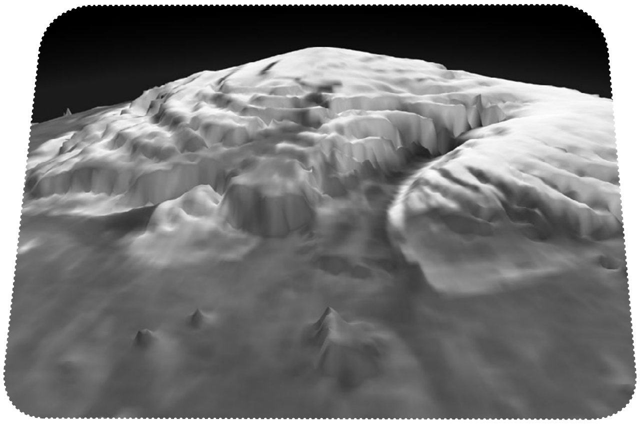
Name:			Date:
EXPLORATION EXTENSION	**1**	**Laser Altimeter**	***Background & Instructions***



First 3-D view of the north pole of Mars from MOLA
(Image credit: MOLA science Team/NASA/GSFC SVS)

Background

A laser altimeter is a device used aboard planet-orbiting satellites to map a planet's terrain. The elevations of surface features can be calculated by comparing how long it takes a laser pulse to echo back at different locations.

On NASA's Earth-orbiting ICESat satellite, a laser altimeter (Geoscience Laser Altimeter System) is used to obtain data on the elevation or thickness of ice sheets. This is relevant to understanding global climate change.

NASA's Mars Orbiter Laser Altimeter (MOLA) is currently in orbit around Mars on the Mars Global Surveyor satellite.

Spacecraft name = Mars Global Surveyor
Instrument name = Mars Orbiter Laser Altimeter (MOLA)
Instrument ID = MOLA
Target = Mars

MOLA's laser altimeter bounces laser pulses off of the surface of Mars at the speed of light and records return times. Laser light returns faster from the top of a volcano than from the lowlands around it because the top of the volcano is closer to the satellite than the lowlands. Three-dimensional mapping of Mars surface features can be done by analyzing the data (as was done to get the image above).

Instructions

To calculate the one-way distance from the satellite to a surface feature, a computer divides the elapsed time of a returning laser pulse by two and then multiplies the quotient by the speed of light. Like a laser pulse, your robot travels at a constant rate. It can "bounce" off the walls of unknown terrain and return data that helps to give a picture of the topography of a vertical surface.
The program below will automatically calculate the distance to a vertical surface once you enter the speed of your robot in centimeters per second.

Write the program ECHO:
(If needed, see PROGRAMMING INSTRUCTIONS on pages 18,19.)

```
PROGRAM: ECHO
   :Disp "SPEED CM/
   S="
   :Input S
   :Lbl A
   :Pause
   : Send ({222})
   : Get (R)
   : Send ({100, R})
   : Get (R)
   : Disp S*R/100
   :Disp "CM"
   :Goto A
```

Name:			Date:
EXPLORATION EXTENSION	1	Laser Altimeter	*Challenge*

Your mission is the exploration of Planet X. Your robot is in orbit around the planet on a spacecraft and will be sent to explore the surface. Unfortunately, cameras won't work in this environment because of a constant thick fog. You'll need to use the echo feature of your robot to analyze the topography of the steep cliffs on the planet's surface. These may be similar to those seen in the 3-D image of Mars's north pole on the previous page.

1. Describe what type of spacecraft your robot is on and how your robot will get to the planet's surface without damage.

....

....

....

....

....

....

....

Fill out the following:

SPACECRAFT NAME ....

INSTRUMENT NAME ....

INSTRUMENT ID ....

TARGET ....

You are on an important mission to map the fog-hidden, vertical cliff face on Planet X. Position a transect line (a line along which measurements are taken at intervals), marked with 10-centimeter increments, parallel to the cliff face. Use your robot to measure the distance from the transect line to the cliff face at each increment. Record your data below.

Table 1

TEST INTERVAL (In centimeters)	DISTANCE (In centimeters)
0	
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Graph the data from Table 1 as points on graph paper with TEST INTERVAL on the horizontal or x-axis, and DISTANCE on the vertical or y-axis. Draw a line connecting the points to picture what the vertical surface of the cliff face looks like.

