Exploring the EARTH-MOON SYSTEM

Learning Guide

Poster by Gregg Maryniak and Dennis Smith
Activities by Gregg Maryniak and Jennifer Boxer,
Illustrated by Dennis Smith
Cover Design by Dennis Smith

www.googlelunarxprize.org

Google LUNAR X PRIZE

An international competition with $30 million in prize funding for private teams of scientists and engineers who land a vehicle on the Moon that can drive over the lunar surface and send pictures to the world

What challenges will the Google Lunar X PRIZE Teams Face?

Soft Landing on the Moon. To date only the Soviet Union and the United States have soft landed vehicles on the moon.
Organization and Finance. Teams need to raise private funding for their missions -- a task arguably as difficult as the technical challenges.
Communications. Teams are required to transmit information, pictures and video to enable people around the world to participate in the mission via the Internet.
Environment. Lunar temperatures range from 253˚ Fahrenheit (123˚ Celsius) at noon down to –387˚ F (–233˚ C) at midnight. Lunar days and nights are each 14 Earth days long.

What is the X PRIZE?

In 1996 when the first X PRIZE was announced, nearly everyone thought that only governments could conduct human spaceflight. The X PRIZE Foundation and a group of courageous leaders from St. Louis challenged the world to change the way we think about space flight. On October 4, 2004, SpaceShipOne won the Ansari X PRIZE when Brian Binnie piloted it to an altitude of more than 367,000 feet, its second suborbital space flight in 5 days. These flights launched a new *personal spaceflight* revolution which holds the promise of dramatically altering the economics of human spaceflight.

Photo credit Jim Campbell

In 2006, a second X PRIZE was launched, the Archon X PRIZE for Genomics, (**http://genomics.xprize.org/**) for rapid, low-cost decoding of the human genome which will bring about a new era of personalized medicine.

Today, the Google Lunar X PRIZE challenges private enterprise to reach to the Moon -- 10 times beyond the current frontier of commercial space activity -- to lower the cost of space exploration and increase the number of explorers. For additional information, including X PRIZE guidelines, visit **www.xprize.org.**

How are Science Centers and Museums Involved?

The Saint Louis Science Center and the international *Science Beyond the Boundaries* network are the Education Partners of the X PRIZE. Our educational programs connect more than 18 million science center visitors with the advancing frontiers of science. There are no costs associated with membership in the network.
For further information or to join the network email **jboxer@slsc.org**.

SCIENCE BEYOND the BOUNDARIES a program of the Saint Louis Science Center

Welcome to the Earth-Moon System, Our Neighborhood in Space

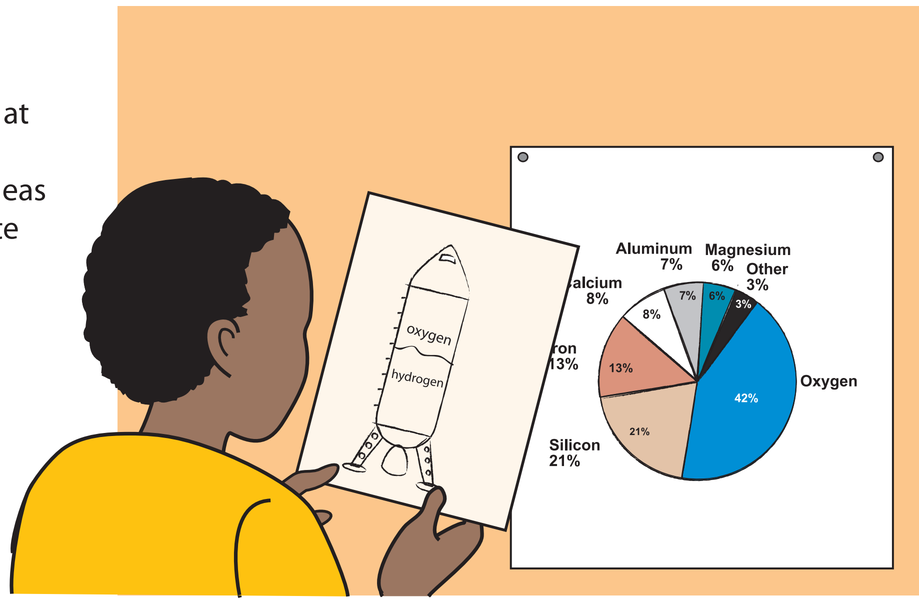
Educator's Introduction

Activities.

It is our pleasure to share some of our favorite space science activities in conjunction with the launch of the new Google Lunar X PRIZE. This Educator's Guide includes activities for all ages. We have recommended grade levels that have worked well for us, but, of course, every group is different so feel free to adapt to meet your students' needs. Many of the activities that work well with younger students are just as enjoyable for adults! The language in the activities is addressed to the student, so that you can photocopy and distribute a panel directly to your class. You can use the activities as a take-home family assignment or divide students in groups and have them present to the class. Supplies are inexpensive and easy to find. Activity Answer Sheets, when needed, can be found at the end of this Guide.

Poster.

This guide is accompanied by the Earth-Moon System poster which can be found at **http://www.googlelunarxprize.org /education/poster** and suggests more ideas for your classroom. Feel free to incorporate the poster into your science curriculum however you see fit.



Lunar Bibliography.

Please visit **http://www.googlelunarxprize.org/education/bibliography-and-resources** to find many excellent books, resources and additional lesson plans.

Visit http://**www.xprize.org**/ for the latest news on the progress of the competitors for this and other X PRIZES.

Ready for launch? We hope you enjoy your lunar voyage!

Why Explore the Moon?

Educator’s Background
by Gregg Maryniak, Director, J.S. McDonnell Planetarium, Saint Louis Science Center

We live in a unique two-world environment -- the Earth-Moon System. Earth’s offshore island, the Moon, is a stepping stone to the rest of the Solar System and a source of solutions to some of the most pressing environmental problems that we face on the Earth.

The Moon is the closest source of materials for doing anything in space. Right now we have to bring every single bit of material that we need for space operations at great expense from the bottom of the Earth’s deep gravity well. It’s 22 times easier to launch from the Moon than from the Earth. The lack of an atmosphere on the Moon also makes it possible to launch materials using electric motors rather than expensive rockets.

The Moon is more than 40% oxygen by weight. Oxygen is the main component of rocket propellant. Much of the rest of lunar soil is silicon (useful for making solar cells) and metals like aluminum and iron.

Clean solar energy can be sent from space to the Earth using solar collectors in high Earth orbit made from lunar materials. A single solar power satellite could power an Earth city without carbon dioxide or other pollution. Since these systems provide power at night, satellites could charge electric cars or generate hydrogen from water during off-peak times.

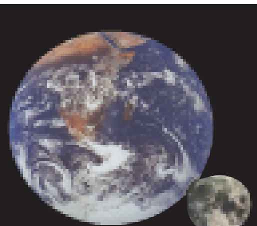
The Moon is so close to the Earth (1.3 seconds for radio or light) that people can directly control lunar robots and other machines from Earth.

Once lunar materials are available for construction in space, we can overcome many of the limits to space exploration that we currently take for granted. We can shield astronauts from cosmic and solar radiation. We can use beamed power to enable fast transportation in the solar system. We can build large telescopes and other astronomical tools to learn much more about the universe and how it came to be.

In addition to using lunar materials to build solar-powered satellites, we can collect energy on the Moon’s surface and transmit it to the Earth.

Thinkers such as Stephen Hawking, Carl Sagan, Konstantine Tsiolkovsky and Gerard K. O’Neill have suggested that it would be wise to spread humanity beyond the confines of our home planet in order to guarantee the preservation of our species. Space habitats constructed from material already in space (such as lunar or asteroid resources) can enable the near-term humanization of the solar system.

By expanding the solution set to include resources outside the Earth’s biosphere, we can solve seemingly intractable problems of energy and the environment and repair the Earth.



Why Explore the Moon? **To Save the Earth.**

www.googlelunarxprize.org

1. MOON PIES

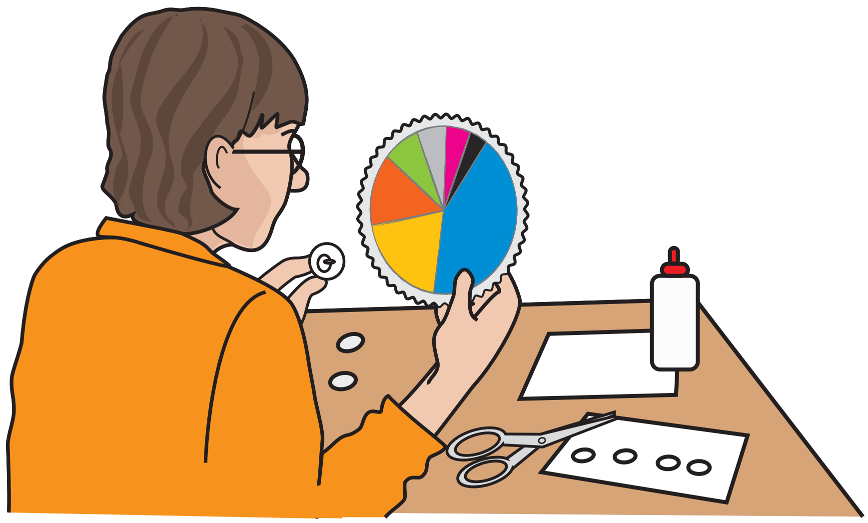
Target Age Group: Elementary

Objective: Students will understand some of the uses for elements found on the Moon.

You will need:

paper plates, photocopy of black line master on the next page, scissors, glue, marking pens, drawing paper

What to do:



1. What is the Moon made of? Use the line drawing on the next page to find out. First, make a copy of the drawing so that you can cut out the big circle and small circles.
2. Now glue the big circle onto a paper plate. Color each different pie shape a different color. The pie pieces represent how much of each element is found on the Moon.
3. Next match the small circles you cut out with the ones on the Moon Pie. Glue them in place. The small circles represent the things we can make from the elements found on the Moon.
4. Draw a picture of a person working on the Moon, building something you learned about on your Moon Pie.

