Cultural Resources
Education

Archaeo-Tech: LIDAR

Created by Jacob Hamill, SCDNR Heritage Trust Public Information Coordinator (2019).

Grade Levels
8th Grade Science; High School Physics

Estimated Time
1 – 1 ½ hours

Goal
Students will learn what laser light is and how it differs from ordinary light. Students will discuss how lasers are used in both everyday life and in a wide range of scientific fields. One application of laser technology is in LIDAR, a remote sensing method that uses laser pulses to examine the surface of the Earth. Students will watch a short film on LIDAR's application in the field of archaeology and replicate the general principles of LIDAR with an in-class activity.

Objectives
After viewing the *Archaeo-Tech: LIDAR* short film and completing the activity, students will be able to:

1. *Define* key terms, such as LASER, LIDAR, Digital Elevation Model, and Remote Sensing.
2. *Explain* what laser light is and *discuss* how it differs from ordinary light.
3. *List* applications of laser light in everyday life and in different scientific fields.
4. *Observe* LIDAR and *explain* its use in the field of archaeology.
5. *Replicate* the general principles of LIDAR using a miniature model landscape.
6. *Record* data on a graph and *apply* math skills to derive information from collected data.
7. *Create* an elevation model using data from the in-class activity and *compare* this model to real world elevation models created using LIDAR data.
8. *Summarize* how LIDAR works, how it has changed the field of archaeology, and *give recent examples* of LIDAR use by archaeologists.

South Carolina Academic Standards
Science

8.P.1 The student will use the science and engineering practices, including the processes and skills of scientific inquiry, to develop understandings of science content.

8.P.3 The student will demonstrate an understanding of the properties and behaviors of waves.

- **8.P.3A.3** Analyze and interpret data to describe the behavior of waves (including reflection, transmission, and absorption) as they interact with various materials.
- **8.P.3A.6** Obtain and communicate information about how various instruments are used to extend human senses by transmitting and detecting waves (such as radio, television, cell phones, and wireless computer networks) to exemplify how technological advancements and designs meet human needs.

H.P.1 The student will use the science and engineering practices, including the processes and skills of scientific inquiry, to develop understandings of science content.

H.P.3 The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.

- **H.P.3F.5** Obtain information to communicate the similarities and differences among the different bands of the electromagnetic spectrum (including radio waves, microwaves, infrared, visible light, ultraviolet, and gamma rays) and give examples of devices or phenomena from each band.
- **H.P.3F.6** Obtain information to construct explanations on how waves are used to produce, transmit, and capture signals and store and interpret information (including ultrasound imaging, telescopes, cell phones, and bar code scanners).

Activity Type: In-Class

This lesson is to be done as an in-class activity. The teacher will provide the required materials and necessary instructions.

Materials

- Sandbox LIDAR Lesson and Worksheet (1 for every student)
- Lab Equipment:
  - Large Clear Plastic Boxes (1 for every group)
  - Sand (enough to fill every box halfway)
  - Small decorative props (like LEGO®, Monopoly® Houses & Hotels, Miniature Plastic Trees, small rocks)
  - Graph paper (1 piece of graph paper for every group)
  - String (2 pieces of string for every group; the string needs to be long enough to stretch across the top of the plastic box)
  - Line Level (or String Level) (1 for every group; this will be used to make sure the students are level when taking measurements)
  - Ruler (1 for every group)
  - Markers or Colored Pencils

Lasers and LIDAR Background Information

- The term **LASER**, which stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation, is a special, artificially created kind of light. Laser light is created when atoms in special glasses, crystals, or gases are excited by an electrical current, causing the electrons of the atoms to emit photons (particles of light).
- Laser light is different from ordinary light. Ordinary light is made up of light waves with many different wavelengths, which spread out as they travel. Laser light only contains light waves of a single wavelength (monochromatic) which travel parallel to each other, with their crests and troughs in lockstep (coherent). This produces an unbroken beam of light that stays focused for vast distances. This property makes lasers very useful in a wide range of applications. One application is measuring distance and mapping the surface of the Earth through a survey technique called LIDAR.
- **LIDAR**, which stands for *light detection and ranging*, is a **remote sensing** method used to examine the surface of the Earth. LIDAR works on the principle of RADAR but uses light from a laser instead of radio waves.
- LIDAR equipment includes a laser scanner, Global Positioning System (GPS), and an Internal Navigation System (INS), generally mounted to a small aircraft.
- LIDAR uses light in the form of a pulsed laser beam to measure ranges (variable distances) to the Earth. In an aerial LIDAR survey, a low flying plane flies over a survey area, sending out laser pulses to the ground surface, which are reflected to the laser scanner.
- Detecting the returning pulses, the LIDAR equipment measures the time it took for the pulses to go from the sensor to the ground and back. The distance between the sensor and the ground is calculated based on the speed of light.
- During a survey, the airplane's position is determined using GPS, and the direction of the pulses are measured using the Internal Navigation System.
- Because one laser pulse may reflect off multiple surfaces, like the top of a tree, a house, or the ground surface, there can be multiple returns for a single pulse, which is used to map things such as forest canopies, buildings, and the ground surface.
- There are two types of LIDAR: topographic and bathymetric. Topographic LIDAR uses a near-infrared frequency laser to map land, while bathymetric LIDAR uses water-penetrating green light to measure seafloor and riverbed elevations.
- LIDAR can map physical features with a very high accuracy and resolution. It can even map features hidden by vegetation.
- A LIDAR system can send out as many as 160,000 laser pulses per second, all of which register one or more points on the landscape. These points are compiled into a "**point cloud**", which generates precise three-dimensional models of the Earth's surface. Different points can be filtered out, depending on the need. For example, archaeologists could remove the vegetation cover from a LIDAR survey and produce an image that depicts only the changes in ground elevation.

