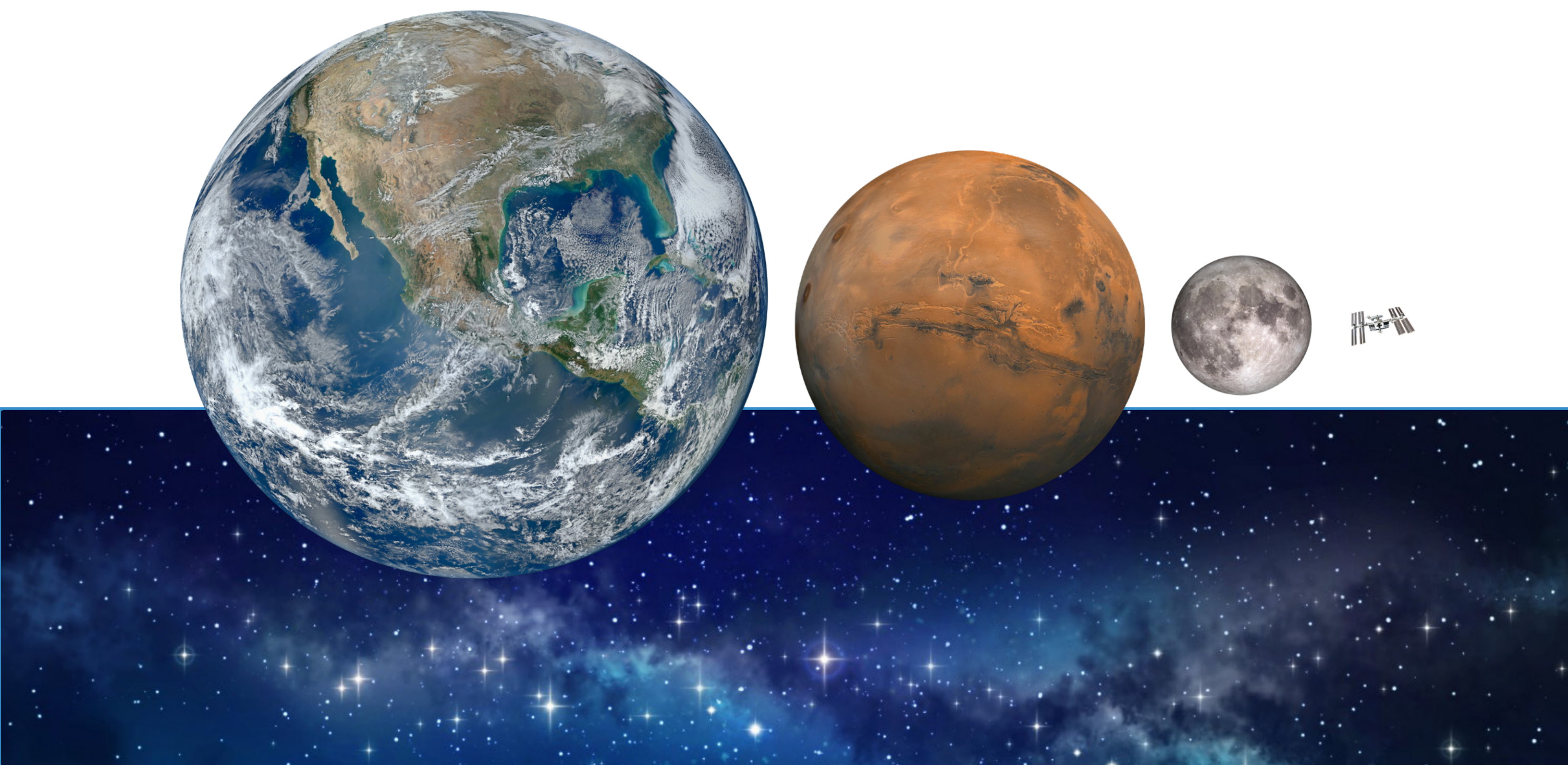
Objective

During this activity, you will:

- Learn about the relative sizes of the Earth, Moon and Mars.
- Understand the relative distances among Earth, Moon and Mars, and how distant deep space objects are

Materials

- Five or six people to perform the demonstration.
- A large ball, such as a basketball or small beach ball (to represent Earth).
- A medium ball, such as a softball or mini soccer ball, that is about half the size of the large ball (to represent Mars).
- A small ball, such as a tennis ball or baseball, that is about a fourth the diameter of the large ball (to represent the Moon).
- A tiny sphere, such as a bead or marble (to represent the ISS).
- A roll of string or long rope (about 10 meters).
- Large space (outdoors, hallway, gym, etc.).



Procedure

1. Begin by giving one person the large ball, and tell them that it represents the size of the Earth.
2. Give another person the small ball and tell them that it represents the size of the Moon on the same scale.
3. Ask the two people to move apart from each other until they think that the Earth and Moon are the correct distance apart. If there are others watching, such as an audience or class, ask for their input as well.
4. Have a third person wrap the string/rope around the large ball (Earth) 9.5 times.
5. Have the person holding the Earth hold one end of the string against the Earth and stretch the string toward the Moon to the distance measured in step 4. This is the correct distance from the Earth to the Moon (252,000 miles, or 9.5 times the Earth's circumference of 24,900 miles).
6. Have the person holding the Moon move to the correct place.
7. Now, give a fourth person the tiny sphere (that represents the ISS), and ask them to hold up the sphere at the distance from the Earth where they think that the International Space Station orbits the Earth.
8. After they make a guess, inform them that the ISS is in near-Earth orbit at an altitude of only 250 miles. At this scale, it would only be about 1/4 inch from the surface of the ball. Explain to everyone how close the objects in near-Earth orbit are compared to the distance to the Moon, and how it is substantially more difficult to send spacecraft all the way to the Moon than just putting them in orbit around Earth.
9. Finally, give the medium ball to another person and tell them that it represents Mars. Ask them to stand where they think would be the correct distance from Earth using the same scale.
10. Explain that it would be impossible in this demonstration, because at this scale, the person holding Mars would have to be almost 3 miles away, and that the average distance between Earth and Mars is about 140 million miles. It is very hard to get to Mars.