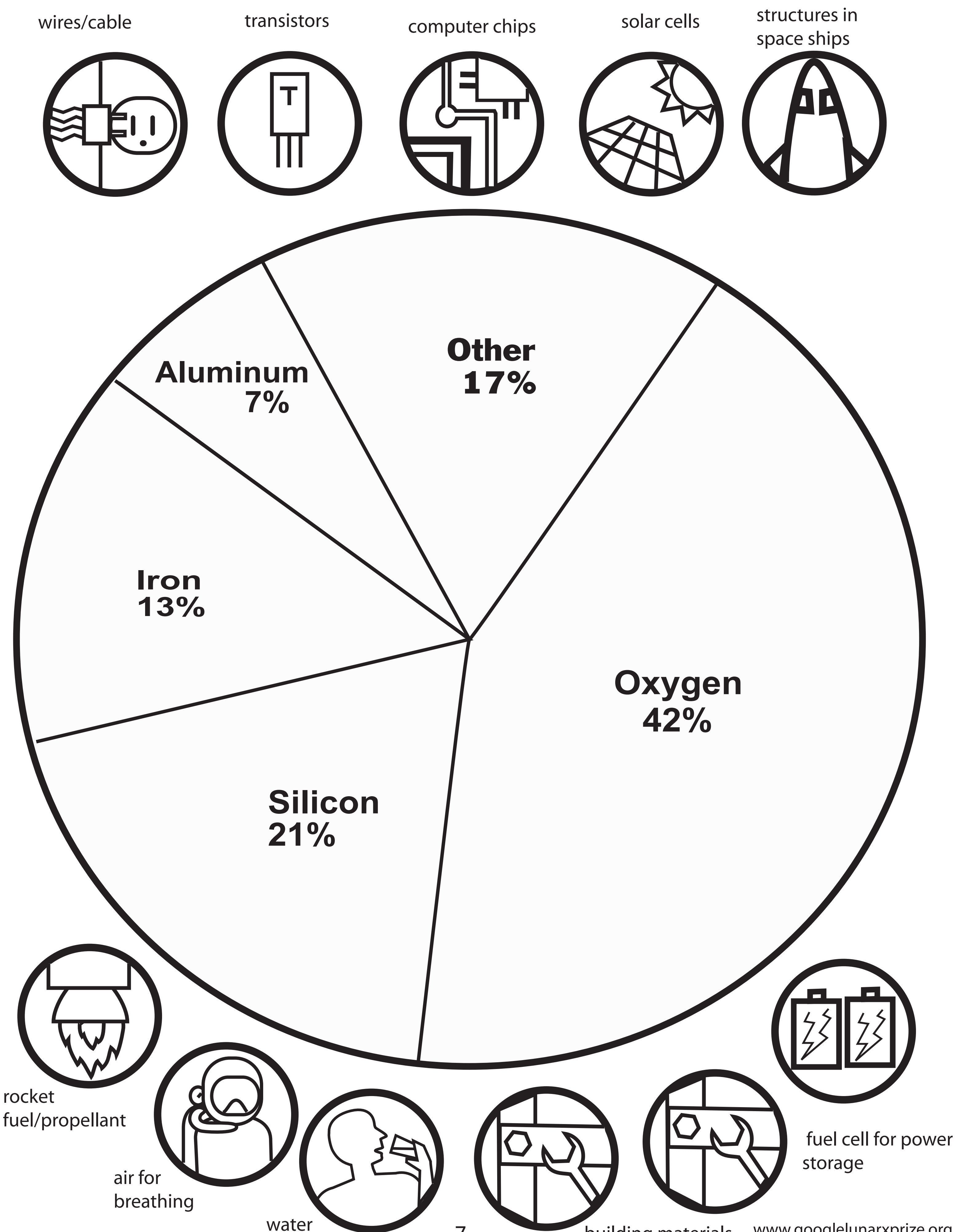
5 Next time you make a pizza, ask an adult if you can put the toppings on to make it look like your Moon Pie. Maybe pepperoni could be the oxygen and mushrooms could be silicon, etc. During dinner you can talk about all you know about the Moon and impress everyone, but remember not to talk with your mouth full.

What's Going On?

The Moon is an excellent source of materials for making things in space. The pie shapes represent that the Moon is 42% oxygen, 21% silicon, 13% iron and 7% aluminum. The symbols represent the uses for those elements. Oxygen can be used for rocket propellant, people breathing, making water, and fuel cells/power storage chemicals. Silicon can be used for solar cells, power control transistors and computer chips. Iron can be used for structural materials. Aluminum can be used for wires and cable, habitat construction or space ship structures. The above activity can be adapted into a Bingo game! It can also be done as a group activity where different students focus on different elements, so that one group would work on oxygen, another on silicon, etc.

See the video ***Earth's Offshore Island: The Moon*** at

http://www.googlelunarxprize.org/education/videos-and-demonstrations


wires/cable
transistors
computer chips
solar cells
structures in space ships
Other 17%
Aluminum 7%
Iron 13%
Oxygen 42%
Silicon 21%
rocket fuel/propellant
air for breathing
water
building materials
fuel cell for power storage

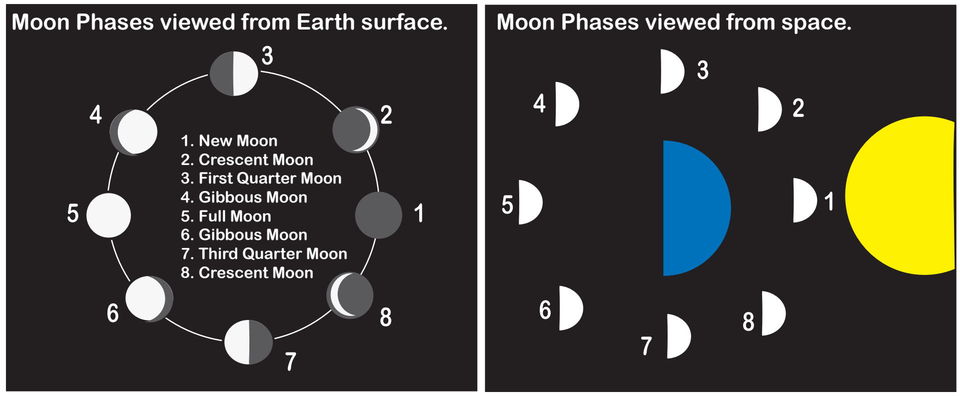
2. COOKIES AND MILK

Target Age Group: Elementary

Objective: Students will understand why the Moon appears to be a different shape on different nights.

You will need:
5 sandwich cookies,
paper plate,
orange, apple, an adult,
milk optional

Phases of the Moon



What to do:

1. Wash your hands. Ask an adult for 5 sandwich cookies. Say "please" and make sure you have just eaten a healthy meal before you ask. If the answer is something like "That's an awful lot of cookies," explain that it is for an important science project and invite him or her to join in.
2. Study the "Phases of the Moon" drawing on this page. If you take the tops off the cookies, can you duplicate those shapes?
3. Now ask the adult for an orange and an apple. (This will probably be easier than asking for the cookies.) Make an arrangement on the table with the orange as the Sun and the apple as the Earth. The orange and the apple represent the positions of the Sun and Earth, but not their relative sizes; they are not to scale. One at a time, position the Moon cookies between the Earth and the Sun to show the phases.
4. Where does the Sun need to be for you to see a full Moon on Earth?
5. When you are done with your activity, enjoy cookies and milk while reading ***Moon Cake*** by Frank Asch or ***If You Decide to Go to the Moon*** by Faith McNulty.

What's Going On?

As the Moon orbits the Earth, sunlight is reflected off different parts of the Moon. The part of the Moon where the sunlight is reflected is the part we can see. So, for a full Moon, your cookie would need to be positioned so that the Sun (orange) can shine on it and it can be fully seen from the Earth (apple). The orange and the apple represent the positions of the Sun and Earth, but not their relative sizes; they are not to scale. For a more advanced Moon Phases activity, use a Styrofoam ball to represent the Moon, sticking a pencil in it to make it easy to hold. Form a circle of friends around a floor lamp with a bright bulb and no shade – the Sun. Move the Moon ball around you and observe how the light falls on the ball in different patterns depending on your – the Earth's – position.

To learn more about the phases of the Moon, visit
http://sunshine.chpc.utah.edu/labs/moon/lunar_phases_main.html.