- Why are archaeologists interested in LIDAR? LIDAR data can be used to create three-dimensional models of landscapes. These models help archaeologists study how people interacted with the physical environment. In the case of the shell rings on Pockoy Island and other archaeological sites across the globe, LIDAR helps archaeologists find sites that were previously unknown because they were covered by vegetation.

Pockoy Shell Ring Background Information

- Pockoy Island (pronounced Pock-ee) is a remote South Carolina sea island and a part of the Department of Natural Resource's Botany Bay Heritage Preserve / Wildlife Management Area. The property is located on the northeastern corner of Edisto Island in Charleston County.
- Botany Bay is one of the largest relatively undeveloped wetland ecosystems on the Atlantic Coast, providing a critical habitat for numerous wildlife species.
- The **cultural resources** of Botany Bay are equally important, with sites dating from approximately 4,000 years ago to the nineteenth century. Several sites are listed on the National Register of Historic Places, including the outbuildings from Bleak Hall Plantation, granite markers from the 1850 Alexander Bache U.S. Coast Survey, and the Fig Island Shell Rings.
- The shell ring on Pockoy Island was first identified in early 2017 by analysts studying Hurricane Matthew's effect on South Carolina's coastline. When studying maps produced by aerial light detection and ranging, or **LIDAR**, the analysts noticed strange circular features on the coast of Pockoy Island, indicating the presence of a shell ring. **Shovel testing** began in the summer of 2017, which confirmed the ring's existence. **Radiocarbon dating** conducted on recovered animal bone revealed that the site was approximately 4,300 years old, making it the oldest known shell ring in South Carolina.
- Testing continued in late 2017, and large-scale **excavations** were conducted in May and December of 2018.
- **Shell rings** are structures found along the coasts of South Carolina, Georgia, Florida, and Mississippi, dating to the **Late Archaic** period (roughly 5,000 – 3,000 years ago). Dating suggests that the shell ring on Pockoy Island was built over a relatively short period of time, around 20 – 30 years.
- As the name indicates, shell rings are large circular or semi-circular structures made from piled shell. Some are C-shaped and U-shaped, while others are irregularly shaped or made up of multiple shapes. Pockoy is doughnut-shaped. Shell rings are primarily composed of oyster shell, but cockles, periwinkles, clams, and whelk shells are also commonly found. Shell rings range in size from 30 to 250 meters in diameter and are between 1 and 6 meters high. The Pockoy shell ring is approximately 60 meters in diameter.

- Another key feature of a shell ring is a central area called a **plaza**, which is devoid of shell. **Archaeologists** speculate that this area was maintained for ceremonial purposes or contained a structure.
- Archaeologists have been studying shell rings for decades but there is still a lot we do not know.
- Archaeologists are unsure if shell rings were intentionally built or not. Some argue that shell rings were inadvertently created from piles of discarded shell following meals over a long period of time. Others believe shell rings were planned structures built from leftover shells from feasts and other quarried shell.
- Archaeologists are also unsure what shell rings were used for. Some believe shell rings were sites of general human occupation, while others theorize shell rings were ceremonial structures only used for specific purposes at specific times.
- Archaeologists have recovered thousands of **artifacts** from Pockoy and other shell rings. The most common artifacts are pottery, shell, and animal bone.
- What archaeologists do not find at a site can also tell them a lot about the people that lived there. Very little stone has been found at Pockoy, telling archaeologists that the people that once lived there did not rely primarily on stone tools. Some archaeologists interpret this as evidence that the shell ring was not a site of human occupation, but others propose that this is reflective of the environment – good stone is hard to find on the coast so the people living there relied on tools made out of shell and bone.
- Due to Pockoy's location on the coast, the site is vulnerable to coastal erosion and rising sea levels. With a rate of 9.5 meters of coastline lost per year, Pockoy is expected to be completely engulfed by the ocean by 2024.
- Climate change, or "heritage at risk", poses a serious challenge to archaeologists, and Pockoy is not the only site facing destruction. According to a report by DINAA (The Digital Index of North American Archaeology), a one-meter rise in sea level would result in the loss of 13,583 archaeological sites across the Southeastern United States. It is imperative to salvage, protect, and study these vulnerable sites before they are gone.

Vocabulary

- **Archaeological Site:** A place where human activity occurred, and material remains were deposited.
- **Archaeologist:** A scientist who studies the material remains of past human activity.
- **Archaeology:** The scientific study of past human cultures by analyzing the material remains (sites and artifacts) that people left behind.
- **Cultural Resources:** Evidence of past human activity. They include archaeological sites, historic homes, battlefields, burial grounds, shipwrecks, historic and prehistoric artifacts.