Conclusion

- What were the initial guesses for the distance between the Earth and the Moon? Where they too close? Where they too far apart? *Answers will vary.*
- Why is it so much more difficult to get to the Moon in a spacecraft than to get to the ISS? What about getting to Mars? *Fuel and time are the two biggest difficulties for deep space travel. It takes significantly more fuel to break free of Earth's gravity than just getting into orbit. Also, the time needed to reach deep space objects requires ships that can sustain humans for the entire trip. It takes less than 10 minutes to get into orbit, about 3 days to get to the Moon and about 9 months to get to Mars.*

Reference

Modified from STEM on Station: https://go.nasa.gov/1LyVi0J

HEAVY LIFTING

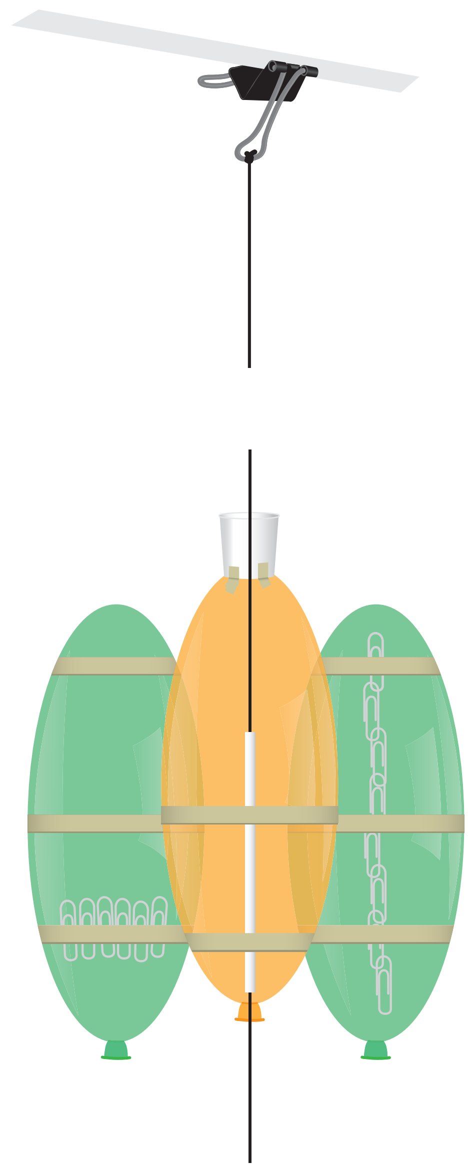
Objective

During this activity, you will:

- Construct balloon-powered rockets to launch the largest payload possible.

Materials

- Large binder clips (one per launch pad)
- Fishing line or smooth string
- Balloons (5-inch x 24-inch long balloons work best, but round balloons will work if long balloons are not available)
- Balloon hand pumps (optional)
- Bathroom size (3 oz.) cup
- 2 straight (non-bendable) drinking straws
- 50 small paper clips
- Sandwich-sized plastic bag
- Masking tape
- Wooden spring-type clothespins or small binder clips
- Printout of Heavy-Lift Rocket Mission Report



Procedure

Setup

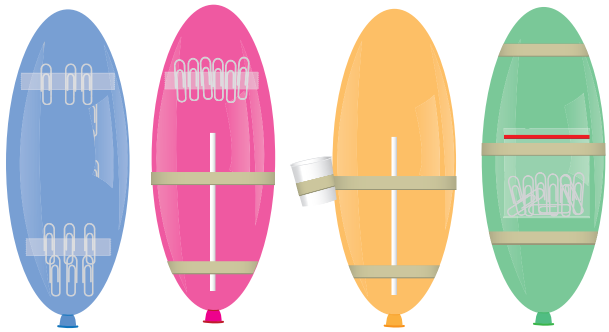
1. Have a parent or adult help you by attaching one end of the fishing line close to the ceiling using the large binder clip.
2. Assemble the materials that are available for the challenge. Try to only use materials that are available on the list.
3. If this is going to be a team challenge, give each team an identical supply of materials.

Launching

1. When it is time to launch, inflate your balloon, or balloons, and keep them from deflating by rolling the nozzles and securing them with a clothespin or small binder clip.
2. Thread the loose end of the fishing line through the guide straw on the rocket from the top.
3. Pull the fishing line tight enough so that there is no slack.
4. Perform a countdown and release all the clips on the balloon nozzles simultaneously.
5. A successful launch is one that reaches the ceiling (or highest point on the string) without spilling its payload.

Challenge

1. NASA is looking for creative ideas for launching heavy payloads into orbit. Payloads will be parts and supplies; large-aperture telescopes; and spacecraft that will carry humans to the Moon and Mars, and possibly transport large fuel tanks to be used to power deep space rockets. You are challenged to design and build a heavy-lift rocket from the set of materials provided. Your goal is build one as powerful as possible, capable of carrying the most payload (paperclips) as possible along. Your rocket will be guided on a string to keep it on its course. A successful launch requires your rocket to reach the end of the string without spilling any of its payload. Be sure to record your progress on the Heavy-Lift Rocket Mission Report.



Heavy-Lift Rocket Mission Report

Name:

Team Name:

Team Members:

Flight Test	Mass Lifted (g)
1	
2	
3	
4	
5	

Describe your rocket:

How did you change your rocket to make it carry more mass?

What other ways could you change your rocket to improve it?

