STUDENT MODULE 1:

GET TO KNOW YOUR TOOLS BY GRAPH MATCHING WITH VERNIER MOTION DETECTORS

(Adapted from https://www.vernier.com/experiments/pwv/1/graph_matching/)

Name: ____ Date: ______ Pd: _____

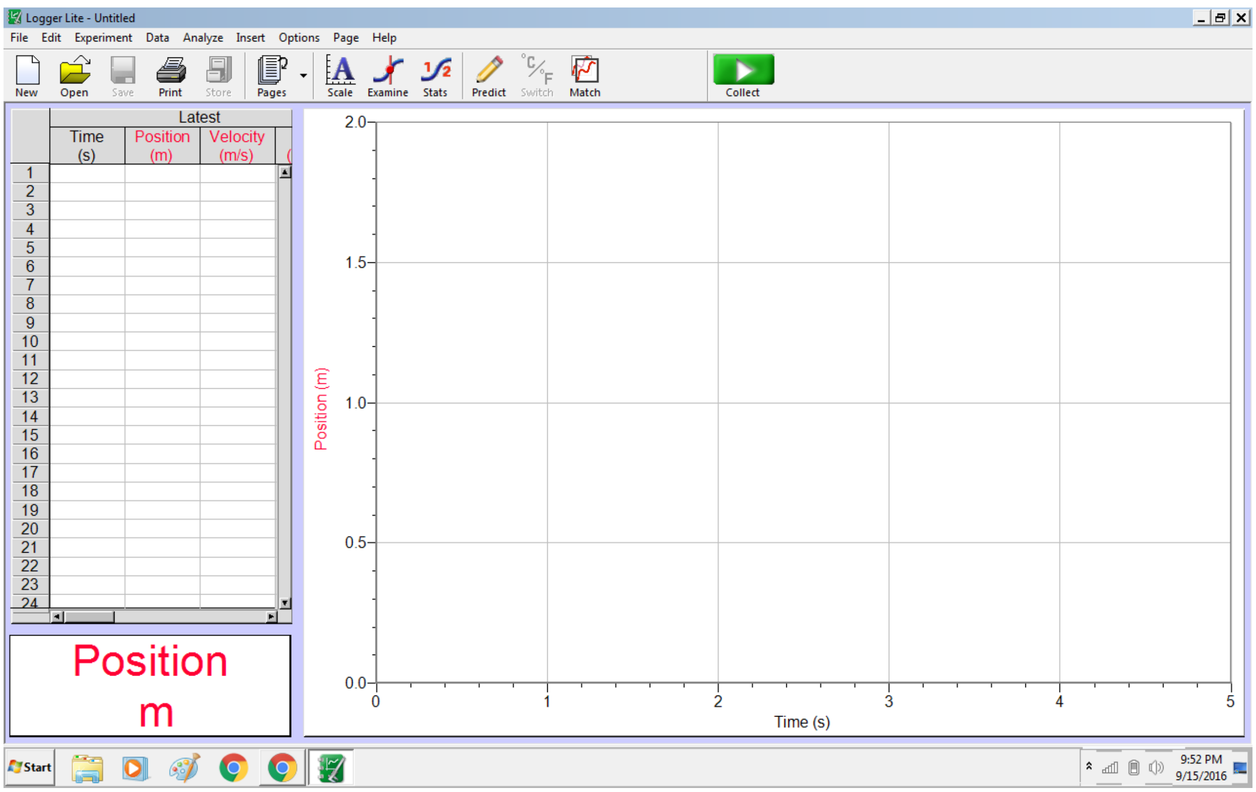
Introduction to Vernier Motion Sensors: GRAPH MATCHING ACTIVITY

Materials Required:

1. Go! Motion Detector connected to Laptop OR Motion Detector connected to LabQuest 2 Handheld Device
2. Meterstick
3. Solid-colored Tape or material to mark position