Name:			Date:
EXPLORATION EXTENSION	**1**	**Laser Altimeter**	***Results***

2. If you were going to a land a spacecraft in the region near the cliff face, are there any areas you might want to avoid? Why?

3. If you discovered any rocky outcroppings jutting out from the cliff face give their approximate area in square centimeters. (Show all work for calculations.) How can you change your data gathering techniques to get a more accurate picture of the outcroppings?

Name:			Date:
EXPLORATION EXTENSION	**1**	**Laser Altimeter**	***Results***

On missions to the Moon, crews from NASA's Apollo 11, 14, and 15 left behind retroreflector arrays that could reflect laser light back to Earth. The distance to the Moon can be accurately determined by "Laser Ranging" or measuring the time it takes a laser pulse (traveling at the speed of light) to go from Earth to the Moon and back again.

4. It takes a laser pulse 2.5 seconds to go to the Moon and echo back to Earth. Given the speed of light as approximately 300,000 kilometers per second, how many kilometers away is the Moon at that point in time? (Show all work for calculations.)

5. In a sense you have a "robot ranger" or distance finder. A robot travels 22.32 centimeters per second and pings off an unknown object in the elapsed time of 3.04 seconds. How many centimeters away is that object? Express your answer to the nearest whole centimeter. (Show all work for calculations.)

Name:			Date:
EXPLORATION EXTENSION	**1**	**Laser Altimeter**	***Programming Instructions***

Turn on your graphing calculator. Press [PRGM], then use the arrow to highlight **NEW**. Press [ENTER], then spell out ECHO by pressing the appropriate keys. Press [ENTER] and you're ready to enter the first command for the program.

Line 1&2: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press [ENTER]. Press [2nd], then [ALPHA]. Press [+] and then spell [SPEED CM] (For the blank space, press [0]). Press [ALPHA] then [÷]. Press [ALPHA], then [S]. Press [2nd], then press [TEST], [ENTER] for the = sign. Press [ALPHA], then press [“]. Press [ENTER]. The first and second line should appear as:
:Disp “SPEED CM/
S=”

Line 3: Press [PRGM], then use the arrow to highlight **I/O**. Press [ENTER] at **1: Input**. Press [ALPHA], then [S]. Press [ENTER]. The third line should appear as:
:Input S

Line 4: Press [PRGM] and **CTL** will be highlighted. Use the arrow to scroll down to **9: Lbl**. Press [ENTER]. Press [ALPHA], then press [A]. Press [ENTER]. The fourth line should appear as:
:Lbl A

Line 5: Press [PRGM] and **CTL** will be highlighted. Use the arrow to scroll down to **8: Pause**. Press [ENTER] twice. The fifth line should appear as:
:Pause

Line 6: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **B: Send (**. Press [ENTER]. Press [2nd] and then press [{] for an open brace. Type in [2][2][2]. Close the braces and parentheses by pressing [2nd], the [}] button, and then [)]. Press [ENTER]. The sixth line should appear as:
:Send ({222})

Line 7: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (**. Press [ENTER]. Press [ALPHA], then press R. Press [)] then [ENTER]. The seventh line should appear as:
:Get (R)

Line 8: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **B: Send (**. Press [ENTER]. Press [2nd] and then press [{]. Type in [1][0][0], then press [,]. Press [ALPHA], then press [R]. Press [2nd] and then [}]. Press [2nd] and then [)]. Press [ENTER]. The eighth line should appear as:
:Send ({100,R})

Line 9: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get(**. Press [ENTER]. Press [ALPHA], then press R. Press) then ENTER. The ninth line should appear as:
:Get (R)

Line 10: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press [ENTER]. Press [ALPHA] and then [S]. Press [×] and then press [ALPHA] and then [R]. Press [÷] and then type in [1][0][0]. Press [ENTER]. The tenth line should appear as:
: Disp S*R/100

Line 11: Press [PRGM], then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press [ENTER]. Press [2nd] and then press [ALPHA]. Spell [CM]. Press [ENTER]. The eleventh line should appear as:
: Disp “CM”

Line 12: Press [PRGM] and **CTL** will be highlighted. Use the arrow to scroll down to **0: Goto**. Press [ENTER]. Press [ALPHA], then press [A]. Press [ENTER]. The twelfth line should appear as:
:Goto A
Press [2nd], then [QUIT].