3. CARRY-ON LUGGAGE

Target Age Group: Elementary

Objective: Students will understand the difference in gravity and weight on the Earth and Moon

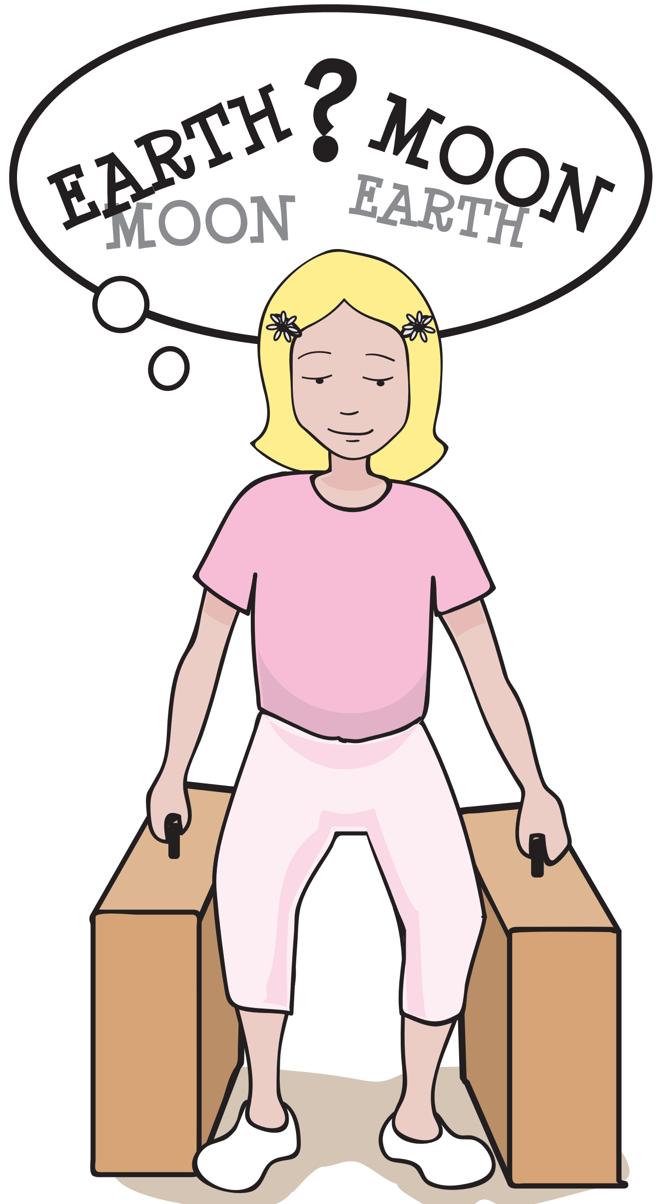
See the Demo at:
http://www.googlelunarxprize.org/education/videos-and-demonstrations

You will need:

2 suitcases or other containers of the same size and weight, unsuspecting friends, scale, 35 lbs.(15.9 kg) of paper or books

What to do:

1. At school, you can probably find 35 lbs.(15.9 kg) of paper – that's 7 packs of 500 sheets of copier paper – or you could collect it from all the recycling bins. At home you might not have that much paper lying around, so use your scale to weigh books – telephone books work very well – to come up with one pile that weighs 5 lbs. and one that weighs 30 lbs.
2. Before you gather your friends around, fill one suitcase with 5 lbs. of paper and the other with 30 lbs. Now, say to your friends, "These two suitcases are identical in every way except, and this part is important, one is on the Earth and the other one on the Moon. Do you think you're strong enough to lift them?"
3. Now that you have their attention, find some people who would like to try lifting the suitcases. Without saying so, try to have them pick up the heavy suitcase first. Give them lots of applause.
4. After they have lifted the suitcases, explain that these two suitcases are identical in every way except, and this part is important, one is on the Earth and the other one on the Moon. Can they guess which suitcase is which? Why do you think they are so different?



What's Going On?

The force of gravity is six times stronger on the Earth than on the Moon. Now that you've experimented with the difference in Earth and Moon gravity, you can figure out what would your weight be on the Moon. If the Earth suitcase is six times heavier than the Moon suitcase, what would the difference be in your own weight? After you've figured that out, with a little more research you can find out how much a space suit weighs on Earth and on the Moon.

Also see the Gravity Well video at:
http://www.googlelunarxprize.org/education/videos-and-demonstrations

4. BALL GAME

Target Age Group: Elementary

Objective: Students will understand the distance between the Earth and the Moon

You will need:

basketball, tennis ball, string about 30 feet long
(keep string in your pocket at first),
marking pen, unsuspecting friends

What to do:

1. Say to your friends, "Did you know that if the Earth was the size of a basketball, the Moon would be the size of a tennis ball? How far away do you think they would be from each other?" Pass the balls to your friends and give them some time to think.
2. After your friends show you what they think the distance is, it is time to pull the string out of your pocket. You can say "Ta Dahh!" if you like, but they may say, "Hey, come on. That's just a piece of a string." Ask your friends to wrap the string around the basketball about 9 ½ to 10 times. Before they unwrap the string they should mark the end with the pen so that they can find it easily.
3. Have your friends unwrap the string one time around and then stop and hold that part of the string out away from the basketball. This is the distance of geostationary orbit. (They may say "Huh?" if you say that.) Most communication satellites are located at this distance. If you have a satellite dish for your TV, that's where it is pointed right now and that's only 10% of the way to the Moon.
4. Keep unwinding the string. Ask one friend to hold the basketball and the other to hold the tennis ball, keeping one end of the string on the basketball while they unwind.
5. Next, ask the friend with the tennis ball to take the other end of the string and back away from the basketball until you see the mark on the string. Now you can say "Ta Dahh!" because that is how far the Moon would be from the Earth, if they were tennis ball and basketball size. See below to find out how far it really is!

To see a video of this demonstration, please go to....

http://www.googlelunarxprize.org/education/videos-and-demonstrations

What's Going On?

The Moon orbits the Earth at an average distance of about 30 Earth diameters. The distance around the Earth's Equator is just under 24,000 miles so ten wraps of string gives a close approximation of the distance . You can also discuss Pi here if you wish to employ Moon Pie pun. Notice that at this scale the International Space Station orbits less than ¼ inch (0.63 cm) above the basketball**!**

The Moon is 240,000 miles from the Earth. When you do this activity, most people find out that's a lot farther than they thought. Most people also have no idea of the true scale of the solar system.

Visit **http://science.nasa.gov/Realtime/jtrack/3d/JTrack3D.html** for an interactive three-dimensional view of the Earth and all the satellites that surround it. Explore and learn about these satellites that are close to the Earth. Geostationary orbit is the current frontier of commercial activity in space.

The Google Lunar X PRIZE will expand that frontier by 10 times.

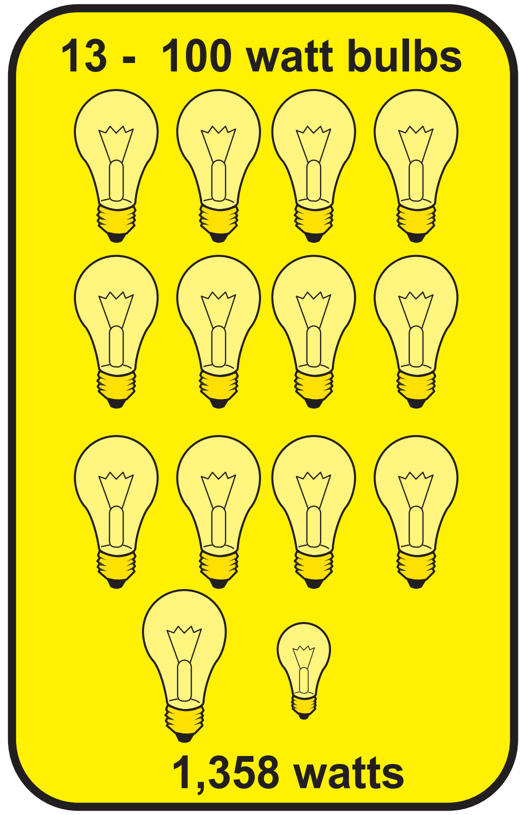
For a view of the Earth and all the satellites that surround it.

http://science.nasa.gov/Realtime/jtrack/3d/JTrack3D.html

5. SUN POWER

Target Age Group: Middle School

Objective: Students will understand the advantages of using solar collectors in space.



For a demo see:
http://www.googlelunarxprize.org/education/videos-and-demonstrations

You will need:

100-watt bulb in simple desk light fixture, a piece of cloth or paper (newspaper works well) that measures 1 sq. meter (1 meter = 1.094 yards), unsuspecting friends

What to do:

1. Ask your friends to gather around. Darken the room. In a mysterious voice, tell them that you have a solution to Earth's energy problems. A solution that is out of this world!!!!
2. Turn on the light and shine it into their eyes. (Don't do this for very long or they will get annoyed and leave.) Discuss how bright that bulb is. Where do we get the energy to power that 100-watt bulb?
3. Now hold up the 1 sq. meter newspaper and ask your friends, "How many 100-watts light bulbs could be powered by a solar panel this size orbiting the Earth and pointed at the Sun?" Collect all their guesses before giving them the answer (below).
4. Discuss Earth's energy problems and why this would help. What would be the advantage of this type of power over a power plant on Earth?

What's Going On?

A 1-sq.-meter solar panel located on a satellite at Earth-Moon system distance from the Sun could power thirteen100-watt bulbs plus one 58-watt bulb. Clean solar energy can be sent from space to the Earth using solar collectors in high Earth orbit made from lunar materials. A single solar power satellite could power an Earth city without carbon dioxide or other pollution. Since these systems provide power at night, satellites could charge electric cars or generate hydrogen from water during off-peak times. Why don't we do this now? Because of the extreme cost of getting material launched from Earth. But if, instead, we use material brought "downhill*" from the Moon, we could build such satellites more economically.

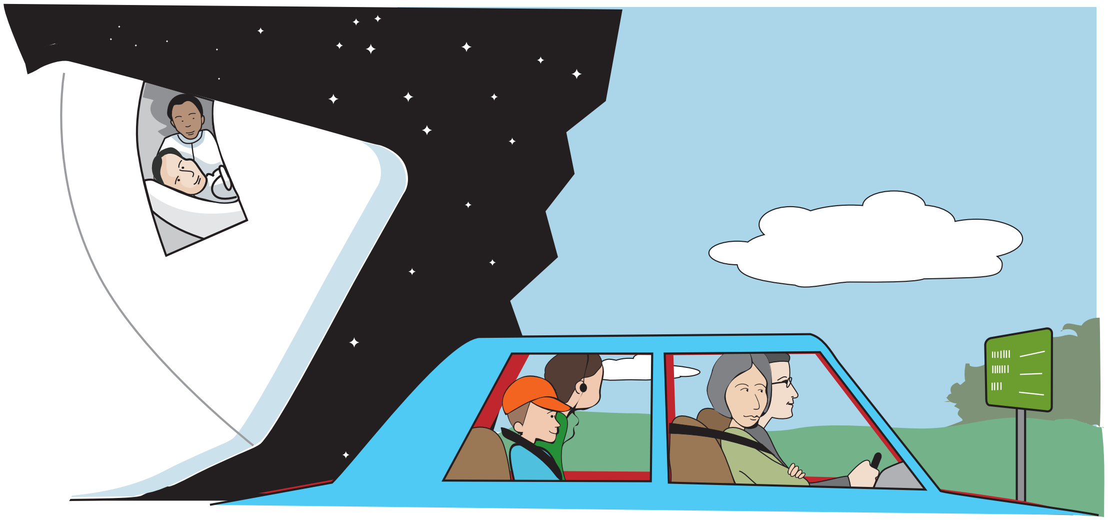
*See **http://www.googlelunarxprize.org/education/videos-and-demonstrations** for an animation of the gravity wells of the Earth and Moon.)