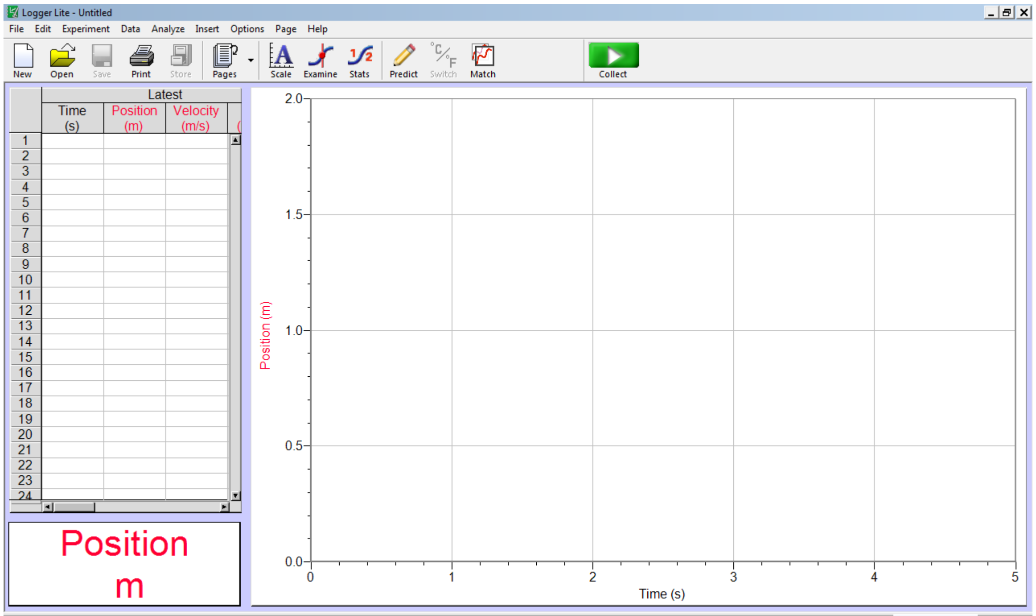
Procedure:

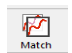
1. Use the USB Cable to connect your Go! Motion sensor to the USB port in your laptop.
2. Open “Logger Lite” or “Logger Pro” from the Desktop (depending on what is available in your classroom). You should see a screen that looks like the one below:

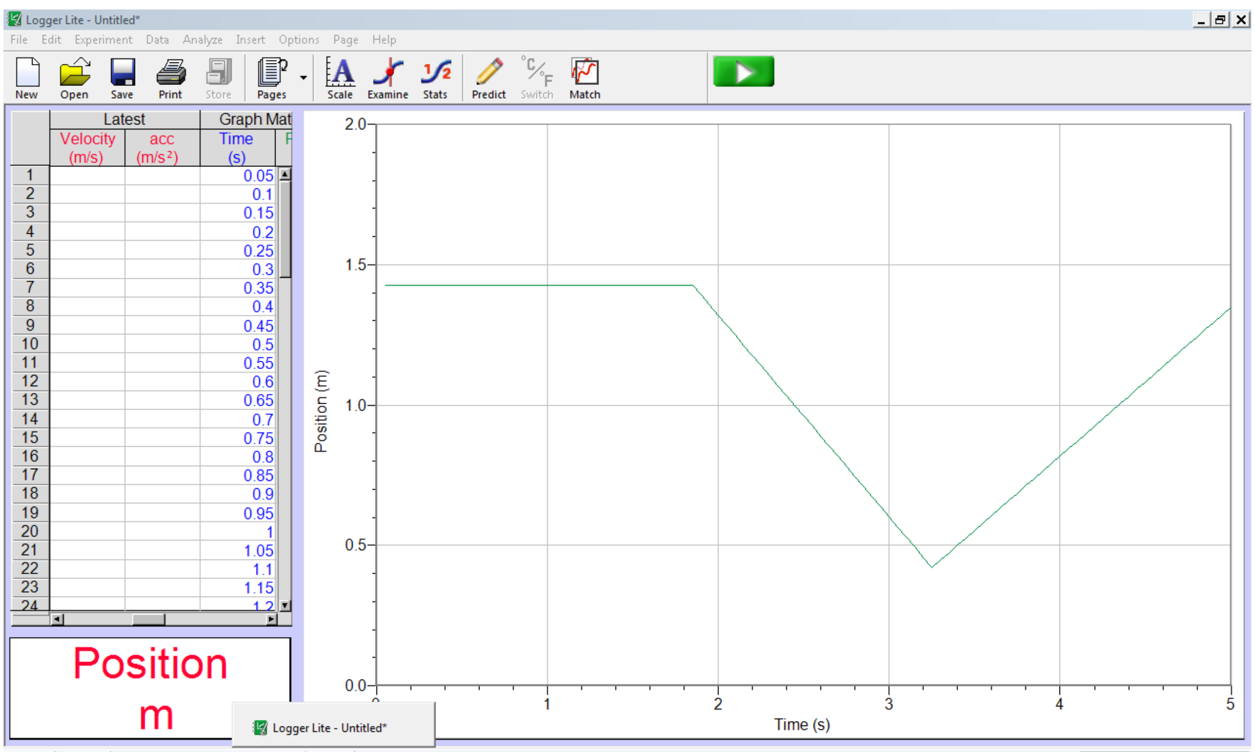


3. Spend a few minutes exploring the Motion Detector functions and the data logging software. When you click the Green “Collect” Icon in the menu bar, you will hear the timer of your Motion detector start ticking. The instrument is sending out a series of ‘pings,’ or sound waves, recording the time it takes to reflect back to its speaker/receiver, and providing a value for distance on your screen. What happens when you move your hand toward the speaker for 5 seconds? What happens when you move it away? ** You do not have to write responses here, but take time to get to know the instrument before starting the exercise.

4. GRAPH MATCHING:



Click the Match Icon (looks like this: ) to generate a Position vs. Time graph on your page. Each group will receive a different version of a graph to match. An example is below:



5. Use the print screen (PrtSc) function on your keyboard to grab the image of the computer generated graph and paste it below. If you are working from a hard copy, sketch the graph below and be sure to label your axes.

With your group, select a test subject for your first Graph Match (Each of you will be a subject at some point during the exercise). Write that person's name here: ________________________

6. Create a list of steps that that person must follow (during the short 5-10 second time span on your screen), to generate a graph that is identical to the one that has been generated for you.

Write your steps below (example: *"For the first 2 seconds, stand still 2 meters away from the motion sensor"):*

7. Practice without the motion sensor turned on, using a stopwatch (classroom timer or smartphone) to get a sense for the speed required of the subject of this graph.

8. Start collecting data by pressing the Green Arrow or hitting your space bar. Paste your best-matched graph below using the PrtSc function again

9. Answer the following Questions
   a. Was your original plan (written out in step 6) sufficient to help your team successfully match the pre-generated Position-Time graph?

   b. What challenges did your group run into while attempting to generate a best-match graph?

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10. In Logger, select the File Option, and “New” to create a clean Position-Time Graph.

11. Generate a second Position-Time graph to match. You can click that icon several times to choose your favorite option.

12. Repeat Steps 5-9 for your new graph with A NEW GROUP MEMBER listed as your test subject. Do not forget to Print Screen both the pre-generated graph and your best match in this document

9. Answer the following Questions for this second graph matching exercise:
   a. Was your original plan (written out in step 6) sufficient to help your team successfully match the pre-generated Position-Time graph?

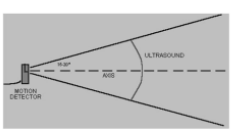
   b. What challenges did your group run into while attempting to generate a best-match graph?

<u>Analysis/Discussion /Questions</u>

The motion sensor you used in this activity is a remote sensing device which takes advantage of SOUND. Sonar is a remote sensing tool used to map surface regions of our Earth. How does it work? **READ THE DESCRIPTION BELOW, AND ANSWER THE DISCUSSION QUESTIONS.**

How the Sensor Works

This Motion Detector emits short bursts of ultrasonic sound waves from the gold foil of the transducer. These waves fill a cone-shaped area about 15 to 20° off the axis of the centerline of the beam. The Motion Detector then "listens" for the echo of these ultrasonic waves returning to it. The equipment measures how long it takes for the ultrasonic waves to make the trip from the Motion Detector to an object and back. Using this time and the speed of sound in air, the distance to the nearest object is determined.



Note that the Motion Detector will report the distance to the closest object that produces a sufficiently strong echo. The Motion Detector can pick up objects such as chairs and tables in the cone of ultrasound.

The sensitivity of the echo detection circuitry automatically increases, in steps, every few milliseconds as the ultrasound travels out and back. This is to allow for echoes being weaker from distant objects.

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1. If you experienced noise in your data set (rough lines around your target position value, what might be the reason based on the description above?

2. Explain how the motion detector determined how far away from it you were during each time interval of your graph match.

3. How might this tool be used to create a graph showing an elevation profile for a surface region of Earth? Would your experimental set-up be the same? List your ideas below (we'll revisit this question after our remote sensing demonstration).

