Lunar Reconnaissance Orbiter: (LOLA)

Audience
Grades 6-8

Time Recommended
45-60 minutes

AAAS STANDARDS
- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

NSES STANDARDS
Content Standard A (5-8), Scientific inquiry:

c. Use appropriate tools to gather, analyze and interpret data.

d. Develop descriptions and explanations using evidence.

Content Standard E (5-8), Understandings about Science and Technology:

b. Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique.

MATERIALS
- Data worksheets (one per student)
- Science notebook
- Ping-pong ball
- Wooden blocks of various sizes (could substitute other objects like hard boxes or large textbooks)
- Masking tape: 2 pieces, 10 cm each (optional)
- Meter stick
- Stop watch
- Graph paper (enough for 3 graphs per group)
- Pen/pencil

Lunar Laser Altimetry Studying the Topography of the Moon

Learning Objectives:
- Students will understand, through a hands-on experience, the basic concepts behind the use and working of a laser altimeter for the study of solar system topography.
- Students will plot and graph data they have collected using a hands-on version of laser altimetry.
- Students will gain an understanding of the use of laser altimetry in the study of planetary topography.

Preparation:
Provide the included worksheets and procedure to each student participating in the activity.

Background Information:
In order to be prepared for further exploration on the Moon's surface we need to map the topography of the surface to ensure its safe and successful exploration. There are multiple methods to determine topography, including photoclinometry (a method that uses algorithms informed by Sun angles and the observation of shadow lengths of features on the surface). Currently, one of the best methods for determining topography is to use laser altimetry. While photoclinometry provides relative measurement, laser altimetry can provide more accurate, absolute measurements.

The spacecraft currently orbiting and studying the Moon's surface is called the Lunar Reconnaissance Orbiter (LRO). It includes such an instrument— the Lunar Orbiter Laser Altimeter (LOLA). The LOLA instrument is used to take topographical measurements of the surface of the Moon using sophisticated laser technology. Topographic maps and 3 dimensional models are created using this data. This activity will introduce you to the concept of laser altimetry and how the data are used in order to create maps and model solar system bodies. For more background on the LRO spacecraft mission and the laser altimetry instrument onboard please visit: http://lunar.gsfc.nasa.gov

Procedure:
Take some time with students to brainstorm about why it may be important to know the topography or physical terrain of the surface of the Moon? This is a good time to connect Lunar exploration and exploring here on Earth. Also, have students take a moment to discuss what might be the challenges of measuring and mapping a terrain as far away as the Moon's surface.

Briefly introduce students to the Lunar Reconnaissance Orbiter (LRO) mission and the Lunar Orbiter Laser Altimeter (LOLA) instrument. You can find background information here: http://lunar.gsfc.nasa.gov/. Explain to students they will be modeling the technology behind the LOLA science instrument.

This activity requires at least two people per group; however, three people per group would be the optimum amount. The jobs can be rotated if group members so desire. Read through the whole activity before beginning. Model if necessary.

STEP ONE:

1. Choose a spot on a wall 2.2 m or higher from the floor and place one 10 cm length of tape on the wall, at that height, parallel to the floor. (You may need a chair)

2. Holding the ball next to the tape on the wall (about an inch away from the wall), between your first finger and thumb, drop it and watch to see how high it bounces back up. Mark that spot on the wall with your finger. It is best to do this particular step two or three times to determine the highest point of return. (Using the mortar lines on cinder block walls will work well, too, if you have them. Be sure to use the same two lines throughout the whole activity.)

3. Measure 45 cm from the tape down toward the floor and mark this spot with the second piece of tape. This will be the constant for measuring the time of the ping-pong ball's period.

4. Measure the distance from the first piece of tape (or mortar line) to the floor and back up to the second tapeline. Record this on Data Table I. This distance will be used to create a baseline for all other measurements, so be as precise as you can.

5. Just like "number two," one partner should hold the ping-pong ball next to the higher piece of tape, between the first finger and thumb, and approximately one inch from the wall.