To see the Gravity well animation, please go to....
http://www.googlelunarxprize.org/education/videos-and-demonstrations

6. ARE WE THERE YET?

Target Age Level: Middle School

Objective: Students will understand distance and travel times between the Earth and the Moon.



You will need:
the chart below, pencil, paper

What to do:

1. Think about the longest trip you have ever taken. Where did you start? Where did you finish? Did you go by car, on an airplane, on a bicycle? Did you make stops along the way?

2. Use a map or website to figure out how many miles you traveled. Draw a map showing the trip you took. Chart the distance you traveled, your speed and the number of hours it took. Compute the number of hours by dividing the distance by your speed.

3. Now imagine you are an astronaut. Compute the time it would take you to travel to the International Space Station (ISS) or Moon at car or jet aircraft speeds. Record your results on the chart below.

Car at 60 mph			
Location	Distance	Time	
International Space Station	300 miles		minutes
			hours
Moon	240,000 miles		hours
			24-hour days

Jet at 500 mph			
Location	Distance	Time	
International Space Station	300 miles		minutes
			hours
Moon	240,000 miles		hours
			24-hour days

What's Going On?
Answer Sheet can be found at the back of the Guide.

7. SOLAR SYSTEM IN YOUR NEIGHBORHOOD

Target Age Level: Middle School

Objective: Students will understand the immense distances between the planets by converting them to a scale where the Earth is a basketball, the Moon is a tennis ball, and the Sun is in their neighborhood.

For an automatic version of this activity using Google Maps

http://www.googlelunarxprize.org/education/scale-solar-system

You will need: computer with Internet service

What to do:

1. To make a solar system in your neighborhood, first go to **http://earth.google.com/** and find your home or school.
2. Decide where you would like the Sun to be. Put a marking pin there with the Placemark tool (which looks like a push pin) and label it "Sun."
3. Refer to the Scale Planet distance table (below). Use the Ruler function in Google Earth to find a point as far from the Sun as the planet that you want to place. Try to find a town or some other landmark at the appropriate distance. When you have found a good place, put a marker there and label it.
4. Zoom and tilt your view of the world so that you can clearly see the Sun and the planet.
5. Take a screen shot of your view. For example, on a PC press "Print Screen."
6. Paste your screen shot into a document. You can use PowerPoint or the equivalent free open-source software.
7. Keep adding planets until your solar system is complete. If you were going to take a trip from your Google Earth Sun to Pluto, how many Earth miles would that be?

What's Going On

If Earth is a Basketball, the average distances between the Sun and the planets are:	Statute Miles if Earth is a Basketball	Actual Distance in Astronomical Units (A.U.)
Mercury	0.6	0.38
Venus	1.3	0.72
Earth	1.8	1
Mars	2.8	1.52
Ceres*	5.5	2.76
Jupiter	9.5	5.2
Saturn	17.5	9.58
Uranus	34.5	19.22
Neptune	54.9	30.5
Pluto*	72	40
Eris*	122	67.6

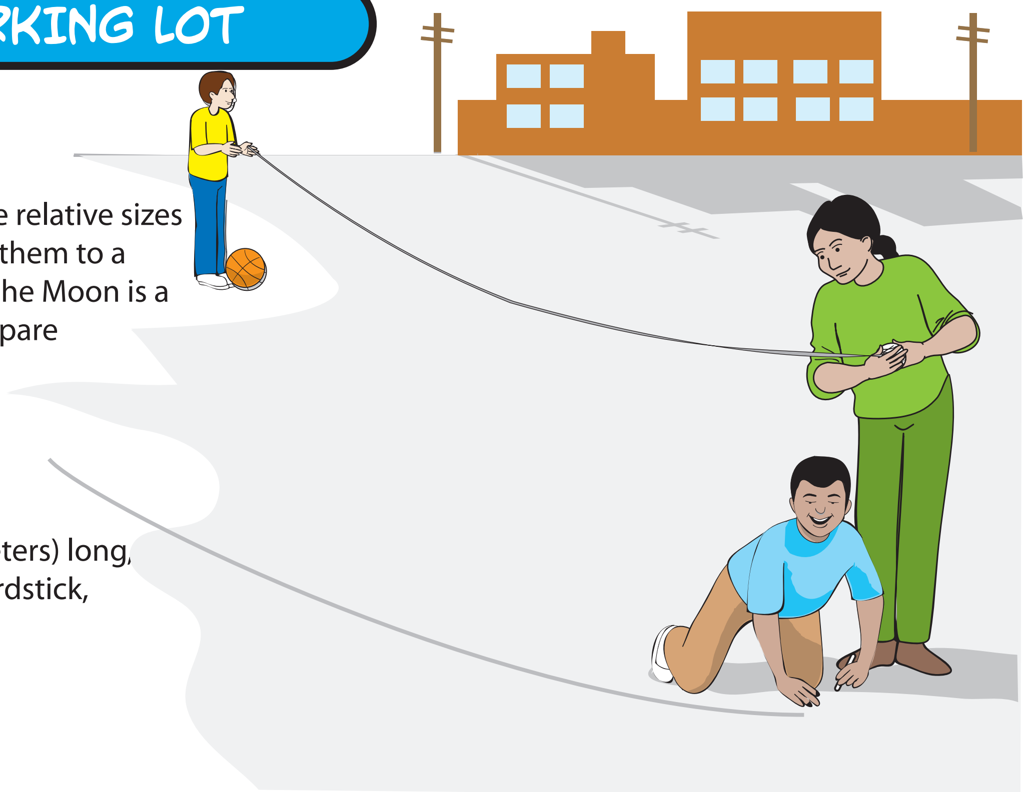
(At this scale a light year (63,000 AU) is 63,000 x 1.8 miles. The nearest star is about 5 light years away or more than 300,000 miles at the scale where the Earth is only as big as a basketball.
The Earth-Sun distance, ~93 million miles or 8 light minutes, is known to astronomers as 1 AU or 1 Astronomical Unit.)

*Ceres, Pluto and Eris are the planets newly classified as "Dwarf Planets."

Learn more about dwarf planets at:

http://solarsystem.nasa.gov/planets/profile.cfm?Object=Dwarf&Display=OverviewLong.

8. PLANETARY PARKING LOT



Target Age Group: Middle School

Objective: Students will understand the relative sizes of the Sun and planets by converting them to a scale where the Earth is a basketball, the Moon is a tennis ball and they can see and compare these bodies in a parking lot.

You will need:
rope or strong string 43 feet (13.1 meters) long, sidewalk chalk, parking lot, friends, yardstick, marking pen, basketball, tennis ball

What to do:

1. Stand at a central point in the parking lot. You are going to need 43 feet of space all around you. To make sure you are at a good spot, hold one end of the 43-foot rope; then have a friend hold the other end and walk until the rope is stretched out all the way.
2. While you continue to hold the rope at your center spot, have your friend walk in a complete circle around you. That complete circle represents the circumference of the Sun.
3. As one friend walks around with the rope, have other friends draw around the circumference with the sidewalk chalk. That is the outline of the Sun.
4. Use the table below to compare the size of the Sun to other planets. Mark the radius of each planet on the long string, find another point in the parking lot to be the center, and walk it around the same way you did for the Sun.
5. How does our Earth-Moon system compare to the size of the Sun? To find out, place the basketball at the center of the parking lot Sun and the tennis ball about 27 feet away.

It's raining and you don't want to go outside? No parking lot nearby? Don't despair. You can do a version of the same activity without leaving your computer, go to the next activity. A planetary radii table for both activities is also on the next page.

9. VIRTUAL PLANETARY PARKING LOT

Target Age Group: Middle School

Objective:

Students will understand the relative sizes of the Sun and planets by converting them on a computer to a scale where the Earth is a basketball and the Moon is a tennis ball.

You will need:

computer with internet access

What to do:

1. On a rainy day, you can compare the sizes of the planets without going to a parking lot by using Google Sketchup. Start with the self-paced tutorial to learn how to draw circles on the virtual ground. Sketchup allows you to input the radius of circles in a box on the lower right of the screen so that you can get precise drawings. You can also watch the box in the lower right of the screen to see the dimensions while you stretch out your circle manually.
2. After you have drawn the Sun, add the planets and Earth-Moon system over the top.
3. Even if it's still raining, you can use Sketchup to add a Google Earth view of your local parking lot to the Sketchup drawing space and place your planet drawings right outside your door, or anywhere you wish.

What's Going On?

For the computations of the diameters for the Sun, Jupiter and Saturn at the scale where the Earth is a basketball, please go to the Planetary Parking Lot Answer Sheet at the end of this Guide.

Planetary Radii Table

OBJECT	ACTUAL RADIUS IN STATUE MILES
SUN	436,800
MERCURY	1,520
VENUS	3,800
EARTH	4,000
MARS	2,120
CERES*	~303
JUPITER	44,800
SATURN	37,880
URANUS	16,240
NEPTUNE	15,480
PLUTO	2,000
ERIS	750

* Ceres is actually elongated in shape so the term radius is not precisely accurate in this case.