STUDENT MODULE 2:

CONTEXT, DEMONSTRATION, INTRODUCTION TO REMOTE SENSING IN EARTH SCIENCE

Name: ____Date: ____________ Pd:

REMOTE SENSING: GATHERING INFORMATION FROM A DISTANCE

THE CHALLENGE (PREVIEW): *You have been contracted by NASA to develop a prototype for a sonar device that can be used to produce a vertical profile replicating the topography of any surface region on Earth. NASA'S Operation IceBridge uses many devices to collect information about the polar regions of Earth from an airborne laboratory for scientists and citizens to use who can't necessarily access those places. Sonar has been used for decades to map our ocean floors and provide us with information we would otherwise not have access to. Before you develop your design, we are going to walk through the basics of remote sensing, focusing on SONAR.*

Part 1: Some Background Information

Using sources from the web or those provided by your instructor, respond to each of the following questions below. Include the source(s) used to find each answer next to your response.

Question	**Response**	**Source**
1. One of the remote sensing devices used by NASA's Operation IceBridge is an Airborne Topographic Mapper (ATM) which uses LiDAR. How does this instrument provide information about the surface of polar ice sheets?		
2. How often and where does Operation IceBridge fly to collect information about polar regions?		
3. Other than LiDAR, what other remote sensing instruments are used during Operation IceBridge missions?		
4. Sonar is another type of remote sensing device. What happens to a sound wave traveling through air if it comes in contact with a solid object?		
5. Describe 2 differences and one similarity between LiDAR and SONAR.		

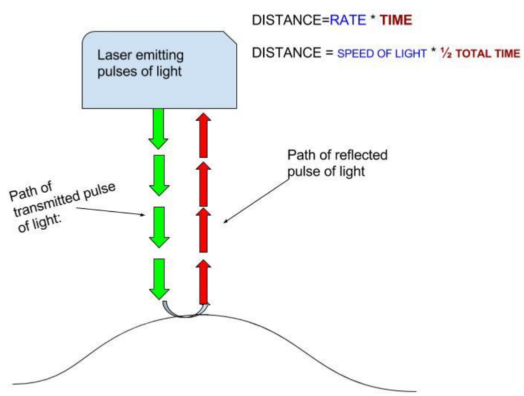
Below write, in your own words, how remote sensing is used as a tool in Earth Science:

Part 2: Math Drives the Process

In part 1, you described how LiDAR was used to collect data on Earth's surface topography. Follow the example below to investigate some of the math behind that process. Then try it yourself with **Practice Problem A.**

Example: A pulse of light travels from a remote sensing source as depicted in the cartoon below (SIMPLIFIED DEPICTION!). The pulse is reflected back in a total time of $3 \times 10^{-6} s$. This means it took half of that time $1.5 \times 10^{-6} s$ to reach the object in the first place. The speed of light in air is $c = 299{,}792{,}458\ m/s$.

Using the formula $distance = \frac{rate}{time}$, we can calculate the distance of the object from the sensor as $distance = \frac{299792458\ m/s}{1.5 \times 10^{-6} s}$ = 457 meters or about 1500 feet.



TRY IT!

Practice Problem A

1. The speed of sound in water is 1,484 m/s. If a sonar device attached to the bottom of a ship emits a 'ping' or a sound wave and detects that the wave has echoed back in a total time of 10.0 seconds, what was the time required for the ping to reach the ocean floor at that point (half of the total time)?______

2. How far away from the sensor was the ocean floor at that point (using the distance-rate-time formula as described in the example)?

   ____

3. Extension: If the ship with the sensor was sailing 12,100 m above absolute ground level, how high above the lowest level of the ocean floor was the surface point described in this problem? If you're not sure how to answer this yet, come back after the demonstration!

Debrief: *The remote sensing devices used on NASA's Operation IceBridge calculate points in a similar way throughout 8-12 hour missions over pre-planned flight lines. View the video on data visualization of Greenland's Helheim Glacier linked below to get a better picture about how height is used to measure ice topography.*

Laser Visualization of Helheim Glacier

Next, follow along through the 'textbook-mountain remote sensing demo!'

PART 3: DEMO TIME!

Respond to the following questions throughout the "Textbook Mountain" Demo:

1. Describe the procedure and set-up used to produce a graph representing the "textbook mountain" set up in front of you.

2. Did the graph on the screen match the shape of the textbook mountain range on the table? If not, describe the difference between the graph and the real set-up.

3. Draw a model that illustrates what was happening (both visible and invisible) as the motion detector/sonar passed above the textbook mountain range.

4. Describe at least two similarities and two differences between today's demonstration and your graph matching activity.