- **Digital Elevation Model:** a 3D representation of terrain elevations found on the Earth’s surface, created from point cloud data.
- **LASER (Light Amplification by Stimulated Emission of Radiation):** A device that generates an intense beam of coherent monochromatic light (or other electromagnetic radiation) by stimulated emission of photons from excited atoms or molecules.
- **LIDAR (Light Detection and Ranging):** A detection system that works on the principle of radar but uses light from a laser. It is a remote sensing method used to examine the surface of the Earth**.**
- **Point Cloud:** Large data sets composed of 3D point data collected from a LIDAR aerial survey.
- **Remote Sensing**: the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.

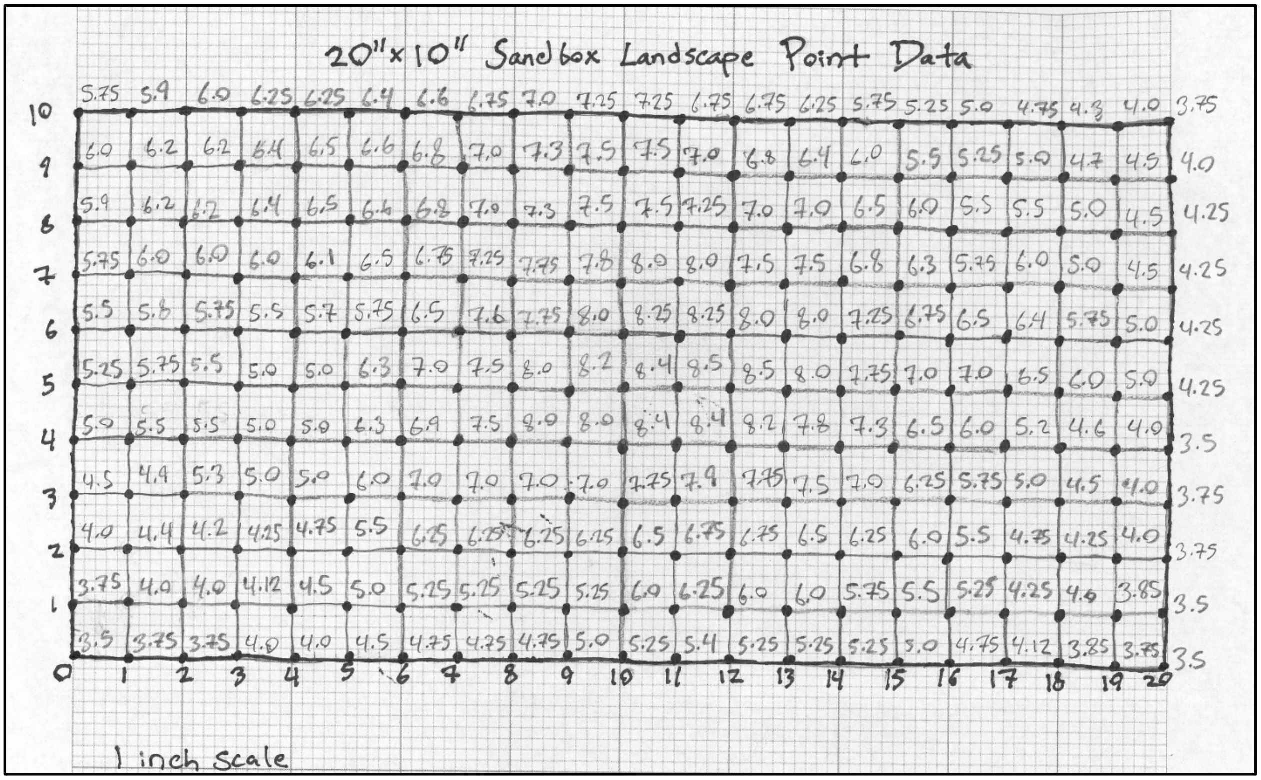
Lesson

1. Before starting this lesson, students should be familiar with the scientific definition of waves, the electromagnetic spectrum, and the properties of light waves.
2. Prepare the required materials for the activity before beginning the lesson.
    - Sandboxes should be of a uniform size. Using a ruler, mark equal intervals of measurement on the lip of the box. Students will use these markings to guide themselves when measuring distances from the top of the box to the sand. Note that smaller units of measurement will yield more detailed elevation models.
        - Students can complete this step during the activity if desired.
    - Create a two-dimensional graph that corresponds to the width and length of the plastic box. Have the box’s width be the y-axis and the length be the x-axis. The graph should be large enough to write measurements at each point. It is also recommended to use light ink or a pencil when creating the graph because students will color in their graphs at the end of the activity to produce their elevation models.
        - Alternatively, students can use the graph paper from the worksheet to create their own graphs.
    - Fill each sandbox halfway with sand and give each box a few props to decorate with.
    - Give each group the necessary tools specified in the **Materials** section under “Lab Equipment”.
    - Print copies of the Sandbox LIDAR Lesson and Worksheet.
3. Begin the lesson by reviewing what your students have learned about light waves so far. Answer any questions students might have about the behavior and properties of light.
4. Demonstrate the differences between ordinary light and laser light with a flashlight and laser pointer. Ask you students to brainstorm how these devices use light waves in different ways.