10. BIKE RIDE

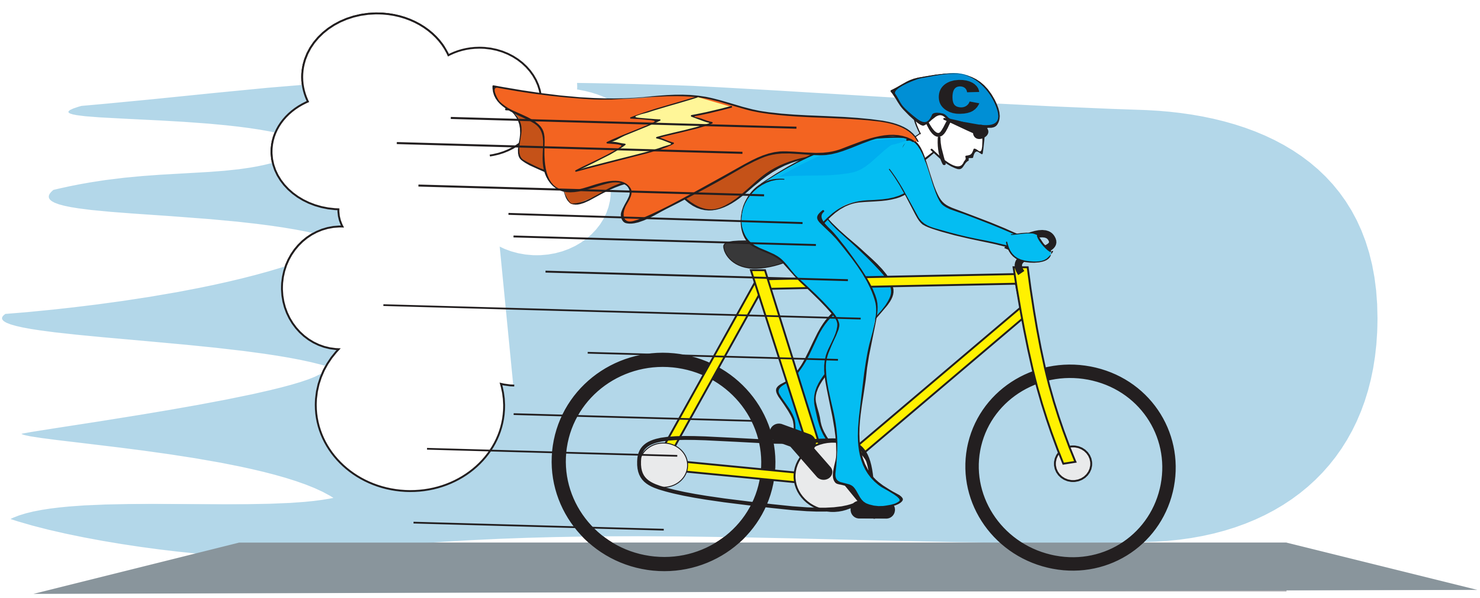
Target Age Group: Middle School

Objective: Students will understand the immense distances between the Sun and planets by calculating speed of light at the scale where Earth is the size of a basketball and the Moon is a tennis ball. (See the Solar System in Your Neighborhood activity)

You will need: paper, pencil, bicycle optional

What to do:

1. Nothing travels faster than the speed of light. It is so fast, we cannot see it, but our solar system is so huge – that when we think about communicating in space, we have to factor in the time it takes for light to travel. To find out just how huge the solar system is, let's bring it down to size a little bit.
2. You can translate the speed of light to the scale where Earth is the size of a basketball. What we know: It takes light (or radio waves) about 8 minutes to go from the Earth to the Sun. In our model the Sun-Earth distance is 1.8 miles.
3. So, to perform the calculation…
   1.8 miles divided by 8 minutes = 0.225 miles per minute
   0.225 miles per minute times 60 minutes per hour = 13.5 miles per hour
4. Can you ride a bicycle at this rate of speed?



What's Going On? The speed of light = 186,000 miles per second. We can't see light travel, but we can experience it. If you have been talking on the phone and noticed the pauses between when you say something and the other person hears it, that may be because of the delay as the signal gets passed back from a satellite in Space. We also experienced the delay when the astronauts talked to us from the Moon.

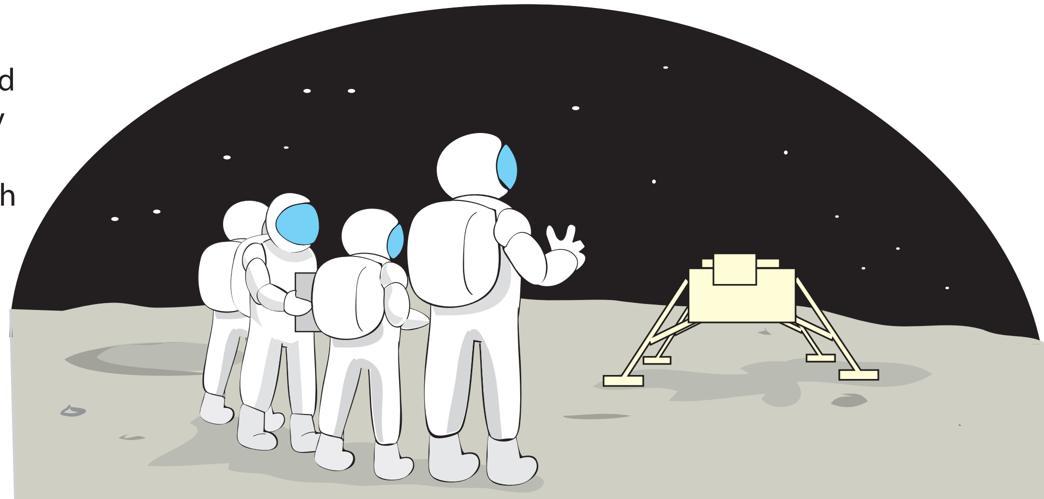
See a demonstration of the speed of light travel time between the Earth and the Moon at:

http://www.googlelunarxprize.org/education/videos-and-demonstrations

11. FIELD TRIP TO THE MOON

Target Age Group: Middle School

Objective: Students will understand the environment on the Moon by seeing actual photos taken there and "traveling" on the surface with the Google Moon program.



You will need: computer with Internet service

What to do:

1. Ready to go to the Moon? 10, 9, 8, 7.... Okay, we're really going to a website. At Google Moon **moon.google.com** you will find panaromic views of the Moon surface and close ups of the lunar equipment still providing data to scientists today.
2. Explore the website. Seeing the Moon for yourself, what do you notice about the environment there? How does it compare to the Earth?
3. Visit the Apollo Lunar Surface Journal website **http://www.hq.nasa.gov/office/pao/History/alsj/frame.html** (for more information, see activity #14) and research the Apollo 11 and 12 missions. See and hear video and audio clips of the actual exploration. The Laser Retroreflector placed on the Moon by the crew of Apollo 11 is still there! You can find it using Google Moon and find out what it does from the Apollo Lunar Surface Journal website.
4. Now, go to the Apollo 12 landing site on Google Moon. Find the Surveyor III robot spacecraft that Alan Bean and Pete Conrad visited. They brought a part of the Surveyor back to Earth to study how materials withstand multi-year exposure on the Moon. Using the Apollo 12 Press Kit (also at the Apollo Lunar Surface Journal website) can you find out what year Surveyor III landed on the Moon? What else can you find out about Bean and Conrad's exploration?
5. To find out more, explore the Apollo Image Gallery at **http://www.apolloarchive.com/apollo_gallery.html** or the Great Images in NASA website at **http://grin.hq.nasa.gov/**. Print your favorite images and write captions explaining their importance.

What's Going On?

Google Moon uses a Mercator Projection to make a rectangular map of the Moon. The mapmaker's challenge is making flat two-dimensional maps from spheres. Mercator projections are most accurate at the equator and most distorted at the poles. Compare a mercator projection world map with a world globe and look at how Greenland appears on both. You can also download a historical NASA Lunar chart at **http://www.hq.nasa.gov/alsj/NASALunarChart.jpg** The Laser Retroflector (p. 51, Apollo 11 Press Kit) is a special mirror system still used by scientists today to reflect laser light sent from Earth. By precise measurement of the transit time of the laser signal, an ultra accurate Earth-Moon distance measurement can be taken. Using this retroreflector, scientists have determined that the Moon is actually moving away from the Earth at a rate of 1.5 inches (3.81 cm) per year. (Surveyor III landed in 1967.)

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See Apollo Image Gallery at :

http://www.apolloarchive.com/apollo_gallery.html

12. FIELD TRIP TO THE UNIVERSE

Target Age Group: Middle School

Objective: Students will understand what can be seen with telescopes outside Earth's atmosphere by using Google Sky to "see" deep into Space.

