How does GPS Work?

Objective:
Students will be able to use GPS to pinpoint locations and explain how the GPS system works.

Background:

As each GPS satellite circles the earth, it transmits a radio signal called a pseudo random code. Each signal is encoded with information used to determine a receiver's location. The signal transmission includes the time the signal was sent and the satellite's location in space. Receivers on earth receive this signal. All the satellites in the constellation send their information at the same time. However, they arrive at different times due to the distance the signals travel.

The signals travel at the speed of light which is 186,282.3976 miles per second (mps). The formula *Distance = Speed x Time* is used to determine the distance between a satellite and a location on earth. This formula is used because the both the speed and time are known. For example, it takes a signal 1 second to reach a receiver. So, we know that the receiver is 186,282.3976 miles from the satellite. However, the actual calculation is slightly more complicated than this.

GPS uses a process called trilateration to determine a precise location on Earth. Trilateration is the process of measuring the distance from at least three satellites to determine a location on earth. One satellite can determine a receiver's position somewhere on a sphere. Two satellites narrow the position down to a circle where the two spheres intersect. Three satellites locate the position to one of two points at the intersection of all three spheres. The second point is automatically ruled out because it is located somewhere in space.

Three satellites calculate a 2D position while four or more satellites calculate a 3D position. 2D positions consist of latitude and longitude measurements. 3D position contains both latitude and longitude in addition to altitude measurements. The differences between the two is that a 2D position can track movement, while a 3D position can calculate speed, bearing, trip distance, distance to destination, sunrise/sunset, etc.

GPS is based on the coordinate system using latitude and longitude lines. Latitude lines run horizontal with the equator being 0°. The North and South poles are each 90°. They are noted as north or south of the equator. Longitude lines, also known as meridians run vertical. Longitude lines run from 0° to 180°. The Prime Meridian located in Greenwich, England is 0° and the International Date Line is 180°. They are noted as east or west of the Prime Meridian. Sometimes a negative is used to designate south or west instead of S or W. On a GPS unit this negative may show up as a zero in front of the coordinates. An example coordinate for Oklahoma City, OK is 35° 24' N 097° 36' W.

For more information:

www.nasm.si.edu/exhibitions/gps/index.htm
www.navcen.uscg.gov/gps/default.htm
http://gpshome.ssc.nasa.gov/content
http://tycho.usno.navy.mil/gps.html
www.4-H.org
www.trimble.com
www.garmin.com

How does GPS Work?
Activity

This is a Garmin eTrex Legend GPS receiver (this is the receiver Oklahoma 4-H has). It has five buttons and a click stick. It is important to learn what these buttons are and their functions.

1. Turn GPS receiver on by pressing the flat power button on the right side.

2. The screen will show satellites trying to acquire a signal. This is called the sky view (the view if you were looking straight up). The empty circles are satellites and the filled in circles are satellites that have acquired a signal. The numbers in the circles is the satellite number. The first satellite to acquire a signal downloads an almanac of satellite information to help the GPS determine where it is at. (If a "D" shows up, it means that satellite is receiving a differential correction signal or DGPS.)

3. GPS signals only work outside, so to use the receiver inside, the GPS signal is turned off. When the screen pops up, "Use with GPS off?" push down on the click stick. The GPS will now stop searching for satellites. **OR** To turn off GPS: Using the click stick, move until the "On Screen Page" button is highlighted. Press click stick down to get a drop down menu. Select "Use with GPS Off" and push click stick down.

4. Back to satellite screen, hit page or big button to go to Map Page (it looks like a map). Use the Zoom In/Out buttons to see the features of where the map is at. The filled in triangle is a "you are here" marker.

5. Using click stick, highlight "On-Screen Page" button. Highlight Pan Map and then press down on click stick. The arrow pointer tells you where you are as you fly around the world.

6. Using zoom in/out buttons and click stick, fly around the world. To exit Pan Map, press the big button.

7. Hit page/big button again, this will be the navigation screen. This page looks like a compass. It will show which direction you are going, speed, etc. You must be moving for this to work.

8. Press page/big button, goes to trip page. This page contains travel information.

9. Pressing the page/big button again takes you to the Main Menu page. From here we will learn how to create and find waypoints. Waypoints are locations that are saved in you GPS. They may be home, school, favorite place, etc.

10. First make sure all the units are all in the same format. To check this, from main menu go to setup, enter. Then to Units, enter. The Position Format should be hddd°mm.mmm' or hddd.ddddd°. The Map Datum should be set to WGS 84. When making waypoints, have the students turn the units off and then on outside.

11. Back to the main menu. The man with the flag labeled "Mark" is how a waypoint is established. Highlight "Mark" on the main menu and press the joystick down to enter.

12. The page will have a guy holding a flag and we will call him "Mark". Once you hit "Mark" from the main menu, the waypoint is marked where you are at. Therefore, do not hit "Mark" the man until you are where you want the waypoint to be.

13. The waypoint is assigned a three digit number. You have the option to name the waypoint. To name: use the click stick to highlight the number, press enter. A keypad will come up and enter the name you want. Then highlight OK, press enter.

14. Select OK (bottom right) on the mark waypoint page. A waypoint has been made! It is important to remind the students what number or name the waypoint is.

15. To find a waypoint: Go to main menu page, and select "Find", "Waypoints" and then "Nearest".

16. Select the waypoint you want to find (by number or name). The waypoint page will show, select "Go To".

17. Compass page will show and students will need to move in the direction of the large arrow. This page will also tell you how far you are from a waypoint in miles, feet, etc.

18. Things to remind the students of:
    - They must be moving in order for the receiver to know their location and the direction they are moving
    - The receiver will not be completely accurate. They may have to look around depending on the accuracy factor.

Prior to lesson, mark a waypoint and record the coordinates. Give these coordinates to the students to find before letting them create and find their own waypoints. Make sure all students understand how the compass works and how to read the coordinates.

Give each student a plastic egg or similar object to mark the waypoints they create. Have the students trade their GPS units and find each others waypoints.
Continue activity until the students have a good understanding of how to make and find waypoints.

ACCURACY

Look at the coordinates on the instructor's GPS receiver. Give those coordinates to the students and have them match their receiver to those coordinates. Everyone will have the same coordinates on their receiver, but will be located at different spots. Use this as an example of GPS accuracy problems or errors. This is a good example of how the coordinates may be off some and students need to look around to find the hidden treasure.

OPTIONAL ACTIVITY

1. Create a start and finish line.

2. Put students into groups of 2-4.

3. Have each group member line up at the start line with their GPS receiver. Make sure there is enough distance to get a speed reading.

4. GPS receivers need to be on the Navigation page.

5. Ready, Set, Go! Have students race to the finish line.

6. Have the students compare their speeds.

There are a lot of variations with this activity.

- Heat races with a grand finale race
- Have one member from each team race. After everyone has raced, the team with the lowest/highest total speed, average speed, etc., wins

Have the students make up their own game using GPS and then share it with the rest of the students.