6. One partner should have a stopwatch (the "timer") and have his or her eyes level with the second piece of tape. A third partner, if available, should be recording the results of each ball drop using the data sheet provided. Note: A spreadsheet would work well for recording and calculating this data.

7. Drop the ball, and as you do say, "go," the "timer" will then start the stopwatch.

8. The timer will stop the watch when the ball rebounds and reaches the lower line. (His/her eyes should be level with the lower piece of tape. The time should be stopped as soon as any part of the ball touches any part of the line.) Record the time on Data Table I. Repeat this step four more times.

9. Calculate the velocities (V=D/T). After finding the velocity for each of the trials, find the average velocity of the ping-pong ball. This average will be used later in this activity. It will be your baseline for comparing data.

STEP TWO:

Now that you have found the velocity of the ping-pong ball, you will use this information to plot the topography along a line of latitude on the Moon. You will be creating your own lunar terrain on the floor against the wall where you just completed Step One.

1. Create the topography model of your Moon, along the wall where Step One was performed. In order to do so, place the wooden blocks against the wall in a line about 2-2.5 m long. Be sure that you build in some hills, mountains, valleys, etc. (See Figure A for example).

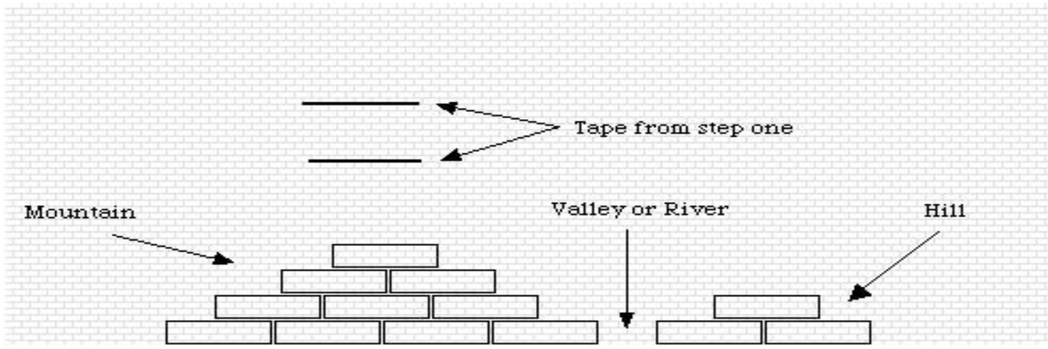

Figure A

2. If you used tape in Step One instead of the mortar lines, you will probably want to add new lengths of tape to the originals that extend over the entire length of your topographical model. Be sure that the new lines remain parallel to the floor so that the heights don't change along the length of the model.

3. Starting at the beginning of the top piece of tape, place a mark every 20 cm. The bottom piece does not need to be marked.

4. Again, starting at the first interval mark made at the beginning of the tape, drop the ping-pong ball as you did in Step One, and have the "timer" record the time in Data Table II. Drop the ball and record the results two more times for each interval. Be sure to be as accurate as you can with the timing.

5. Repeat "number four" for each of the interval marks placed on the wall.

6. Find the average time/ distance for each of the intervals and record it on the Data Table II worksheet.

7. Put all related data into Data Table III from the previous tables (I and II).

STEP THREE: PLOTTING AND GRAPHING THE DATA

Plot the data for the average times and create graphs in your science notebook of the altimetry readings for your topographic model. These graphs will use different intervals between readings, so compare the preciseness of different levels of accuracy (called spatial resolution). Model is necessary.

Graph 1

1. Plot the average time for every 60 cm interval. (0 cm, 60 cm, 120 cm, etc.)
2. Connect the points with a smooth line.
3. Label the graph appropriately.

Graph 2

1. Plot the average time for every 40 cm interval.
2. Connect the points with a smooth line.
3. Label the graph appropriately.

Graph 3

1. Plot the average time for every 20 cm interval.
2. Connect the points with a smooth line.
3. Label the graph appropriately.