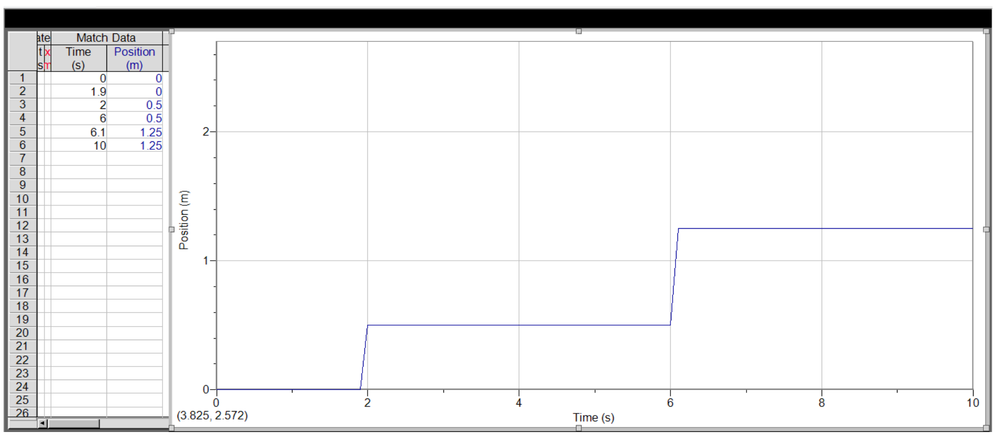
5. What further steps should be taken to create a vertical profile that truly matches the mountain range as it appears?

Part 4: Data Use and Interpretation

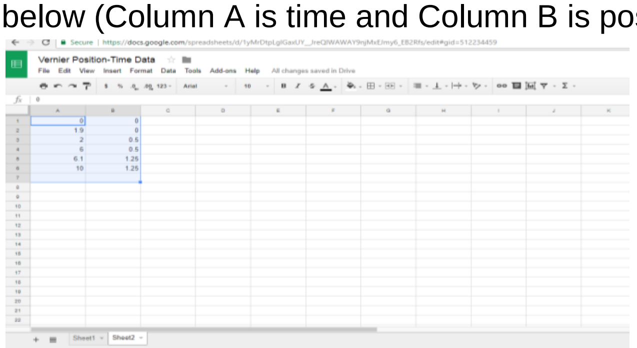
Transform data from demo scan into a true representation of Textbook Mountain. Obtain data from instructor (most likely shared in a Google Sheet. Follow the instructions below to create an accurate representation of the elevation profile for Textbook Mountain. **Your instructor will share the data with you via Google Docs. MAKE A COPY and RENAME** before editing! If you are not using Google Docs, follow instructions from your teacher for how to proceed.

GOOGLE SHEETS METHOD:

Below is a sample data set. Yours may look similar or very different and it may have more or less data points. You might see noise thanks to interference from other objects beneath the scanner. (TIP: If you are not seeing the table to the left of your graph, select ‘Insert’ and then ‘Table’ from the menu at the top of your Logger window).



1. Use your arrow to select both the Time and Position columns for the data representing your demo mountain range. Use the Ctrl+C combination to copy the data from those columns. Paste that data in a new Google Sheet as shown below (Column A is time and Column B is position)*:

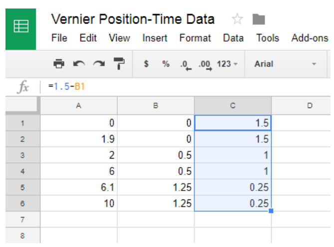


2. Next, in order to find the true height of each mountain, the position data recorded should be subtracted from the height above tabletop (or height above ground level) of the sensor.

Explanation: In the instructions, 1.5 m was used, but in practice use the actual height of the sensor during its scan in your classroom. (So if the reading was **0.5 m**, that means the surface was **0.5 m from the sensor**. Given that the sensor was 1.5 m from 'ground level', the actual height of that surface is 1.5-0.5= 1.0 meter.

To quickly calculate the actual surface height in Excel follow these steps:

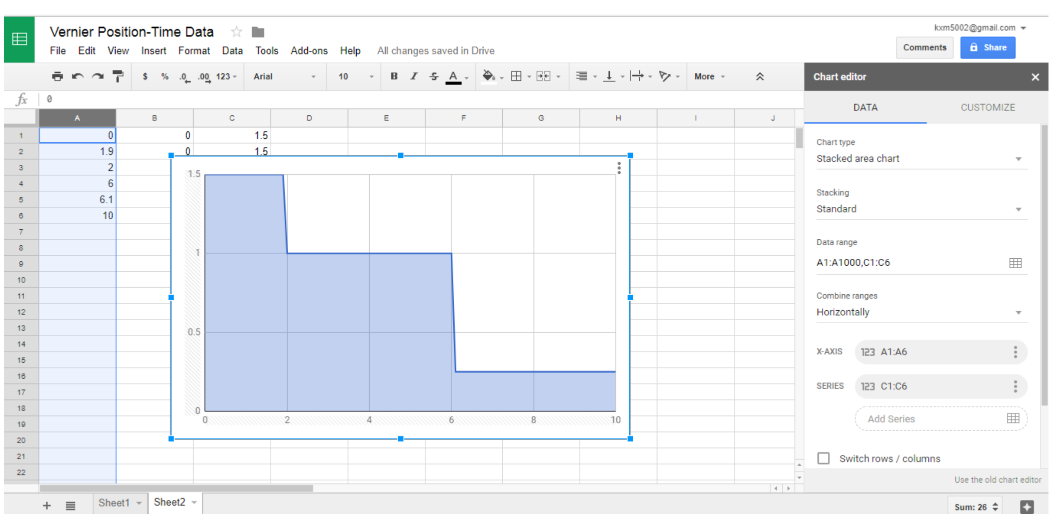
1. Select Cell 'C1.'
2. Assuming Column B holds your position data, in cell 'C1,' enter the formula =1.5-B1
3. Click the bottom left corner of Cell C1 and drag it down through column C until all position data has been transformed.



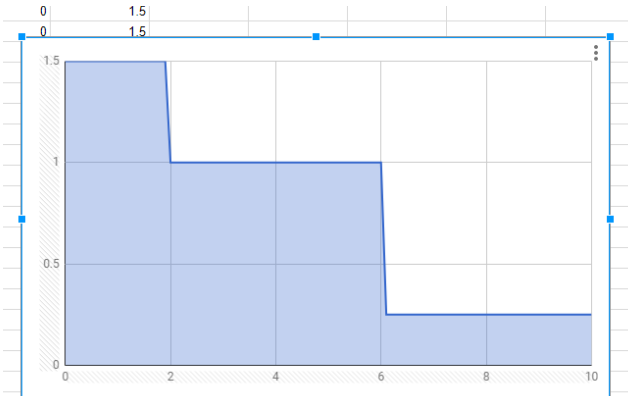
	A	B	C	D
1	0	0	1.5	
2	1.9	0	1.5	
3	2	0.5	1	
4	6	0.5	1	
5	6.1	1.25	0.25	
6	10	1.25	0.25	
7				
8				

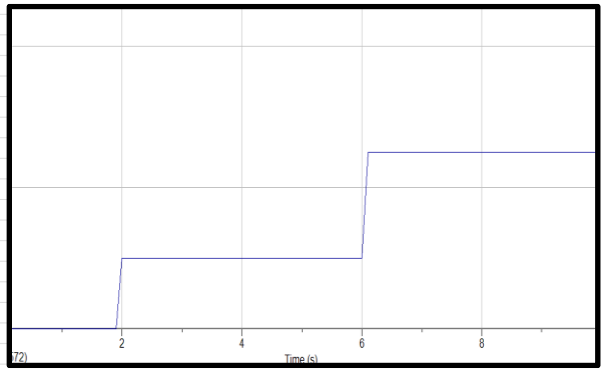
4. Click 'Insert', then 'Chart,' and choose an area chart from the menu in Sheets. In the x-axis option select the entire range of data from Column A (time). In the 'Series' option, select the entire range of data from Column C (new surface height).

5. You should see a graph appear that reveals the true shape of the scanned terrain:



6. Compare the graphs side-by-side and confirm that the new graph does match the original surface topography of the textbook mountain range. Notice the relationship between the sensor-recorded graph and the one revealing true surface data.





7. Checking Mastery:

a. Open a new Graph Matching file in the Logger Pro or Lite software you are using.
b. Once you have a vertical profile in front of you, Insert Table to see position-time data.
c. Follow the methods used with the demonstration data to transform this data set into a true representation of a surface region of Earth. **ASSUME THE SONAR WAS SCANNED AT A HEIGHT OF 10.0 m above ground level (desktop).** Paste or draw the real profile in the space below:

d. Using the data generated, determine the highest mountain peak in this landscape and write it here: ______________

e. Are there any wide valleys or plateaus in this region? In which time interval were they measured?