Conclusion

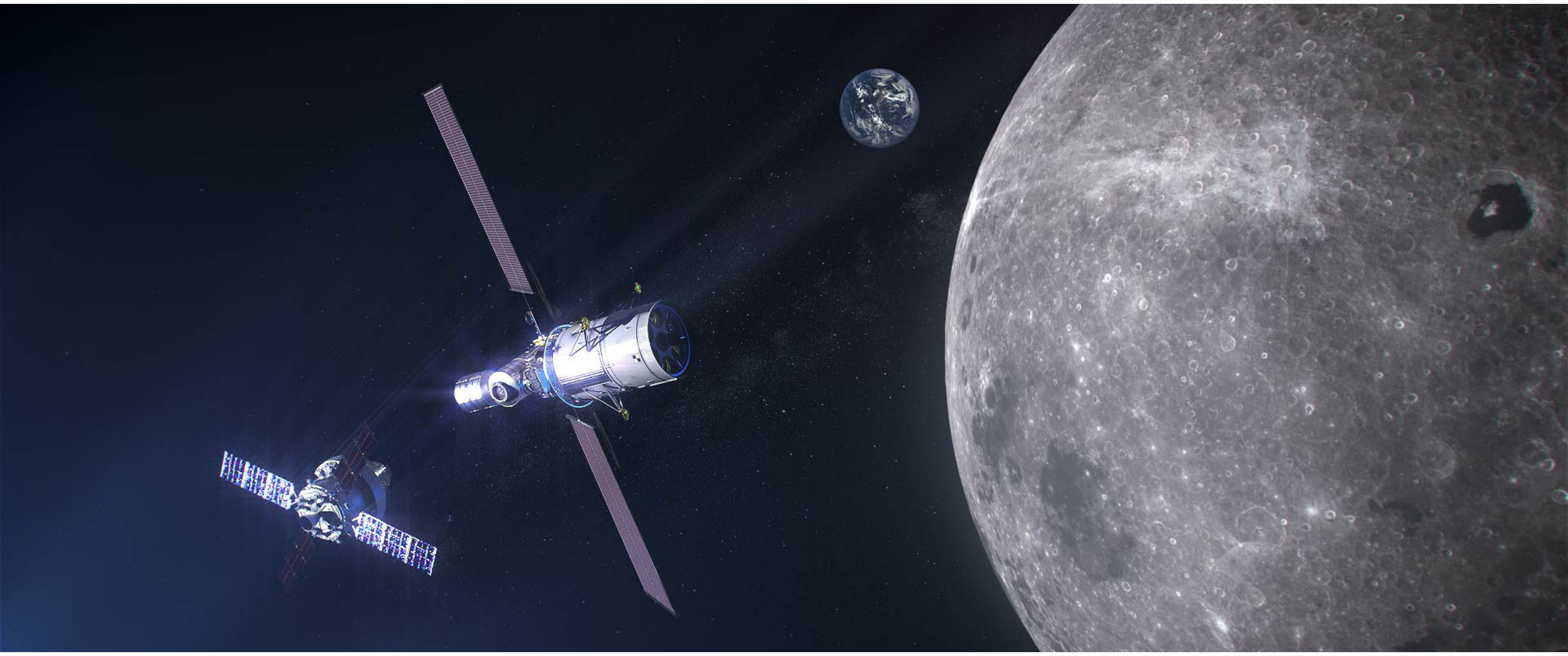
- When attaching the straw to help guide the rocket, why was it important to align it in the same direction as the balloon nozzle?
  The thrust of the rocket needs to be in line with its desired path of travel. Otherwise, thrust will be wasted fighting against the guide string.
- Was attaching a single extra balloon an effective strategy?
  Probably not. Unless the guide straw was placed directly between the two balloons, the thrust would be imbalanced and the rocket would fight against the string.
- How can the lessons learned in your design be applied to real-life heavy rocket launches?
  Modern heavy-lift rockets attach additional rockets, called boosters, to increase the rocket's payload capacity.

Reference

Modified from *Heavy Lifting*: https://go.nasa.gov/2XKTjnz

ORBITING THE MOON ON GATEWAY

It takes three days to go to the Moon from Earth. When astronauts head to the Moon, it will also be orbiting the Earth, and will no longer be in the same spot where they aimed. Instead, astronauts must travel in a trajectory where Orion, and the Moon arrive at the same place, at the same time. Astronauts will also use the Moon's gravity to help them get into its orbit so they don't miss the Moon and keep traveling into space. There, they will dock on NASA's Gateway, an orbiting spaceship near the Moon serving as an outpost and rest area for astronauts visiting the Moon and eventually Mars. Gateway's first phase will be there for Artemis 3's crew. It will have a power and propulsion module for energy and movement in orbit, a living space, supplies for visiting astronauts, and a lunar landing module to take astronauts to and from the Moon. Today, we can get supplies to the International Space Station (ISS) very quickly because it is much closer to Earth. With Gateway, NASA scientists have taken what they learned on ISS so astronauts can recycle water using a water filtration system to keep themselves healthy as they live and work in space.



Related Videos:

Exercise STEMonstration

Nutrition STEMonstration

Challenges of Spacewalking

INVISIBLE FORCE

Objective

In this activity, you will:

- Design a setup so that when a steel ball rolls past a magnet, it changes direction and hits a target that's off to the side.

Materials

Per team

(Invisible Force can be done alone, but works well with teams of two)

- Paper cup (6- to 8-ounce)
- Strip of index card (2.5 x 12.5 centimeters [1 x 5 inches])
- 30-centimeter (12-inch) length of flexible rope (e.g., clothesline)
- 1 steel ball (e.g., 60-millimeter [quarter-inch] ball bearing) *
- 1 strong magnet **
- 1 target (e.g., "X" of tape on the table or object to hit [e.g., a glass, coin, cup, etc.])
- Tape (any kind)

* Available at bike stores. Slingshot ammo from sporting-goods stores works, too. Bike stores sell the 60-millimeter (quarter-inch) ball bearings used in this activity. Slingshot ammo is 80 millimeters (5/16 inch) and is also an option. Balls larger than this build up so much momentum that they don't respond well to weak magnetic fields.

