ICESat-2 Bouncy Ball Photon Collection Activity

Audience: Grades 4-8
Duration (60-75 minutes to complete)

Background

The NASA Ice, Cloud, and land Elevation Satellite-2 or ICESat-2 will provide scientists with height measurements that create a global portrait of Earth's 3rd dimension, gathering data that can precisely track changes of terrain including glaciers, sea ice, forests, buildings and more. These measurements will be taken using Light Detection and Ranging (LIDAR), a detection system that works on the principle of radar, but uses light from a laser. Learn more at:
the official ICESat-2 website

Light is a type of energy known as electromagnetic radiation. It is given out by hot objects such as the Sun, light bulbs, and lasers. When light hits a surface, its energy can be absorbed (soaked up), reflected, or deflected by refraction. This classroom activity focuses on the reflection of the light photons off the Earth's surface. Photons are tiny little particles of light, far too small to see individually. All light is made of photons.

The ICESat-2 satellite uses an onboard laser system to send green laser light photons to Earth's surface. The satellite will emit visible laser pulses at 532 nm wavelength, which is a bright green color on the electromagnetic spectrum. This specific shade of bright green is what the filters on the satellite detector lets pass through in order to count the photons. Any other wavelength gets filtered out as background noise. The satellite is 310 miles (498 km) above the Earth's surface. The ICESat-2 satellite precisely records the time-of-flight of individual photons as they travel from the instrument, reflect off Earth's surface, and then are detected as they return to the instrument's detector. These measurements allow scientists to calculate Earth's surface elevation. By doing this, they are able to measure the height of everything on our planet, including sea ice, ice sheets, landforms, forest and tree canopies, ocean surface and clouds. Depending upon the color, size, and shape of the objects the photons are bouncing off of, this determines how many photons will be reflected off a surface.

When we talk about the ability of light to reflect off the Earth's surface, we use the term albedo. The higher the albedo, the greater the reflectivity. Areas of the Earth that are white in color (ie snow and ice) have a greater albedo and therefore reflect more light. Darker areas will absorb more of the light.

The purpose of this activity is to show that only a small percentage of laser light photons make it back to the satellite, but are extremely valuable to scientific research. Scientists and engineers have been working on ways to retrieve more and more photons through the development of a sophisticated detector onboard the satellite. Learn more about space lasers at: NASA Space Lasers

SAFETY

When performing this activity, please be aware that there is a lot of motion of the participants and the bouncy balls. Make sure that the location chosen is in a closed environment in order to minimize the need to enforce larger safety measures. It is highly recommended that, if the activity is broken into groups, that there is only one "ball drop" occurring at a time.

TASK

To show the actions of light photons when laser light leaves the ICESat-2 satellite to take measurements of the Earth's height. Students will act as the ICESat-2 satellite and drop ten green bouncy balls, at once, and try to catch as many as they can. Each ball caught represents 10% of the returned photons. Students should work in teams of 3-5 students per team.

What You Need

Ten green bouncy balls (1" or 25mm in diameter)
Pen or pencil
Non-carpeted and carpeted floors
3-4 cardboard boxes of varying heights (boxes represent buildings)
Optional green laser pointer to show how a laser works

What to Do

1. Hold the ten green bouncy balls in one hand.
2. Drop the ten green bouncy balls, all at the same time, towards the ground.
3. Catch as many green bouncy balls as you can after the first bounce ONLY.
    a. Catch the balls using one hand only!
    b. Alternate doing this on a carpeted floor (represents vegetation) and non-carpeted linoleum/wood floor (represents ice)
4. Record how many balls you caught each time in the chart below.

ICESat-2 Photon Counting Activity	# of balls caught on carpeted floor	# of balls caught on non-carpeted floor	% of balls caught on carpeted floor	% of balls caught on non-carpeted floor
Drop 1				
Drop 2				
Drop 3				
Drop 4				
Drop 5				

5. Calculate the percentages of balls caught on the carpeted floor and balls caught on the non-carpeted floor. Since you are using 10 balls, each ball caught represents 10%.
6. Now, add a few cardboard boxes, sealed side facing up, onto the floor into the drop area.
7. Repeat Steps 1-3 from above.
8. Record how many balls you caught each time in the chart below.

ICESat-2 Photon Counting Activity	# of balls caught on carpeted floor	# of balls caught on non-carpeted floor	% of balls caught on carpeted floor	% of balls caught on non-carpeted floor
Drop 1				
Drop 2				
Drop 3				
Drop 4				
Drop 5				

Extension Activity:

What bouncy ball collecting techniques could you change in order to ensure a greater return of the bouncy balls (photons)?

- Think about using two hands.
- Think about how an engineer might designer a larger, or differently-shaped detector on the satellite.
- Does a larger detector mean you could catch more bouncy balls?

1. Try the activity again with the new techniques and boxes and fill in the table below.
2. What is/are your new techniques? List some ideas below:

a. _____
b. _____
c. _____
d. _____

ICESat-2 Photon Counting Activity	# of balls caught on carpeted floor	# of balls caught on non-carpeted floor	% of balls caught on carpeted floor	% of balls caught on non-carpeted floor
Drop 1 - Boxes				
Drop 2 - Boxes				
Drop 3 - Boxes				
Drop 4 - Boxes				
Drop 5 - Boxes				

Questions for Review:

1. Was there a difference in the amount of balls caught on the carpeted surface versus the non-carpeted surfaced? If so, why do you think there was a difference?
    a. Answer: This is subject to the results of the activity. Typically, you will get few returned balls on the carpeted surface, due to less bounce. This is because the pile of the carpet affects the bounce of the ball. Areas of vegetation have a lower albedo.

2. Will the satellite ever collect back every photon from the lasers?
    a. Answer: No, as light travels from the satellite to the Earth's surface, photons will can be absorbed (soaked up), reflected, or deflected by refraction.

3. What has an effect on what the photons do once they leave the satellite?
    a. Answer: Just about everything from the atmosphere, clouds, precipitation, types of surface on the Earth, angle of reflection, etc.

4. What do the cardboard boxes, in the activity, represent in the real world?
    a. Answer: The boxes represent buildings. ICESat-2 can measure the height of buildings too. Reflectivity of the photons from buildings can be different from that of ice, trees, roads, oceans, etc.

5. Did you notice a difference in how many bouncy balls (photons) were collected when you added the boxes to the activity?
    a. Answer: This is subject to the results of the experiment.

Next Generation Science Standards

MS-PS2-1 Motion and Stability: Forces and Interactions - Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

MS-ETS1-3 Engineering Design - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

4-PS3-3 Energy - Ask questions and predict outcomes about the changes in energy that occur when objects collide.

K-2-ETSI-1 Engineering Design - Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.