STUDENT MODULE 3:

THE CHALLENGE, DESIGN, AND PROPOSAL

Name: ________________________________ Date: _______ Pd:_____

REMOTE SENSING EARTH'S DYNAMIC SURFACE OFFICIAL CHALLENGE SHEET AND RUBRIC:

As described in your challenge preview, NASA has contracted you to design and test a prototype for a sonar scanner that can provide information about any 'hidden' surface region on earth. We will assume that the scanner will automatically identify the medium it is travelling through to complete accurate calculations (since the speed of sound in air is much slower than in water). To test your prototype you will be provided with a hidden mountain range (a simulated mountain range has been developed for you inside an opaque box with an open top). Your job is to design a method to produce an accurate representation of the hidden mountain range. The team at NASA is waiting on your prototype proposal; these are the minimum requirements:

Minimum Requirements:

- You must use a Vernier Motion Sensor as your sonar device and Vernier Logger Pro or Lite to record all data.
- You must pre-determine the height at which your scanner will move and for how long it should collect data BEFORE your test.
- You must develop a method to scan the region from a distance of **2 meters AWAY** (horizontally) from the box.
- You must complete the final reflection sheet to prepare a proposal recommending your design and acknowledging areas for improvement or further development.

Options for design:

Think about how you can create a scanner that moves at a constant speed and a consistent height above ground level (desktop) over the hidden surface region in question. Lego Mindstorms Robotics, hydraulic systems using syringes and tubing, or human-controlled handles attached to the sensor are all options. If you are limited in resources, be creative!

Procedure:

1. Submit design on a sheet of paper to be approved or revised by your instructor.

2. Once approved, build scanner and connect to computer.

3. Retrieve your group's mountain/box from your instructor. Ensure you are at least 2 meters away from the box. Run the scan and save your data in Vernier Logger.

4. Repeat 1-2 times to check precision. Make sure your data is repeatable when scanning from the same direction multiple times.

5. Once you are sure you are receiving repeatable data with your scanner, transform your data into a profile of the hidden mountain (recall steps used during demonstration). *The results of this step will be recorded in #**2 C** on the Data Log/Reflection Sheet.*

6. Bring your final image to your instructor and check with the actual 'mountain' topography found in the box--see Step 7

7. Using a meter stick, measure the height of the "mountain peaks" in the simulated mountain range Record those measurements in the space below:

Values of Object Heights in Simulated Mountain Range:

8. To check if your position-time plot matches the shape of the hidden terrain, compare the values of the high and low points on your graph (your peaks and valleys) to the object heights measured in step 7. Be sure you are comparing the heights in the same order/direction that they were scanned in your test.

9. a.) If your team's vertical profile matched the simulated mountain in the box, congratulations! Begin to prepare your reflection and proposal for NASA.

   b.) If your team's vertical profile did NOT match the simulated mountain in the box, determine *why*. Back to the drawing board--revise design and repeat on a DIFFERENT mountain range (borrow from another group's original test).

10. Complete reflection below and use it to develop your proposal pitching your group's prototype to NASA.

NAME: ____ DATE: __________

REMOTE SENSING CHALLENGE DATA LOG AND REFLECTION

1. Draw and label a diagram to illustrate the scanning apparatus you and your group designed to map the hidden terrain.

2. Data and Evidence:
   A. How high above ground level (desktop) does your instrument scan?_____________

   B. Paste or CLEARLY draw the graph of your group's best trial in the space below. This should be the original graph generated by the sonar device.

C. Follow the procedure from our class demonstration to transform the data generated into an accurate depiction of the hidden terrain. Paste or CLEARLY draw the transformed plot in the space below.   (Check: Did you use the height above ground level/desktop of your sonar device to find the actual surface height of the mountain range?)

D. For the graph pasted in ‘C,’ label the **COORDINATES** of each minimum and maximum point on the graph. Provide a name for each minimum and maximum (A, B, C, D, etc.).

E. How did your data compare to the measured heights of objects used in your mountain simulation? *Use specific data points as evidence to support your response.*

F. Based on the shape of the graph, what landform could you have uncovered if this was a real region on Earth? Describe or draw the region of Earth that might have been hidden beneath your sonar device.

3. Reflection

A. Describe two obstacles that challenged your group in finalizing a design for this assignment.

B. Explain, USING EVIDENCE FROM YOUR DATA LOG TO SUPPORT YOUR RESPONSE, what made your design and procedure successful (Why should NASA use it?).