** Available at toy, dollar, craft and office supply stores. The best magnets for this activity are the silver three-inch-long oblong magnets sometimes called "cow" or "snake-egg" magnets. If you use disc magnets, kids may need to stack a few to produce a strong magnetic field.

Procedure

Challenge 1

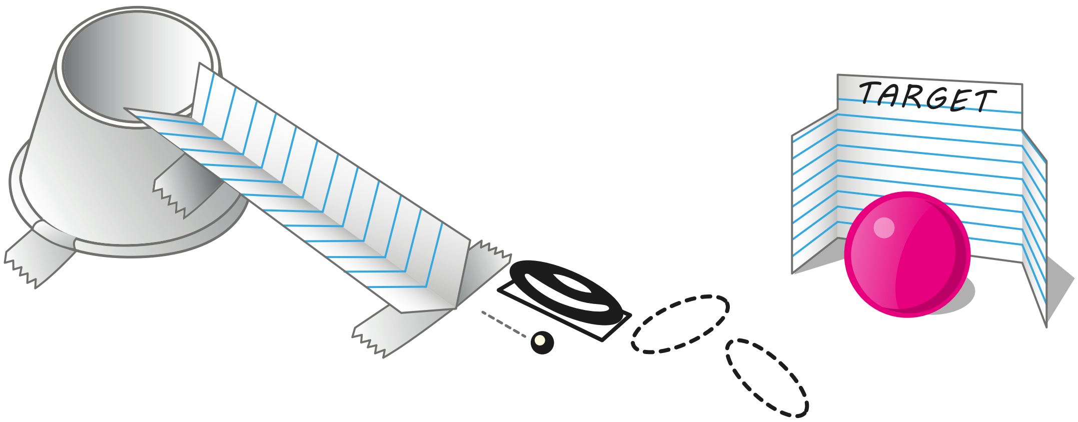
Roll a ball down a ramp and use a rope to guide it to a target that's set off to the side.

1. Brainstorm and Design
   a. How should you line up the rope with the end of the ramp so the rope can guide the ball?
2. Build and Test (**Note: Taping the ramp in place is very helpful for consistent results**.)
   a. You can change the ball's speed by launching from different places on the ramp.
3. Evaluate, Redesign and Retest
   a. What were the "wackiest" target positions that you could hit with your ball?

Challenge 2

Roll a ball down a ramp and use a magnet to guide it to a target that's set off to the side.

1. Brainstorm and Design.
    a. Where should you tape the magnet so the ball's path curves?
2. Build and Test a Model.
    a. Find the right speed and distance from the magnet so the ball curves over to the target.
3. Evaluate, Redesign and Retest.
    a. How extreme a turn can your ball make?
    b. How many times in a row can you get the ball to hit the target?



Conclusion

Emphasize key elements in this activity by asking:

1. Engineering: How did testing help you decide how to change to your setup? What changes would you make next time? *Answers will vary.*
2. Science: Why did your ball change direction? What did you have to do to get it to change direction? *The ball passed through a magnetic field. To change the path, the ball has to pass close enough to the magnet so the magnetic force affects the path of the ball.*
3. NASA: What part of the model represents the launch pad, spacecraft, gravity and the planet or Moon? Is the rope or magnet a better model of how spacecraft travel? *There are no physical guides in space, but there are invisible forces. The magnetic field is a stand-in for gravity.*
4. Extend the challenge:
    a. Sharpest turn. Which team can consistently achieve the largest change in direction of the launch path? Can anyone do better than a 90-degree bend?
    b. Which team can consistently hit the target?
    c. Go longer. Find a large, level area. Challenge teams to hit a target that is at least 30 centimeters (1 foot) away. Next, try 60 centimeters (2 feet) away.

Reference

https://go.nasa.gov/2XEKzil

CLEANING WATER

Objective

Following this activity, you will be able to:

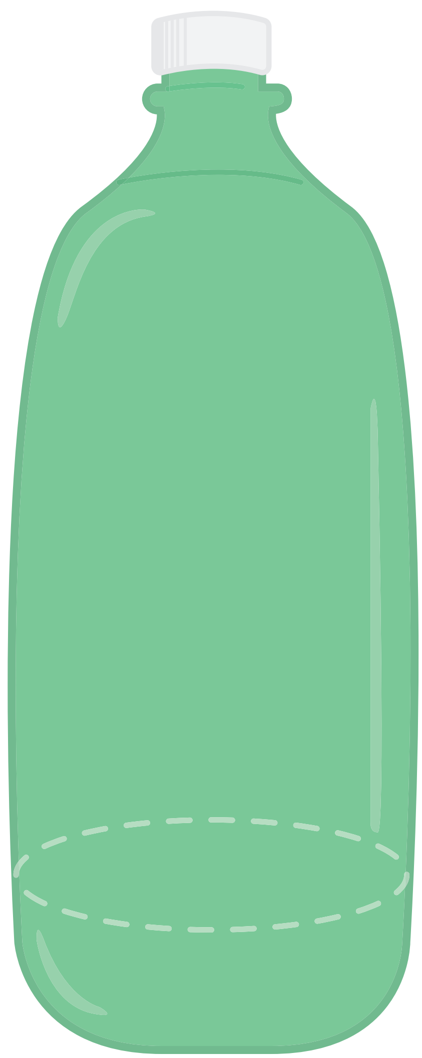
- Design and build your own water-filtration system.
- Collect data to compare water before and after filtration.
- Develop a conclusion based upon the results of this experiment.