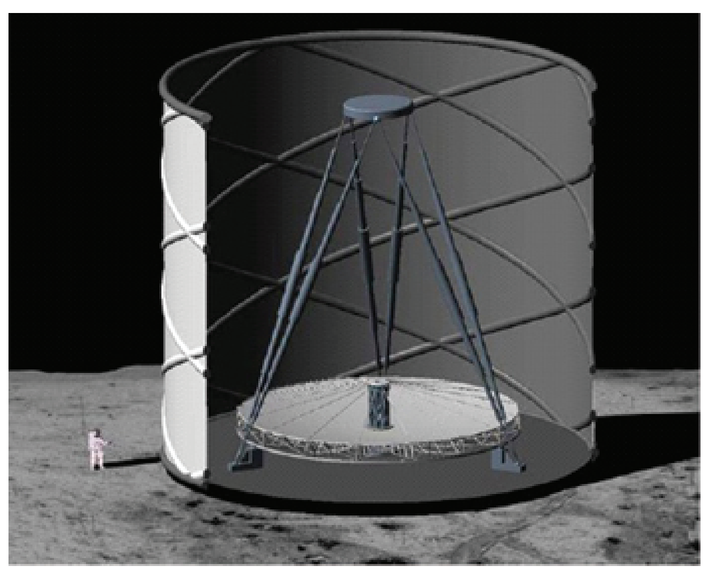
You will need: computer with internet service

What to do:

1. Want to soar through the universe without leaving your seat? First, load the newest version of Google Earth. Now go to the View Menu and pull down "Switch to Sky".
2. Then, for an excellent tour of Hubble images prepared by the Space Telescope Science Institute , go to **http://services.google.com/earth/kmz/best_hubble_n.kmz.**
3. The Layers Controls on the lower left sidebar of the screen determine the level of information shown. Check and uncheck the layers to learn how they work.
4. To find an object in the sky, enter it in the "Search the Sky" box on the upper part of the left sidebar. For example, the central star in Orion's belt is called Alnilam. After Google Sky takes you there, pull out until you can see the entire Orion Constellation. While you're in the neighborhood enjoy the beautiful nebulae in Orion. Search for Andromeda to see a beautiful spiral galaxy.
5. What advances in technology have made it possible for us to see so clearly, so far away? What are the advantages of placing a telescope outside Earth's atmosphere?

What's Going On? Many astronomers are interested in using the Moon as a base for viewing the sky or as a source of construction materials for future space-based optical and radio telescopes. For example, NASA is planning a variety of astronomy tools for use on the Moon. In the future it will be possible to build an optical telescope on the Moon that would use a spinning pool of fluid to make a 100-meter wide reflector that would be thousands of times more powerful than the Hubble Space Telescope. See a recent article about this concept at **http://www.photonics.com/content/spectra/2007/August/tech/88448.aspx.**

Want to Learn More?
Go to **earth.google.com/sky/skyedu** for a short video showing how to use Google Sky. Go to the Google Earth Gallery to find other tours and features to explore at **http://earth.google.com/gallery/kml_listing.html#csky#s1#e10.** Visit the Google LatLong Blogspot: **http://google-latlong.blogspot.com/2007/08/sky-final-frontier.html.** Visit The Google Earth Blog at **http://gearthblog.com/**, an independent site by astronomer Frank Taylor with excellent information on Google Earth's many features. See a video of the new Sky features at **http://www.gearthblog.com/blog/archives/2007/08/video_showing_new_sk.html.**



Lunar liquid mirror telescope illustration courtesy of Dr. Roger Angel and Thomas Connors of the University of Arizona.

13. HAVE SPACE SUIT - WILL TRAVEL

Target Age Level: Middle School

Objective: Students will understand the connections between science fiction of the past and what we know about the Earth-Moon system today.

You will need:
Have Space Suit –- Will Travel, the book by Robert A. Heinlein (Simon & Schuster, 1958), World Space Week Heinlein Teacher Guide, © 2005 Spaceweek International Association. Permission has been given for unlimited reproduction for use by teachers. The Guide can be downloaded at no charge from *www.spaceweek.org*.

Background:
We highly recommend the *World Space Week - Heinlein Teacher Guide* developed for Spaceweek International Association by Space Education Initiatives and other leading curriculum developers. Funding for this project was provided by the Heinlein Prize Trust. The activities in the Guide are based on the book *Have Spacesuit - Will Travel* by Robert A. Heinlein. Celebrated in 50 countries, World Space Week was declared by the United Nations as October 4-10 annually.

What to do:
The following list is from the 36-page Guide's Table of Contents.

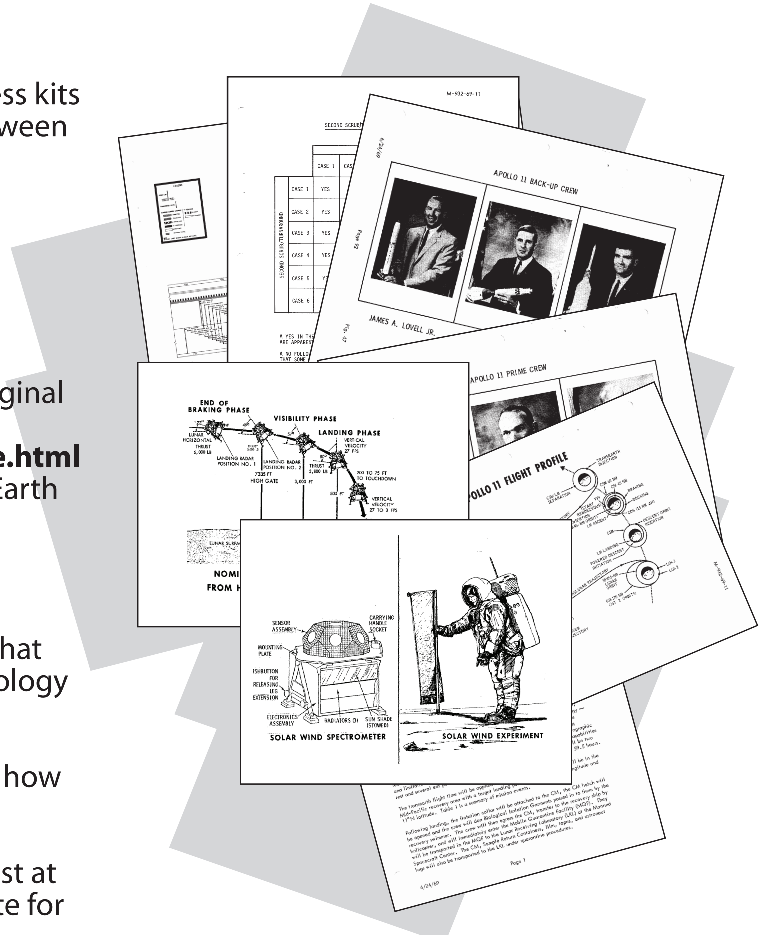
- **Space Suit Design: Electric Circuits.** Students are introduced to series and parallel circuits in a problem-based activity.
- **Earth-Moon System**. Students construct a simple scale model of the Earth, Moon and other Solar System objects that is accurate for size and distance.
- **Lunar Escape!** Students are introduced to the concept of gravity and plan an escape from Wormface.
- **Humans on the Moon**. Students investigate NASA's Apollo program.
- **Space Suit Design: Solar System Diversity.** Students design space suits for survival on different Solar System objects.
- **Making Observations.** Students explore how we use multiple senses while making observations.
- **Imagery.** Students use the text excerpt to identify the author's use of imagery.
- **Descriptive Writing: A Lesson in Revision.** Students create a monster and then write a description of it. Students exchange descriptions and attempt to draw the monster. Students then revise their original description.
- **Tone / Mood**. Students use a text passage to explore the concepts of tone and mood. Students then write a passage to convey a specific tone or mood.
- **The Journey of a Hero: A Discussion.** Students reflect on the entire novel to determine if the main character, Kip, fits the role of a classic hero.
- **Conflict.** Students explore the concept of literary conflict.
- **Compare and Contrast.** Students compare and contrast two aliens using a text excerpt.

14. THE REAL THING

Target Age Group: Middle School

Objective: Students will study first person accounts and press kits for the Apollo missions to understand the differences between technology then and what we know today.

You will need:
computer with internet service, printer, pencil and paper



Background:
Mathematician Eric Jones spent many years interviewing astronauts about visiting the Moon and compiling the original documents from the Apollo missions. The website **http://www.hq.nasa.gov/office/pao/History/alsj/frame.html** features a wealth of information, including transcripts of Earth to Moon conversations.

What to do:

1. Explore the website and think about a research question that interests you. Are you interested in the science and technology of the time, the details of the missions, or the astronauts themselves?
2. Choose a topic to study and present to the class. Consider how you will assure that what you present is accurate.
3. Here are some ideas for topics and presentations:
   (a) What technology is available to us now that did not exist at the time of the Apollo missions? How did they compensate for some of the inventions they did not have?
   (b) What was it really like to be an astronaut? What were they doing and talking about? Mission transcripts are written like scripts and can be read aloud. For example, if you click on Apollo 11 Surface Journal, drag down to The Journal and click on One Small Step, you will find the famous words that Neil Armstrong and Buzz Aldrin said when they stepped onto the Moon.
   (c) What were the goals of the different missions? How do they compare? How did they build on each other?
   (d) Go on a scavenger hunt! Choose a detail that you are curious about -- for example, "What did the astronauts eat?" -- and search through the Press Kit and/or Journal to find the answer.
   (e) Click on Apollo 13 Surface Journal. Drag down to Cortright Commission Report. Study what went wrong with the mission. Could anything have been done to advoid this mishap?

For a view of the original documents from the Apollo missions.
http://www.hq.nasa.gov/office/pao/History/alsj/frame.html

What's Going On?
Sometimes what we learn about science doesn't come directly from the people who experienced it. It might be a movie we saw, something on the internet or something someone tells us. It may not be correct. Research is important to be sure what we think we know is true. To further explore this idea, view the movie *Apollo 13* (Universal Studios, 1995.)

15. (MOON) ROCK, PAPER, SCISSORS, SPACESHIP!

Target Age Group: Middle School or High School

Objective:
Students will understand the complexity of historical moon rockets and future lunar exploration vehicles by assembling their own paper models.