C. NASA works to develop your prototype further and collects the following data set. Use the data to determine the shape of the terrain being measured by the sensor. Draw an artistic representation of the terrain, **labeling the values of each peak and valley**

*Assume the sensor was scanned at a constant height of **1200 ft above ground level for 2 minutes (120 seconds).** Notice we are using ft instead of meters here.*

I. Determine the actual surface height of the landform using the data collected during each time interval. Fill the correct values into Column 3 below:

Time Interval	Recorded Values of Position from Sonar Device	(a) Height of Landform
1-20 seconds	800 ft	
20-30 seconds	700 ft	
30-90 seconds	1500 ft	
90-95 seconds	200 ft	
95-120 seconds	500 ft	

II. Using the data provided above, sketch the shape of the landform in the space below by plotting position vs. time:

D. Describe in your own words and/or use clearly labeled diagrams to illustrate HOW sonar is used to collect data like that shown above or like the data sets you collected to test your prototype. Think about the model you drew in the discussion questions for the Graph Matching Exercise.

E. What limitations might exist for sonar that may be compensated for with other remote sensing tools (think back to the discussion on NASA's Operation IceBridge)?

F. Draft a proposal in the space below to recommend your device and measurement methods to the NASA team. Include any drawbacks, and use real data points as evidence to support the advantages of your device in measuring surface regions on Earth.

Category	**Advanced** **4**	**Proficient** **3**	**Basic** **2**	**Unsatisfactory** **1**
Technology: Use of appropriate tools, Vernier sensors, logging data and Excel ***Category Weight: x 1***	Students achieved repeatable data using the Vernier motion sensor and logging software and demonstrated an advanced knowledge of how the sensors worked, making connections to graph matching exercise; All tasks are complete and accurate.	Students achieved repeatable data using the Vernier motion sensor and logging software and demonstrated proficiency in knowledge of how sensors worked . All tasks are complete and accurate.	Students achieved repeatable data and demonstrated adequate knowledge of the sensors and logging software. One task is incomplete, missing, or inaccurate	Two or more tasks requiring the use of motion detectors, Excel, or the Vernier data logging software are inaccurate or missing.
Math: Constructing Graphs and Data Interpretation ***Category Weight: x 1***	Student-generated graphs match the simulated terrain or responses indicate advanced understanding of any discrepancies; students are able to accurately construct a vertical profile for the data set provided in Reflection part C with no guidance.	Student-generated graphs generally match the simulated terrain and student responses indicate adequate understanding of any discrepancies; students are able to accurately construct a vertical profile for the data set provided in Reflection part C with little guidance	Student-generated graphs show gaps in accuracy compared to the simulated terrain and student responses are unclear or inaccurate; Reflection part C tasks are complete and accurate.	Student-generated graphs show many inaccuracies compared to the simulated terrain and student explanations are unclear or inaccurate. The vertical profile based on given data in Reflection part C is missing or inaccurate.
Engineering: Optimizing Solutions/Justification ***Category Weight: x 1***	Justification is extremely clear, acknowledges device limitations or areas of growth; cites at least two specific pieces of data from testing in proposal or presentation as evidence to support the design.	Justification is generally clear, acknowledges device limitations or areas of improvement; cites at least one piece of specific evidence or data from testing in proposal to support the design.	Justification is somewhat clear and/or may be missing either specific evidence from testing or information about device limitations and areas of improvement.	Justification is unclear and/or does not include specific pieces of evidence or data from testing to support design recommendation.

Science: Demonstrates understanding of remote sensing physics (wave propagation, distance-rate-time, types of energy waves) ***Category Weight: x 1***	Student responses and illustrations demonstrate an advanced and accurate understanding of the use of remote sensing devices in surface mapping.; include a clear description of the relationship between the speed of sound in air or water, elapsed time during reflection and the distance of the object causing reflection; responses include clear and accurate comparisons between sonar and other remote sensing options such as LiDAR or RaDAR	Student responses and illustrations demonstrate an accurate understanding of the use of remote sensing devices in surface mapping including a clear description of the relationship between the speed of a sound wave in air or water, elapsed time during reflection, and distance of the reflecting object from the source of the sound wave.	Student responses and illustrations include several inaccuracies or misconceptions in the use of remote sensing devices in surface mapping; responses do reference distance-rate-time and forms of remote sensing other than sonar.	Student responses and illustrations include several inaccuracies or misconceptions in the use of remote sensing devices in surface mapping, no reference to the distance-rate-time relationship or types of remote sensors other than sonar.
Engineering: Proposing Solutions ***Category Weight: x 1***	Proposed design is feasible and logical; justification is clear and accurate.	Proposed design is feasible and logical; justification is generally clear and accurate.	Proposed design is somewhat feasible and logical; justification is somewhat clear and accurate.	Proposed design is not feasible or logical; justification is unclear or inaccurate.