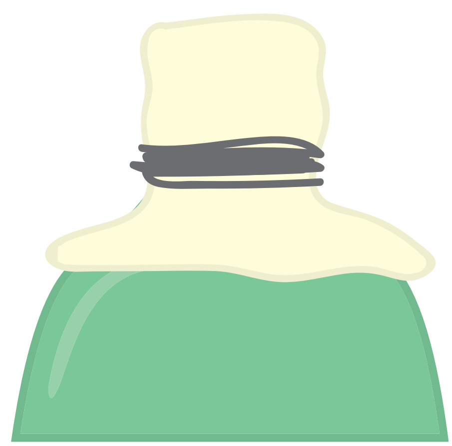
Materials

- Safety glasses
- 2-liter bottle with the bottom cut off and cheese cloth secured around the top
- 3 filtration materials (examples include: aquarium gravel, play sand, activated carbon, activated charcoal, marbles, cotton balls, coffee filters, packing materials)
- 5 litmus paper strips (Note: If you are unable to locate litmus paper, search for an alternate pH detection system using red cabbage)
- 1 metric ruler
- 3 large, clear plastic cups with a hole punched just below the rim
- 3 paper plates
- 1 metric liquid measuring cup
- 500 ml of clean water
- 500 ml of gray water (1 part Italian salad dressing to 5 parts water, shaken, in a large, clean container)

Punch hole near the top of cup.

Cut off bottom of the bottle, just above the curve of the bottle.

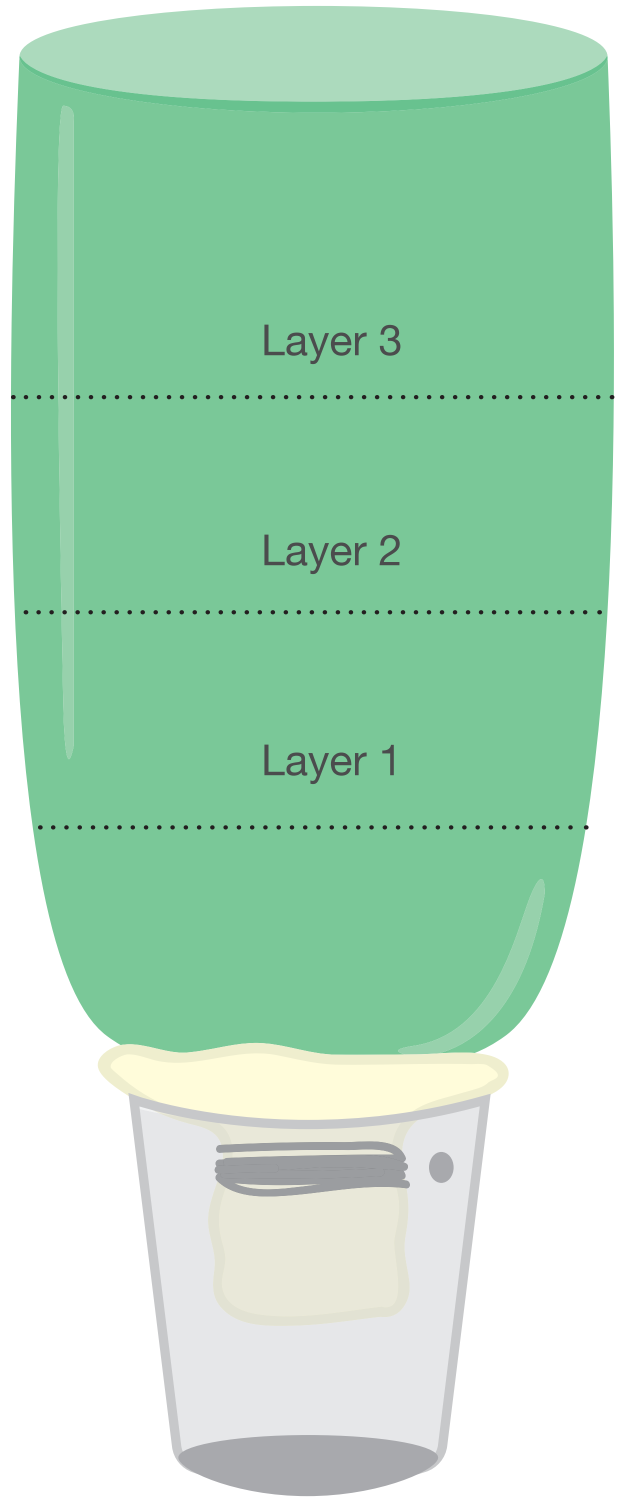




Cover the mouth of the bottle with at least 10 layers of cheesecloth and secure the lid.

Procedure

1. Put on your safety glasses.
2. Watch the STEMonstration: Water Filtration video on YouTube.
3. Place a bottle upside down with its mouth over the clear plastic cup to catch the filtered water.
4. Choose three of the filtration materials listed above.
5. Gather your filtration materials on the paper plates, with one on each plate. Decide the order in which to layer your materials.
6. Fill the bottle with the first filtering material to a depth of 5 to 8 centimeters (cm). Note: Coffee filters and cotton balls will need to be packed down.
7. Place the second filtering material to a depth of 5 to 8 cm on top of the first one.
8. Place the third filtering material to a depth of 5 to 8 cm on top of the second filtering material.
9. Obtain 350 ml of clean water. Observe the properties of the water before you filter it by using the wafting technique to smell the water. Measure the pH of the water with litmus paper and compare it to the pH color chart below.
10. Collect data and record your observations on the Cleaning Water Data Sheet below. Remember the smelling rules in the science lab and do not taste.Run clean water through your water-filtering system to make sure it will allow water to flow through.
11. Once the clean water has gone through the water-filtering system, replace the clear plastic cup with a new one. If the water is sandy, it should be disposed of outside. Otherwise, it can be disposed of in the sink.
12. Get 350 ml of gray water. Observe the properties of the water before you filter it. Check the odor of the water. Measure the pH of the water with litmus paper and compare it to the pH color chart. Collect data and record your observations on the Cleaning Water Data Sheet.
13. Run the gray water through your water filtering system. Observe the properties of the water after it has been filtered once and record your observations on the data sheet. Measure the pH of the water with litmus paper and compare it to the pH color chart. Collect data and record your observations on the Cleaning Water Data Sheet.
14. Replace the clear plastic cup with a new one. Pour the filtered water back into the water-filtering system.
15. Filter the water again. While the gray water is running through the water-filtering system, reflect on what each layer in your filtration system did to the water.