To run the program:

Attach the calculator to your robot and connect link cable. Make sure the robot and calculator are both switched on.
Press [PRGM] and use the arrow to scroll down to **: ECHO**.
Press [ENTER].
Press [ENTER] again.
Enter robot speed in centimeters per second.
Press [ENTER].

Name:			Date:
EXPLORATION EXTENSION	**1**	**Laser Altimeter**	***Programming Instructions***

Position robot on the transect line facing the hidden cliff face.
Press [ENTER] again and the robot will start.
(It will travel until the bumper hits and then return. The one-way distance in centimeters will be displayed.)
Reposition robot along the transect line.
Press [ENTER].
Repeat until the distance is determined for each TEST INTERVAL.

To stop the program:

Press [ON], then [ENTER].
Press [CLEAR] to clear the screen.

For more information on the Mars Orbiter Laser Altimeter see:
http://ltpwww.gsfc.nasa.gov/tharsis/mola.html
http://ltpwww.gsfc.nasa.gov/tharsis/mola.top10.html

A Planet X cliff face could be set up against a wall hidden from view with a curtain. Allow enough room for robots to travel underneath the curtain. A book or similar object could be used to simulate a rocky outcropping along the cliff face. Robots will reflect back more quickly from this region. Have the transect line (a meter stick works well) set parallel to the wall outside the curtain, but not more than 50 cm away. See CHALLENGE SET-UP diagram.

For **question one**, information from the Mars Exploration Rover Mission might be helpful: *http://marsrovers.nasa.gov/home/index.html*

For **question two**, you may want to avoid the newly discovered rocky outcropping region to avoid damage to your spacecraft.

For **question three**, answers will vary for part 1. In part 2, one way to improve accuracy is to shorten the increments along the transect line and take more samples. The MOLA emits 10 laser pulses per second.

For **question four**: 2.5 seconds divide by 2 = 1.25 seconds for the one-way trip and 300,000 × 1.25 = **375,000 km** (rate × time = distance) yields the distance from Earth to the Moon at that time.

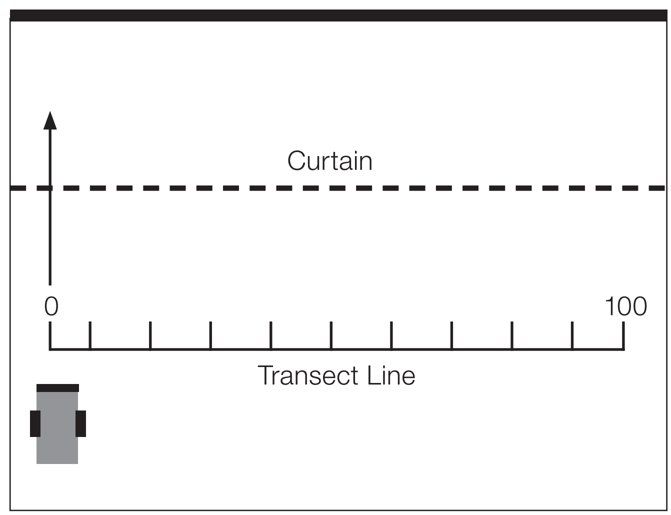
Question five is similar: 3.04/2 = 1.52 seconds, 22.32 × 1.52 = 33.9264 or approximately **34 centimeters**. Also see: *http://en.wikipedia.org/wiki/Lunar_laser_ranging_experiment*

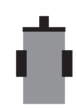
From Planetary Features to Microscopic Creatures

Amazingly, the tapping atomic force microscope (AFM) uses the same basic principles that are at work on the MOLA and the robot exercise above. It has a cantilever that oscillates over extremely small surfaces and can make 3D images of bacteria, viruses, or even DNA. For more information see:

http://en.wikipedia.org/wiki/Atomic_force_microscope
http://en.wikipedia.org/wiki/Tapping_AFM

Challenge Set-up:





Because of the size of the bumper, the robot senses too large of an area. Another challenge for students could be to design a removable probe that could be attached to the bumper to sample a narrower area.