5. Shine the flashlight on a wall or flat surface. Have your students give observations and make connections based on their knowledge of light waves. Then shine a laser pointer on a wall or flat surface. Have your students compare the laser pointer to the flashlight and hypothesize why it is different.
6. Explain to your students that the term laser is an acronym, standing for “Light Amplification by Stimulated Emission of Radiation”. Discuss the science behind lasers and how they differ from other applications of light waves.
7. Ask your students to give examples of technology or jobs that use lasers. Encourage students to consider how often they interact with lasers in their daily lives. Explain that in the field of archaeology, the scientific study of past humans and cultures, lasers are used in a remote sensing method called LIDAR.
8. Show your class the *Archaeo-Tech: LIDAR* short film. After the film, answer any questions students might have about LIDAR or archaeology.
9. Tell your students that they will be conducting a “miniature LIDAR survey” where they will collect elevation data from a sandbox. With their data, they will create a 2-D elevation model that is akin to real-life maps produced by LIDAR data.
10. Distribute copies of the “Sandbox LIDAR” Lesson and Worksheet and divide the class into groups of five to six students. Each group will need two pairs of students to hold the x-axis and y-axis string level across the top of the box, and another student to take measurements of the distance from the string to the sand (which represents the elevation of the airplane).
11. Give an overview of the activity. Students can follow along in their worksheet.
    - Tell your students that the sandboxes are miniature landscapes and they will be mapping the elevations of their landscape using a method that is similar to the way aerial LIDAR data is collected.
    - Have your students create undulations in the sand, creating areas of higher and lower elevation. Students can decorate their landscape using small props, like miniature plastic trees, monopoly pieces, or LEGOS. These props can represent anything, like buildings, archaeological sites, or forests.
    - When their miniature landscapes are ready, have your students measure the dimensions of their sandbox. If you have not done so prior to starting the lesson, have your students mark equal intervals of measurement on the lip of the box using a washable pen or marker. Explain that the smaller the unit of measurement is, the more accurate their elevation model will be.
    - Using the box’s length as the x-axis and the width as the y-axis, have your students create a chart that corresponds to their unit of measurement (see example below). Explain that at each point on the graph they will be writing the distance from the string (which represents the altitude of their airplane, as well as latitude and longitude) to the surface of the sand or prop.

Example 1

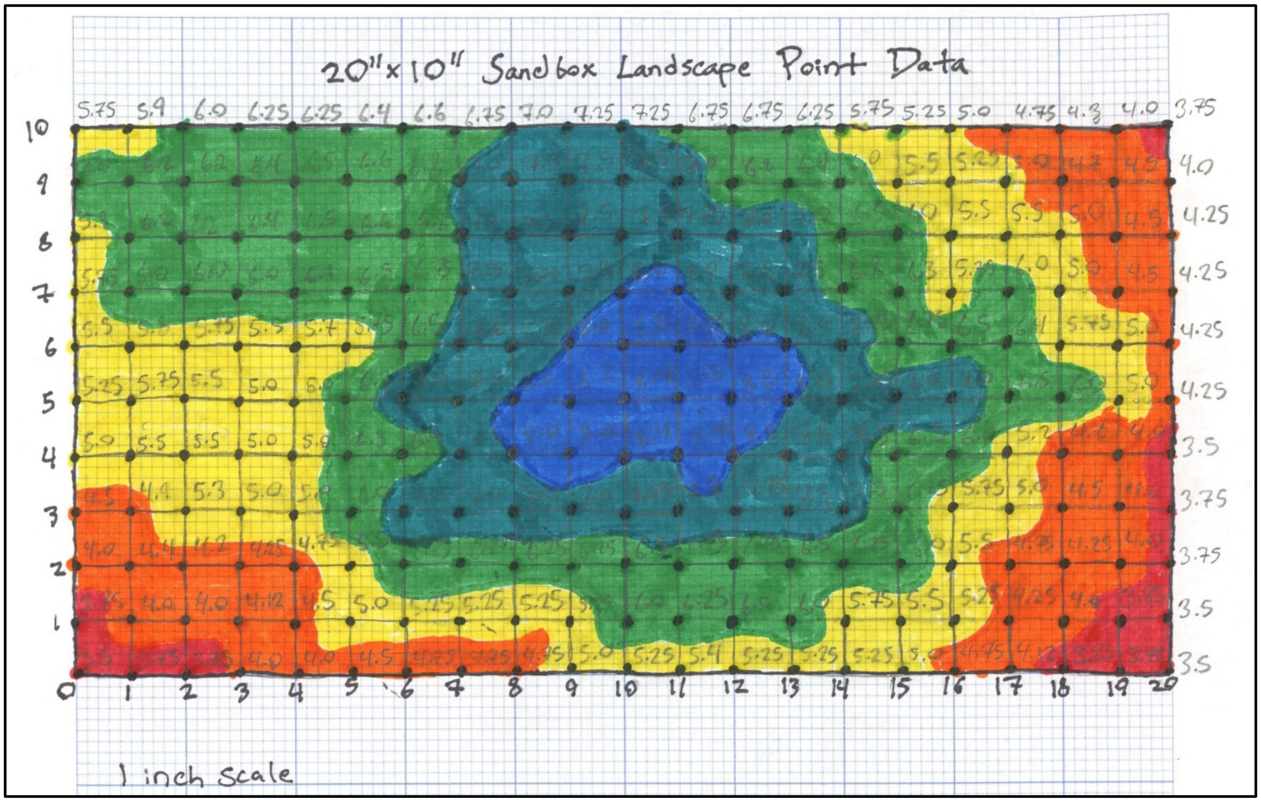
Please note that your version does not need to be this detailed.