16. Observe the properties of the water after it has been filtered for the second time. Check the odor of the water. Measure the pH of the water with litmus paper and compare it to the pH color chart. Collect data and record your observations on the Cleaning Water Data Sheet.

pH COLOR CHART

Acid						Neutral	Base						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Red Violet	Red	Red Orange	Dark Orange	Orange	Orange Yellow	Peach	Yellow	Yellow Green	Green	Dark Green	Green Blue	Blue	Violet

Properties	Clean Water	Gray Water Before Filtering	After 1st Filtering	After 2nd Filtering
Odor				
Appearance				
pH				

Conclusion

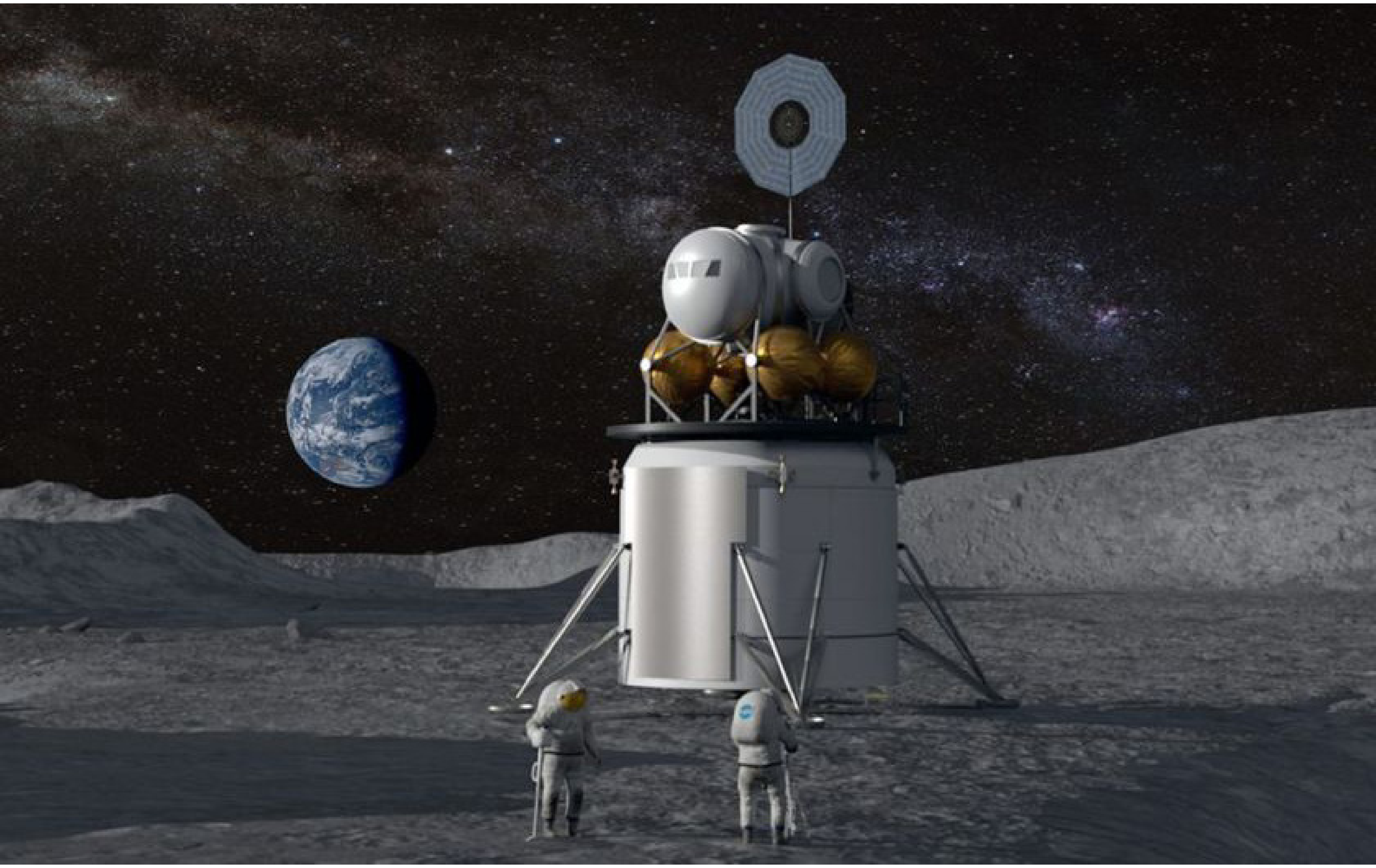
- What happened to the water as it passed through the different layers of the filter? *Some of the contaminants were absorbed by or stuck to the different filter materials, and the water returned to its original clear form.*
- What changes occurred to the properties of the gray water as it was filtered (pH, appearance, odor)? *The gray water lost the gray color and odor after processing through the filtration system. The smell became fainter.*
- Compare your filtered water to the clean water. Did your gray water become "clean?" What properties told you it was or was not "clean?" *Yes, the pH value (varies) was an indicator of the cleanliness of the water.*
- Does this data support your hypothesis? Why or why not? *Answers may vary.*
- If you could build a water-filtering system by using any of the materials available in the class, which three materials would you use, and in what order would you layer them? Why? *Answers may vary. Examples of efficient materials include activated carbon/charcoal and sand.*
- Based on your findings, what would you suggest to NASA scientists and engineers designing filtration systems and water-recycling methods? *Answers may vary.*