You will need:
computer with internet access, printer, razor blade or hobby knife, glue, adult to help

What to do:

1. First go to **http://jleslie48.com/gallery_models_real.html** for an overview of the amazingly detailed, accurate 3D paper models you have to choose from. Choose a model that you would like to build and learn about.
2. Warning: These are serious models. You will need an adult to help you use a razor blade or hobby knife in order to cut out the parts. You'll also need some good fine motor skills to assemble these and some are fairly difficult to build. Finally, consider yourself warned that building these models is really fun, so once you've built one, you're going to want to build another one.
3. Here are some favorites we recommend:
   - **Historical Lunar Module**. **http://jleslie48.com/guylem_gold45.pdf.** Build a model of the historic lunar modul that landed the first humans on the Moon. Back in the 60's the Gulf Oil Company distributed a cardboard model of the Lunar Module that was an instant hit. The authors of this website have enhanced this model to make it easier to build and more authentic in appearance.
   - **Future Heavy Lift Launcher for Moon Exploration. http://jleslie48.com/cevton02/heavylifter.** Build the modern equivalent of the Saturn V intended to launch the Moon lander and the upper stage that boosts the lander and Crew Exploration Vehicle to 7 miles per second for translunar Injection.
   - **Crew Exploration Vehicle (CEV)**. **http://jleslie48.com/cevton02/cev2_0601.** Build a model of the Crew Exploration Vehicle which will carry astronaut crews to the Space Station, the Moon, the asteroids and beyond.
   - **Launcher for CEV. http://jleslie48.com/cevton02/.** Build a model of the launcher that lofts the CEV into Earth orbit at 5 miles per second.
4. Download and print the model pattern you have chosen. Step-by-step instructions are on the website. But don't just stop with the model. Find out all you can about real lunar vehicles of the past, present and future. Create a museum sign for your model explaining it to people who come by to see it.

What's Going On?
Everything you need to understand this activity is included on the website. This model-building activity is a starting point for related activities in science, engineering and social studies. Special thanks to Jonathan Leslie and the Lower Hudson Valley Challenger Learning Center, Airmont, NY, for sharing these wonderful models at no charge.

16. LAND THE LUNAR MODULE

Target Age Level: Middle School

Objective:
Through computer simulation, students will understand the factors involved in making a successful landing on the Moon.

You will need: computer with internet access

What to do:

1. This activity allows you to play computer games and learn science at the same time. That's right. It says "play computer games" in that first sentence. First, visit **http://space.xprize.org/lunar-lander-challenge/games.php.** Here you will find several great online versions of the classic arcade game Lunar Lander. This game allows you not only to soft land but to move sideways. If you use a search engine such as Google and search on Lunar Lander Games you will find a number of different sites that permit you to play this game.
2. There are a number of great games and simulations that let you try your hand at the exciting and difficult business of landing a lunar module. Next, try going to the Project Apollo Archive site at **http://www.apolloarchive.com/lander.html.** Select a low level of difficulty at first. The trick is not to slow down too soon (at too high an altitude). Doing so depletes your fuel. Run out of fuel and a new lunar crater might be named in your memory!
3. The Eagle Lander 3D simulation is much more realistic and difficult than the arcade games. Even experienced pilots feel really great when they finally succeed at a safe landing. A free downloadable version is available online at **http://eaglelander3d.com/.** The freeware version is very nice but limited to the Apollo II simulation. This download is more than 60 Mb so be sure to have your parent or teacher's permission before putting it on your system.
4. What are the challenges that you faced in attempting a safe landing? How did you address those challenges? How is using the software different than the real thing?

What's Going On?

The flights of the Lunar Module certainly rank among the greatest technical achievements of the space age. Making an airless landing balanced on a rocket's thrust is challenging business. Not only are the controls unfamiliar to pilots of airplanes and helicopters, but fuel quantities are very limited. After trying these games you will greatly appreciate the competence of the Apollo crews. For extra credit, research the number of seconds of fuel remaining that Neil Armstrong and Buzz Aldrin had at touchdown.The X Prize Foundation hosts an annual Lunar Lander competition.
See **http://space.xprize.org/lunar-lander-challenge/index.php**

17. COULD YOU SURVIVE A MOON CRASH?

Target Age Level: Middle School through High School

Objective: Students will work as a team to understand the essentials for survival on the Moon.

You will need:
this worksheet, friends to brainstorm with, pencil

What to do:

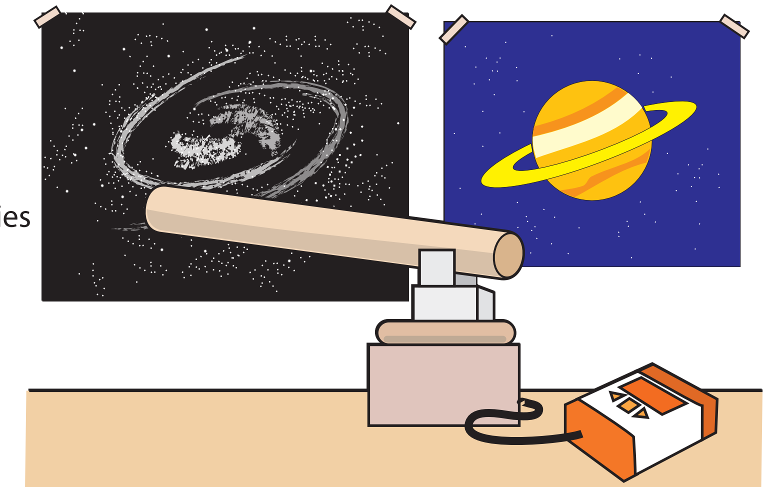
1. Your spaceship has just crash-landed on the Moon! You are 200 miles (320 km) away from Moon Base 3. It's midday. (Remember the lunar day lasts 14 Earth days.) Your crew's survival depends on reaching the base.
2. Choose the five most critical items from the following 15 items salvaged from your wrecked ship. Your task is to rank the items in terms of their importance for survival on your trek to the safety of the base.
3. Place number one by the most important item, number two by the second most important item, and so on through number fifteen, the least important item. If you get four of the top five right, you'll survive.

- [ ] Box of matches
- [ ] 50 feet (15m) of nylon rope
- [ ] Two .45 caliber pistols
- [ ] Self-inflating life raft
- [ ] Ten gallons (38 liters) of water
- [ ] First Aid kit (containing spacesuit injection needles)
- [ ] Solar-powered FM receiver-transmitter
- [ ] Stellar map (for use in navigation)
- [ ] Three 100-pound (45 kg) tanks of oxygen
- [ ] Solar-powered portable heating unit
- [ ] Food concentrate
- [ ] Parachute
- [ ] One case of dehydrated milk
- [ ] Magnetic compass
- [ ] Signal flares

What's Going On? Answer Sheet can be found at the back of the Guide.

18. ROBOTS ON THE MOON

Target Age Level: High School



Objective:
Students will use LEGO Mindstorms NXT robots to simulate and understand how to control a telescope on the Moon from the Earth.

You will need: LEGO Mindstorms NXT kit and other supplies described below, computer with internet access

Background:
Using LEGO Mindstorms NXT hardware you can make a teleoperated lunar telescope, have a lot of fun, experience the ~2.7 round trip speed of light time delay between the Earth and the Moon, and understand how it feels to control equipment on the Moon from the Earth.

What to do:

Download an article, photographs and videos of a LEGO Mindstorms NXT lunar teleoperation demonstration along with software at **http://www.googlelunarxprize.org/education/videos-and-demonstrations.** You'll need to load the Mindstorms software in order to view this code on your computer. Use this link for photos and short video clips of the model telescope in action and watch the two animations at **http://www.googlelunarxprize.org/education/videos-and-demonstrations** depicting the round trip time delay of a radio beam or a light beam between the Earth and the Moon.

The Mindstorms kit comes with directions to build a number of robots and contain a microprocessor controller "brick," plus motors, switches, sensors and structural parts. The brick has a built-in Bluetooth radio which lets it communicate with other bricks or with other Bluetooth devices. For example, if you have a Bluetooth-enabled phone or laptop computer you can use those devices to send commands to your creations. In the model, a second brick represents the Earth control station for the lunar telescope.

Happy Robot Building! Please share photos, movies or links to whatever you devise to experience and demonstrate operating systems at lunar distance via email to gmaryniak@slsc.org.

What's Going On? One of the reasons that the Moon is such a useful target for space activity is that it is sufficiently close to the Earth that people can control equipment on the Moon without leaving their home planet. It takes light or a radio signal about 1.3 seconds to travel between the Earth and the Moon for a round-trip travel time of about 2.7 seconds.

19. HOW DOES YOUR (ROCKET) GARDEN GROW?

Target Age Group: Middle School

Objective: Students will understand the size of space vehicles by comparing them – virtually -- to other landmarks near their home or school.

You will need: computer with Internet service

What to do:

1. How would you like to have a full-size rocket in your backyard? Or how about a few rockets.? Go to **http://www.googlelunarxprize.org /education/rocket-garden** to create your own rocket garden like the kind you might see in a museum.
2. At the website, you will find the rockets for your garden. Enter the address where you'd like your Virtual Rocket Garden to appear. Amazed?
3. How do the sizes of the rockets compare to familiar things in your neighborhood?
4. If you have access to the virtual world Second Life, you can also visit the outstanding International Space-flight Museum. Fly around a large rocket garden. Go inside SpaceShipOne, the winner of the Ansari X PRIZE, and a Mercury space capsule and operate a robotic arm.