12. Have your students complete the activity by taking measurements at uniform intervals and recording data on the graph paper.
13. Optional. After students have finished collecting their data, have them convert their measurements from distance to elevation. Students can do this by subtracting the distance from the altitude (the height of the string or the height of the box). For this activity we will consider the bottom of the box to be sea level.
14. When students are done converting distance to elevation, have them find their lowest elevation point, their highest elevation point and the range of their elevations.
15. Tell your students that they will be coloring in their charts to produce an elevation model, like the maps produced by LIDAR. Have dark blue represent the lowest elevations, and transition from blue to green to yellow to orange to red, with red representing the highest elevations (see example on next page).

Example 2

Marker was used for this example, but colored pencils or crayons will also work.



16. Have your students create their elevation models. Instruct them to first color in the points they took measurements from and then fill in the blank space. If using crayons or colored pencils, students can create a smooth gradient between the different colors.
17. When finished, have your students compare their elevations models as a class. Which models are more accurate than others? Why? What would happen if you doubled the number of points you took?
18. Discuss LIDAR as a remote sensing technique and show your students real examples of digital elevation models, point clouds, or other models produced from LIDAR data. Have them compare their models to real ones. Ask your students what their models might look like if they were three-dimensional and not two-dimensional.
19. Optional. Have your students read this article from National Geographic about how archaeologists found Mayan ruins in the jungles of Belize and Guatemala using LIDAR.
    - https://news.nationalgeographic.com/2018/02/maya-laser-lidar-guatemala-pacunam/

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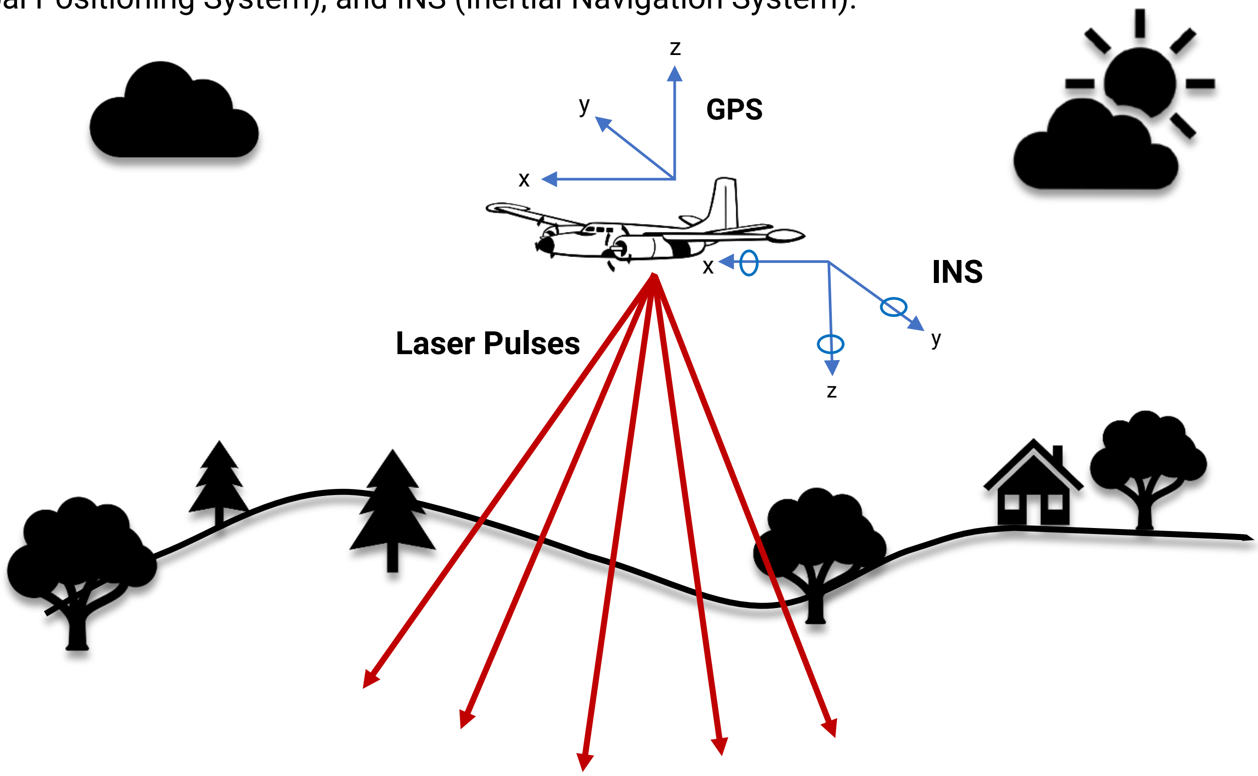
Sandbox LIDAR