Reference

Modified from Cleaning Water Activity: https://go.nasa.gov/30w2s53

LANDING ON THE MOON

Artemis' goal is to land American astronauts on the Moon's South Pole. Later missions will add more aspects to the landing site as steppingstones towards sustainable deep space exploration. The Moon's South Pole is the landing site because of the water ice discovered in the region. Using water as a resource can help create clean air to breathe, clean water for humans and plants, and even hydrogen for rocket fuel. These sustainable resources will lead to permanently crewed bases on the lunar surface, where more exploration and research can take place. Sustainability will allow astronauts to stay for longer periods of time, possibly for a future, permanent presence on a lunar base.



Related Videos:

Houston We Have a Podcast: Space Habitats

We Are Going

HABITAT PLANNING

Objective

During this activity, you will:

- Discuss the basic needs for a permanent habitat on the Moon's surface.
- Discuss possible daily activities that lunar astronauts would do.
- Create a plan for a lunar habitat.

Materials

- Moonquakes article (following pages)
- Paper
- Large drawing paper
- Colored pencils

Procedure

1. Read the article "Moonquakes: NASA Astronauts May Need Quake-Proof Housing"
2. Discuss what kinds of work astronauts might be doing on the Moon, and make a list of the most likely activities.
3. Discuss what you do to relax, and make a list of activities that you think astronauts on the moon might do.
4. Discuss and list things that would be needed to keep astronauts healthy, and alive, on a day-to-day basis.
5. List needed resources for waste management and recycling.
6. Think about, or walk around your house, considering all of the rooms and thinking about what is done in them.
7. Go through your lists and identify the type of room that each activity would use. Add any extra rooms that would be needed and are not part of a normal house.
8. On a large sheet of paper, draw a rectangle that is 20 in. x 24 in. This represents the area of your lunar habitat. Use a ruler to help you draw rooms and buildings. Consider:
9. How much space is needed for each of your requirements?
10. Can any of the spaces serve two purposes?
11. Include a space (8 in. x 8 in.) to house plants or animals that may be needed to provide food.

Conclusion

- Were there any spaces that share activities? Why did you combine those activities? *Answers will vary, but might include options such as cooking and health because they both need water, or recreation and sleep, as the room could change purpose at night.*
- Were there any rooms that needed water supplied to them? If yes, did you put those rooms close together to minimize pipes needed? *Water is needed for kitchen, bathrooms and health area at a minimum.*
- Would an astronaut who is not feeling well be able to rest while the others were working? *Answer will depend on their design.*

Reference

Modified from Field Trip to the Moon LRO/LCROSS ed. Informal Educator's Guide: https://go.nasa.gov/2I2Kzv5

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 geo-logical sciences at the University of Notre Dame, after he and a team of 15 other planetary scien-tists 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.

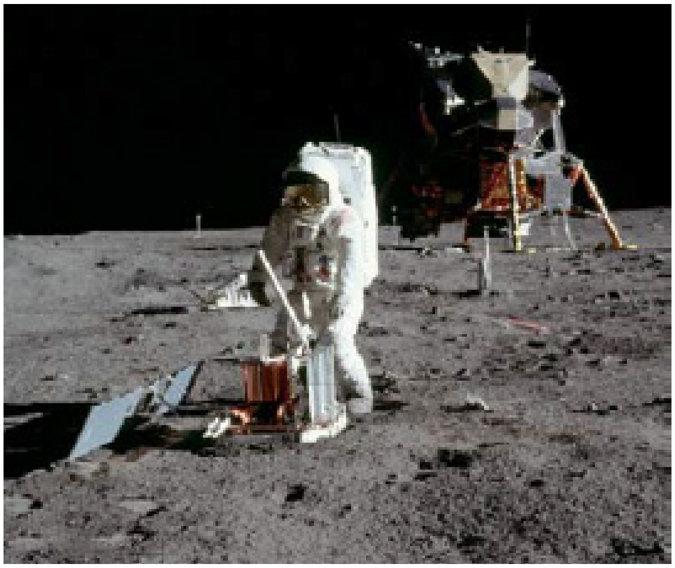
And what did they reveal?

There are at least four different kinds of moon-quakes: (1) deep moonquakes about 700 km be-low the surface, probably caused by tides; (2) vi-brations 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 seis-mic network saw 28 of them; a few "registered up to 5.5 on the Richter scale," says Neal. A magni-tude 5 quake on Earth is energetic enough to move heavy furniture and crack plaster.

Furthermore, shallow moonquakes lasted a remark-ably 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 weak-ens stone, expanding the structure of different min-erals. When energy propagates across such a com-pressible structure, it acts like a foam sponge—it deadens the vibrations." Even the biggest earth-quakes stop shaking in less than two minutes.



Buzz Aldrin deploys a seismometer in the Sea of Tranquillity.

The Moon, however, is dry, cool and mostly rigid, like a chunk of stone or iron. So moonquakes set "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 fa-tigue threshold of building materials," that is, how much repeated bending and shaking they could withstand. 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.