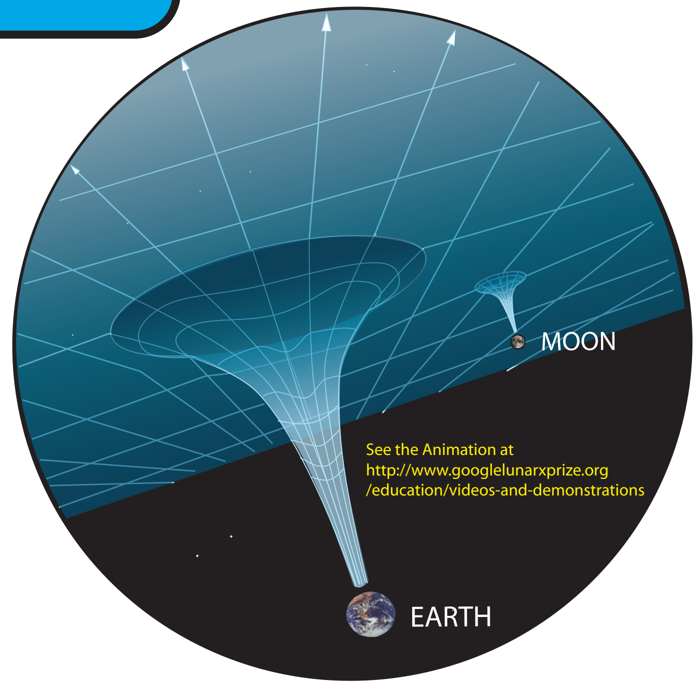
What's Going On? Here is the background on the vehicles found on the website. The Space Shuttle (officially the Space Transportation System) is capable of placing the Orbiter (the airplane-like part of the system) into Low Earth Orbit -- approximately 250 miles above the Earth. The new Crew Exploration Vehicle (CEV) will send a crew capsule to that same altitude. The new Heavy Lift Vehicle (HLV) will put the lunar lander and a large upper stage into Low Earth Orbit. The CEV will dock with these other parts and the upper stage will accelerate the CEV and Lunar Lander from 5 miles per second (7.8 km/sec) to Earth escape velocity of 7 miles per second (11.2 km/sec.) The CEV and HLV are both still under development and the designs are likely to change over the next few years. You can watch these developments through the X PRIZE web site and other Internet resources.

20. ESCAPE FROM THE MOON!

Target Age Group: High School

Objective: Students will understand escape velocity, or the speed needed to escape the gravitational field of a body.

You will need:
computer with internet service, pencil, paper



Background:
Any body that has mass has an associated gravitational field, or "pull". The more massive an object is, the greater its gravitational pull. This concept can be generalized for any object of mass. This force is proportional to the product of the two masses and inversely proportional to the square of the distance between the two masses:

$$F = \frac{Gm_1m_2}{r^2}$$

where F = the magnitude of the gravitational force between the two masses, G is the gravitational constant (6.67 x 10^{-11} Nm^2kg^{-2}), m_1 and m_2 are the masses of the first object and second object, respectively, and r is the distance between the two objects. From this equation, you can see that if you were orbiting Earth at some distance r, and if m_1 was your mass and m_2 was the mass of the Earth, F would be very large. However, if you were orbiting Jupiter at the same distance r, and m_2 was the mass of Jupiter, F would be much larger. Therefore, the more massive an object is, the greater its gravitational force.

In order to escape the gravitational force of a massive body, like a planet or a moon, an object on that body has to travel at a particular minimum speed, which we call the **escape velocity.** Since larger, more massive bodies exert a stronger gravitational force on objects, anything that wants to escape, or "break free" from that force has to travel at a very high speed. Likewise, anything trying to escape the gravitational force of a less massive object can travel at a lower speed. Anything traveling at a speed less than the escape velocity will either fall back to or stay in orbit around the source.

Equation and Finding Earth's Escape Velocity:
The escape velocity from a body is given by the following equation:

$$V_e = \sqrt{\frac{2GM}{r}}$$

where v_e is the escape velocity, G is the gravitational constant, M is the mass of the body being escaped from, and r is the distance between the center of the body and the point at which the escape velocity is being calculated.

Let's use this equation to derive the escape velocity of the Earth. Given that:

- $G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
  (recall that $1N = 1kgm/s^2$)
- $M = 5.9736 \times 10^{24}$ kg
- r = mean radius of the Earth (if we want to escape from Earth's surface)
  = 6372.797 km
  = 6,371,797 m

We will now plug these numbers in to find out v_e:

Therefore, the escape velocity for the Earth is about 11.2 km/s, or roughly 7 mi/s.

$$V_e = \sqrt{\frac{2GM}{r}}$$

$$= \sqrt{\frac{2(6.67 \times 10^{-11}\ Nm^2\ kg^{-2})\ (5.9736 \times 10^{24}\ kg)}{6{,}371{,}797m}}$$

$$= \sqrt{\frac{7.9688 \times 10^{14}\ Nm^2\ kg^{-1}}{6{,}371{,}797m}}$$

$$= \sqrt{\frac{=125{,}063{,}343.98\ m^2}{s^2}}$$

$$=11{,}183\ \frac{m}{s}$$

$$=11.18\ \frac{km}{s}$$

Finding the Moon's Escape Velocity:

Given:

- $G = 6.67 \times 10^{-11}\ Nm^2\ kg^{-2}$
  (recall that $1N = 1kgm/s^2$)
- $M_{moon} = 7.3477 \times 10^{22}$ kg
- r_{moon} = mean radius of the Moon
  (if we want to escape from the Moon's surface)
  = 1737.103 km
  = 1,737,103 m

$$V_e = \sqrt{\frac{2GM}{r}}$$

$$= \sqrt{\frac{2(6.67 \times 10^{-11}\ Nm^2\ kg^{-2})\ (7.3477 \times 10^{22}\ kg)}{1{,}737{,}103m}}$$

$$= \sqrt{\frac{9.8018 \times 10^{12}\ Nm^2\ kg^{-1}}{1{,}737{,}103m}}$$

$$= \sqrt{\frac{5{,}642{,}631.32m^2}{s^2}}$$

$$=2{,}375\ \frac{m}{s}$$

$$=2.375\ \frac{km}{s}$$

So, the escape velocity for the Moon is about 2.38 km/s, or about 1.5 mi/s.

Starting from the calculations above, you can build a spreadsheet to calculate escape velocities for all the different bodies in the Solar System.

About Gravity Wells: For more about Gravity Wells, see the Gravity Well Animation and Earth's Offshore Island: The Moon at **http://www.googlelunarxprize.org/education/videos-and-demonstrations** for views of the relative ease of escaping from the Moon compared with Earth launching.

Now that you know the escape velocities of the Earth and the Moon, it's easy to compare the relative energy required for Earth vs. Lunar escape. Energy equals the square of the velocity. So let's square both of these and look at the ratio.

Earth Escape velocity $= 11.18\ \frac{km}{s} \times 11.18\ \frac{km}{s} = 125\ \frac{km^2}{s^2}$

Lunar Escape velocity y= $2.38\ \frac{km}{s} \times 2.38\ \frac{km}{s} = 5.66\ \frac{km^2}{s^2}$

$\frac{125}{5.6}$ equals 22.32.

In other words, it takes 22 times more energy to launch material into free space from the Earth than it does from the Moon. So we say that the Earth's gravity well is 22 times deeper than the "gravity dimple" of the Moon. In reality the benefits of lunar launching are even greater than this ratio since the Moon has no atmospheric drag.

Are We There Yet? Answer Sheet

	Car	Jet
Speed	60 mph	500 mph
Distance		
ISS (300 miles)	5 hours	36 minutes
Moon (240,000 miles)	4,000 hours	480 hours
# of 24-hour days	166 days	20 days

It took astronauts about 4 days to get to the Moon. The recently launched New Horizons Pluto probe covered the Earth- Moon distance in 9 hours. It takes light or a radio beam about 1.3 seconds.

Planetary Parking Lot Answer Sheet

Follow the steps below to compute the diameter of the Sun, Jupiter and Saturn at the "Earth is a Basketball" scale.

Known factors:
Real Sun diameter = 873,600 miles
Real Earth diameter = 8,000 miles
Basketball Earth diameter = 9.46 inches

Sun / Earth = 436,800 x 2 = 873,600 / 8,000 = 109.2

This means that the Sun's diameter is 109.2 times that of the Earth.

So at "Earth is a Basketball" scale the Sun is 109.2 x 9.46 inches.
This is 1033.032 inches or 86 feet.

Jupiter
Jupiter's diameter = 89,600 miles

89,600 / 8,000 = 11.2 (Jupiter is 11.2 times Earth's diameter) so Jupiter is 8.83 feet or 106 inches at "Earth is a Basketball" scale.

Saturn
Saturn's diameter = 75,760 miles

This is 9.47 times Earth's diameter or 89.6 inches
Or 7.47 feet at "Earth is a Basketball" scale.

Divide the diameter by 2 to get the radius for the Planetary Parking Lot Activity.

You can assign your students to calculate the other Planetary diameters and radii in a similar manner.

Could You Survive a Moon Crash? Answer Sheet

Group One:
The essentials

One: Air is essential to sustaining life so it should be the #1 priority.
Two: Water is also necessary during your multi-day lunar hike so it is #2.
Three: A star map will help you find your way to the base; after basic survival it's tops.
Four: Food will keep your strength up.
Five: The solar-powered radio may enable you to call for rescue, shortening your ordeal.

Group Two:
Potentially useful

Six: 50 feet of rope could help you traverse difficult terrain.
Seven: The first aid kit could be a lifesaver.
Eight: You could make a sunshade with the parachute canopy, but there is no atmosphere on the Moon.
Nine: Signal flares might help you when you are very close to the base.
Ten: Dehydrated milk could add to your food but is not absolutely essential for the hike.

Group Three:
Arguably deadweight on the Moon

Eleven: Self-inflating life raft. Some have argued to use the carbon dioxide bottle for propulsion. This might be true in weightlessness, but it isn't large enough to use on the Moon.
Twelve: Solar-powered portable heating unit. The problem during the day will be too much heat!
Thirteen: Pistols. It has been suggested that you could use the pistols for propulsion but this will not work in the Moon's gravity field.
Fourteen: Magnetic Compass. A compass will not work on the Moon because, unlike the Earth, it has no appreciable magnetic field.
Fifteen: Matches. These won't work on the airless Moon.

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SCIENCE BEYOND the BOUNDARIES

a program of the Saint Louis Science Center

www.googlelunarxprize.org

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