Lesson and Worksheet

Reading for Understanding: LIDAR

LIDAR, which stands for **Li**ght **D**etection **A**nd **R**anging, is a remote sensing method that uses light in the form of a laser to measure the elevation of the ground, as well as any features on the ground (like trees, buildings, etc.). **Remote sensing** is the science of obtaining information remotely, or from a distance, usually from aircraft or satellite. LIDAR data is commonly obtained using an airplane. Three major pieces of equipment are used in obtaining aerial LIDAR data: a laser scanning system, GPS (Global Positioning System), and INS (Inertial Navigation System).



In a LIDAR survey, a pulsed laser light is sent from the airplane to the ground. When a laser pulse hits either the ground or an object (like the top of a tree), the pulse is reflected back to the laser scanner, which measures the time it took for the pulse to travel to the ground and back. The distance between the scanner and the ground is then calculated using the speed of light.

A single laser pulse can return to the scanner as one or multiple reflections. If a pulse encounters multiple surfaces as it travels towards the ground, for example if it travels through the canopy of a tree, it will split into as many returns as there are reflective surfaces. Scientists can use LIDAR data to not only study the elevation of the ground but also the elevation of different features on the landscape.

Ground elevation is calculated using information from the GPS, which keeps track of the airplane's altitude and location. The distance between the sensor and the ground is subtracted from the plane's altitude to give an accurate reading of elevation. The INS is a complex device that monitors the

plane's tilt in the sky, as well as the angle of the laser pulses. These measurements are factored in when calculating elevation.
A LIDAR system can send out as many as 160,000 laser pulses per second! That creates a lot of elevation points, all of which have an x, y, and z coordinate. Scientists compile all these points into a "point cloud", which generates precise three-dimensional models of the Earth's surface. Different points can be filtered out, depending on the need. For example, archaeologists could remove the forest cover from a LIDAR survey and produce a map that showed only the changes in ground elevation.

Because of LIDAR's versatility and high resolution, it is used in a wide range of professions, such as archaeology, urban planning, geology, forestry, hydrology, and more.

Instructions

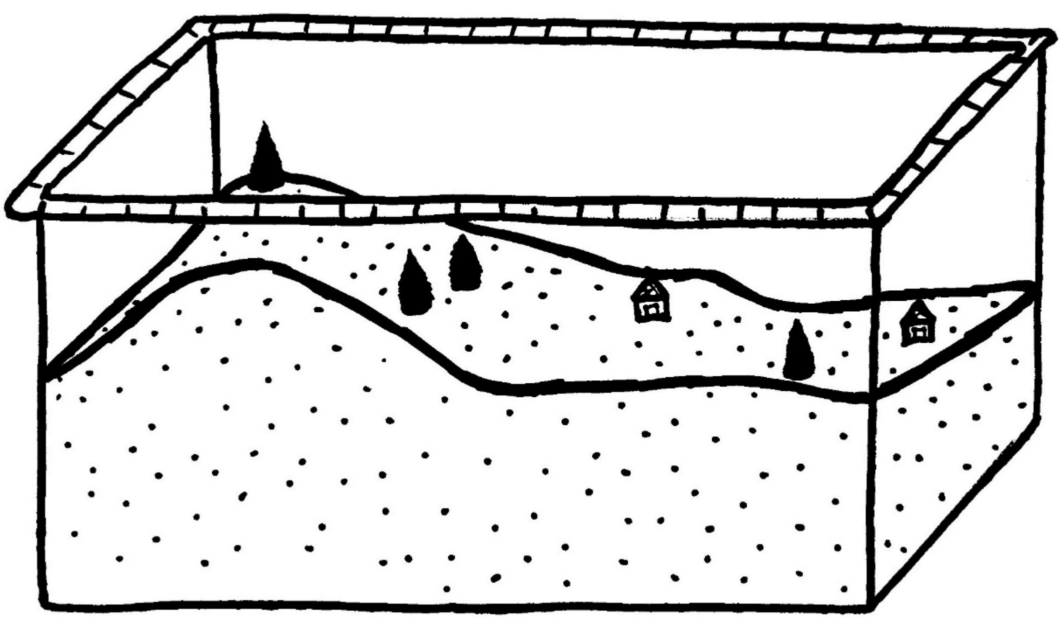
In this activity you will be you will be conducting a "miniature LIDAR survey" to measure the elevation of sand in a sand box. After collecting your data, you will create a two-dimensional elevation model, similar to the models scientists use when studying data collected from aerial LIDAR surveys.

For this activity your group will need a plastic box filled halfway with sand, two pieces of string long enough to stretch tightly across the top of the plastic box horizontally and vertically, a line level, a ruler, graph paper, and colored pencils or markers.

Step One

Create your landscape. Move the sand around in the sandbox to create areas of high and low elevation. Decorate your landscape with props. These items can represent trees, buildings, ruins, etc.