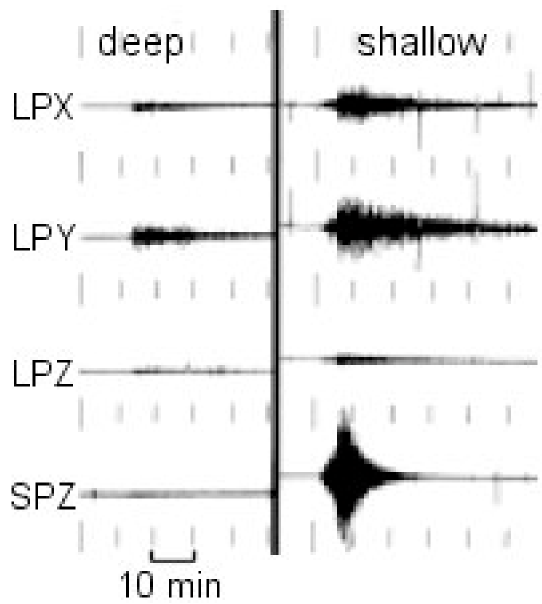
What causes the shallow moonquakes? And where do they occur? "We're not sure," he says. "The Apollo seismometers were all in one relatively small region on the front side of the Moon, so we can't pinpoint [the exact locations of these quakes]." He and his colleagues do have some good ideas, among them 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 candi-date 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 propos-al 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 perma-nent lunar bases.

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

MOONQUAKES



Representative lunar seismograms from the Apollo 16 station.

MOON MINING

Objective

During this activity, you will:

- Simulate the search for ilmenite for its oxygen from the surface of the Moon. The mineral ilmenite is Iron Titanium Oxide.
- Simulate mining and processing of the ilmenite.
- Discuss the need for ice mining by future lunar astronauts.

Materials

- 1 divided, disposable plate Moon prepared before activity (see step 1)
- 1 - 8.5 in. x 11 in. red transparency (red plastic wrap will work)
- 1 - 8.5 in. x 11 in. blue transparency (blue plastic wrap will work)
- 1 quart-sized freezer, zipper-sealed bag
- 1 spoon
- Centimeter ruler
- Stopwatch, watch or clock
- Safety glasses
- Graph paper

Procedure

1. Prepare the disposable plate Moon (at least one day before).
2. Crush three effervescent tablets and mix with enough crushed ice to fill in one section of a white, divided disposable plate. Work quickly so that the ice does not melt and activate the effervescent tablet.
3. Place only crushed ice into the other sections of the white, divided disposable plate.
4. Prepare and freeze one disposable plate per group.
5. Keep cold until students are ready to conduct the test procedure. (This will ensure that the ice does not melt and activate the effervescent tablet.)
6. Put on your safety glasses.
7. Observe your disposable plate Moon with your partner.
8. Draw a line to divide the graph paper in half. Sketch your disposable plate Moon on one half of the graph paper. Label your drawing. Title the drawing “Before Mining.”
9. Place red transparency on half of the plate, and blue transparency on the other half.
10. Look for ilmenite (effervescent tablets) by moving the transparencies around the plate. What color can you see the ilmenite through? What color hid the ilmenite? NASA researchers use colors to locate certain items on the surface of other bodies. This is called “spectroscopically,” locating the ilmenite.
11. When the ilmenite is located, extract the section it is in from the disposable plate (take it off of the plate with the spoon) and place it into the zipper-sealed bag. Zip the bag, making sure all air is locked outside the bag.
12. Place the bag in a sunny location. This represents the solar energy that may be used to power the machinery that extracts the oxygen from the ilmenite.
13. Evenly flatten out the contents of the bag by pushing it down with your palms. This will allow you to see the profile, or side, of the bag.
14. Observe the bag. Sketch what it looks like on your Moon Mining Data Sheet.
15. Measure from the tabletop to the top of the bag, using the profile, or side, of the bag. Record data on your Moon Mining Data Sheet at zero minutes.
16. Predict how the bag will change over time, and record your prediction on your Moon Mining Data Sheet.

17. Guess what is inside the bag. Record on your Moon Mining Data Sheet.
18. Every 3 minutes for the next 12 minutes, repeat steps 9 to 12. Do not disturb the ilmenite sample.
19. Discuss what you see happening to your zipper-sealed bag with your group. Why is the ice melting?

<table>
<tr><th></th><th>0 minutes</th><th colspan="2">3 minutes</th><th colspan="2">6 minutes</th><th colspan="2">9 minutes</th><th colspan="2">12 minutes</th></tr>
<tr><td>Sketch an outline of the bag profile</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Measure in cm from table to top of bag (laying flat)</td><td></td><td>PREDICT</td><td>ACTUAL</td><td>PREDICT</td><td>ACTUAL</td><td>PREDICT</td><td>ACTUAL</td><td>PREDICT</td><td>ACTUAL</td></tr>
<tr><td>What do you think is inside the bag?</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Other observations</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
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1. Sketch your disposable plate moon on the other half of the graph paper. Make sure you label where the ilmenite was found. Label your drawing. Title your drawing “After Mining.” What are these deep places on the moon called?
2. After taking all measurements, study the data and draw conclusions by answering the questions following the Moon Mining Data Sheet.

Conclusion:

- What do you think the ilmenite is doing in the bag as it is warmed to room temperature by solar energy? *It is giving off gas (simulated oxygen).*
- What do we need in order to mine ilmenite from the surface of the Moon? *Answers will vary, but should include energy and tools at a minimum.*
- Where is ilmenite found on the Moon? *Ilmenite is found all over the Moon, mostly in craters.*
- How do we locate ilmenite on the Moon? *It is found using color or other sensors.*
- Why would astronauts need to mine ice from the deep craters at the poles of the Moon? *Ice may be melted for water for many uses, including drinking, washing, medical and, if separated into parts, rocket fuel.*

Reference

Modified from NASA’s Moon Mining Activity from the 21st Century Explorer series: https://go.nasa.gov/2l2KB6b

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