STEP FOUR: REFLECT AND ANALYZE YOUR RESULTS

Use the measurements taken from the experiment to complete the questions on the worksheet (see attached). Be thinking about how this investigation and process could be similar to and different from the real laser altimeter instrument onboard the LRO spacecraft.

worksheet

PING-PONG ALTIMETER

Name ______________________________

Data Table I

Drop	Distance ball traveled	Time (seconds)	Velocity (distance/time)
1			
2			
3			
4			
5			
		Average Velocity:	

Data Table II

Interval	Trial 1	Trial 2	Trial 3	Average Time (sec)	Distance Ball Traveled (cm)
0cm					
20cm					
40cm					
60cm					
80cm					
100cm					
120cm					
140cm					
160cm					
180cm					
200cm					
220cm					
240cm					
260cm					
280cm					
300cm					

worksheet

Data Table III

°R Interval	Original Distance Ball Traveled (From Data Table I) {D1}	Distance Ball Traveled (cm) {from Data Table II} (D2)	Altitude (cm) {D1-D2= Altitude}
0cm			
20cm			
40cm			
60cm			
80cm			
100cm			
120cm			
140cm			
160cm			
180cm			
200cm			
220cm			
240cm			
260cm			
280cm			
300cm			

Use your graphs and data to answer the remaining questions.

1. Why is it important to keep the distance between each altimeter measurement consistent?

2. How could we make the topographic profile more accurate?

worksheet

3. What does the graph look like in comparison to your model (i.e.. the same, inverted, etc.)?

4. Which looks more like the model, the graph you generated from the shorter or longer distances between readings (intervals)? Why do you think that is?

5. What will you have to do to the data to make the graph look right-side up?

6. The Lunar Orbiter Laser Altimeter aboard LRO sends out a laser beam and “catches” it as it returns from being reflected by the surface of the Moon. The instrument records how long it takes the beam to reach the surface and bounce back up. The scientists know how fast the beam is traveling; therefore, they can calculate how far it traveled. By measuring this time and multiplying by the velocity of the beam, they calculate how far the laser has traveled. They must then divide the distance the beam traveled in half.

   Why did you not divide in half to find the distance to the object in your topography model? How does this experiment work in comparison to the laser altimeter instrument on LRO?

7. Next, the scientist must compare this distance to a “baseline” distance we will call zero. On Earth, we might use sea level as the baseline. Another way to set the baseline is to start at the center of the planetary body being studied and draw a perfect circle as close to the surface of the body as possible. Using this baseline, the altitude compared to zero can be calculated and graphed. (Here, on Earth, we often say that some point is a certain number of feet above of below sea level.)

   Why do we not use the term “sea level” for Mars and other planets?

8. You will now calculate the altitude of the points along your model. To do this, subtract the distance the ball traveled, at each interval (from Data Table II) from the distance the ball traveled in Step One (see Data Table I). The number you come up with will be zero or greater. Use Data Table III to do your calculations. {The number in column B of this table should be the same for every interval. Remember, it was the baseline altitude and does not change.}

SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

Further Investigation:

The LRO spacecraft has six other scientific instruments onboard in addition to the Lunar Orbiter Laser Altimeter (LOLA). Check out http://lunar.gsfc.nasa.gov to find out more about the current science being done with the many different types of data from LRO.

To learn more about the LOLA instrument and view real laser altimetry data from the LRO spacecraft check out http://lunar.gsfc.nasa.gov/lola

This lesson is modified from the "Ping Pong Altimetry" lesson:
http://education.gsfc.nasa.gov/experimental/all98invProject.Site/Pages/ping.html

Extension Activities:

Look into how else NASA uses laser technology. Relate and compare that to how it is used onboard a spacecraft like LRO (examples include laser ranging and laser sensors).

How does the laser altimetry technology we use to study the topography of the Moon compare to the way in which we study the topography of the ocean floor?

Before we had laser altimetry instruments to collect precise or more absolute measurements many studies used more basic methods of determining topography through utilizing the observation of shadow length and sun angles. These measurements are more relative than absolute, however this method is still valued and employed by many scientific investigations. Can you determine why photoclinometry would still be valuable?