Example



Step Two

Measure the dimensions of your sandbox using a ruler. As a group, decide what units of measurement you want to use to plot your points. Remember, the smaller the unit of measurement you use, the more accurate your elevation model will be. With a ruler, mark the edges of the sandbox using a marker or pen. These lines will be used to line up the string when taking distance measurements in STEP FOUR.

Sandbox Dimension (in centimeters or inches):

Height: ____________
Length: ___________
Width: ____________

Unit of measurement used:

Step Three

Using the length and width of the sandbox and the unit of measurement you chose in STEP TWO, create a chart for your landscape. Have the box's length be the x-axis and the box's width be the y-axis. You will use this chart to record distances for each point. You may use your own graph paper, or the graph paper provided in the back of the handout.

Step Four

Record your distance measurements. The string represents the altitude of your airplane. The string will also help you keep track of your location on your miniature landscape. Using the markings you made on the edge of the box, line the strings up so they intersect perpendicularly. Use the line level to make sure the string is level with the top of the box. Where the strings intersect will be a point on your graph and where you will take a measurement. Using a ruler, measure the distance from the string to the ground or top of a prop. Record your data on the graph from STEP THREE. Repeat this step until you have completed your survey of the sandbox.

Step Five

After you have collected all the distance readings, convert your measurements from distance to elevation. You can do this by subtracting distance from the height of the string (altitude), which for this activity is also the height of the box.

Altitude (Box Height) – Distance (from string to ground) = Elevation

Next, find your lowest recorded elevation and write it in the space below.

Now, find your highest recorded elevation and write it in the space below.

Calculate the range of elevation for your landscape.

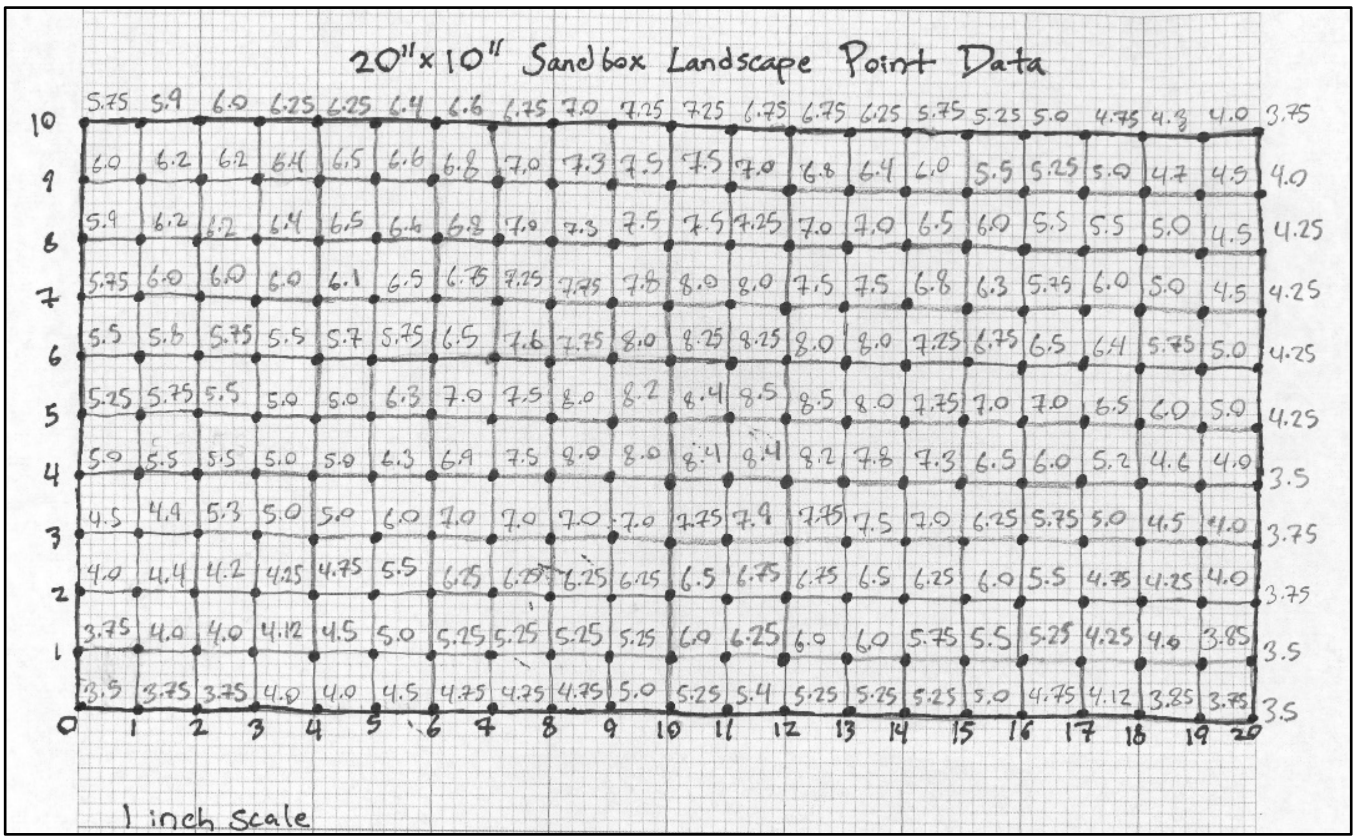
Using this information, create a color scale for your elevation map. Have dark blue represent the lowest elevations and red represent the highest elevations. Fill in the scale going from blue to green to yellow to orange to red.

Lowest Elevation **Median** **Highest Elevation**

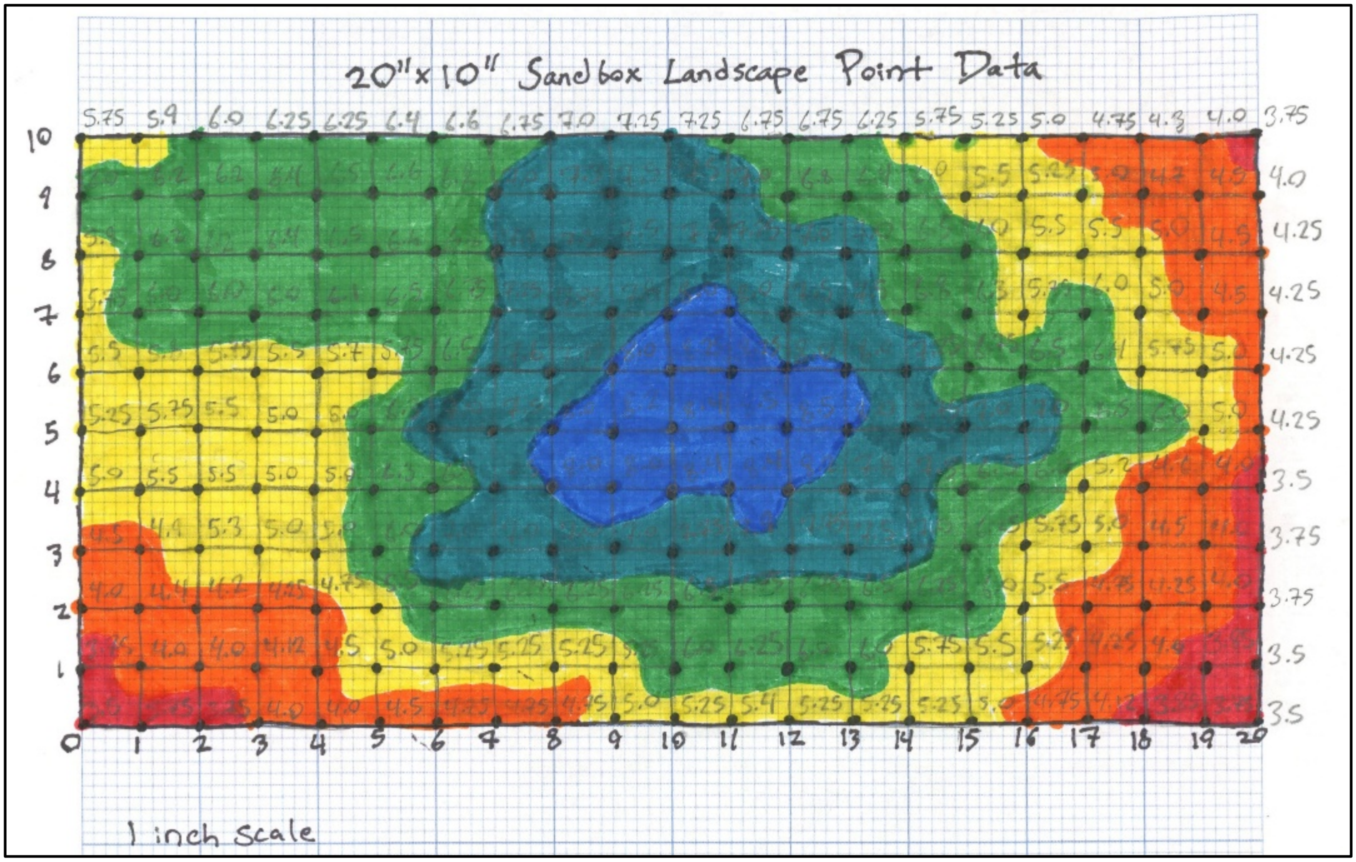
Step Six

Using the color scale from STEP FIVE, color in your graph from STEP THREE. Start by coloring in the points you recorded on the graph. Then shade in the areas around the points, creating a gradient from areas of higher elevation to lower elevation.

Your graph should go from looking like this:



To this:



Step Seven

Now that you have completed the activity and finished your elevation model, compare your model with a model from another group and answer the following questions.

How are your models similar?

How are they different?

Which model has a higher accuracy? Why?

Now reflect on the activity and answer the following questions.
How many distance measurements did you take? Do you feel like you took enough measurements to accurately model your miniature landscape?

Did any props show up in your elevation model? If so, how did they appear on the model? Describe their shape.

Describe the limitations of this activity. What are some of the problems of taking the distance readings by hand?

Explain how the methods you used in this activity are similar to the process of aerial LIDAR.

Describe how LIDAR is different from the methods you used in this activity.

GRAPH PAPER **Name: ______________________**