GLOBAL POSITIONING LESSON PLAN

I Know Where You Are!

Theme

Global Positioning

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/navops/positioning/
http://oceanservice.noaa.gov/education/kits/geodesy/geo09_gps.html
http://oceanservice.noaa.gov/education/kits/geodesy/geo03_figure.html
http://oceanservice.noaa.gov/education/kits/geodesy/geo08_spatref.html
http://oceanservice.noaa.gov/education/kits/geodesy/geo10_cors.html

Subject Area

Earth Science/Physical Science
Geography

Grade Level

9-12

Focus Question

How does the Global Positioning System work?

Learning Objectives

- Students will explain how global positioning satellites are used to determine the location of points on Earth's surface.
- Students will identify at least three practical uses for the Global Positioning System.
- Students will be able to identify the location of points on Earth's surface using methods similar to those used in the Global Positioning System.

Materials Needed

- Copies of "GPS Coordinate Grid" copied onto clear acetate; one copy for each student or student group
- (Optional) computers with internet access; if students do not have access to the internet, see Learning Procedure Step 1
- Drafting or wrapping tape
- Drafting compasses, one for each student or student group,

and/or string and two pencils; see Worksheet Step B2

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Classroom style or groups of 2–4 students

Maximum Number of Students

30

Key Words

Global Positioning System
GPS
Trilateration
Benchmark
Geocaching

Background Information

The Global Position System (GPS) is a system for accurately determining the geographic position of any point on Earth. GPS instruments are standard tools for navigation on aircraft and commercial ships, and are becoming increasingly popular among backpackers, recreational fishermen, and in private automobiles. GPS data are used in many other applications as well, including surveying, land use planning, and disaster preparedness.

The geographic position of a specific location on Earth is defined by the horizontal coordinates (latitude and longitude) and elevation (see *http://oceanservice.noaa.gov/education/kits/geodesy/lessons/geodesy_meet.pdf* (263 kb, 20 pages) for additional discussion about geographic position and coordinate systems). The basic concept underlying GPS is the idea that the geographic position of an unknown location can be determined by measuring the distance from that location to three reference points whose location is known. This method for finding position is known as trilateration (often mistakenly called "triangulation," which is the method for finding position using angles (instead of distance) between an unknown point and two or more reference points). Visit *http://en.wikipedia.org/wiki/Trilateration* for a more detailed discussion.

The reference points for GPS are 24 satellites, launched, operated, and maintained by the U.S. Air Force (actually, 24 satellites is the minimum number required so that at least four satellites are always visible from any point on Earth, but there are usually a few more backup satellites in orbit as well). The other essential components of the system are a global network of ground monitoring stations and users who have GPS receivers that can captures signals from the satellites and process information from the signals to calculate position. The locations of ground monitoring stations are precisely determined, and these stations provide data to the satellites about their exact location. In the U.S., GPS is further enhanced by a network of hundreds of stationary, permanently operating GPS receivers known as Continuously Operating GPS Reference Stations (CORS). CORS continuously receive GPS radio signals and transmit position data to the National Spatial Reference System (NSRS) operated by NOAA's National Geodetic Survey. Using CORS data allows GPS users to determine the accuracy of their coordinates to the centimeter level. Visit *http://www.ngs.noaa.gov/PUBS_LIB/develop_NSRS.html* for more information about CORS and NSRS.

A GPS receiver computes the distance to a satellites based on amount of time required for a radio signal from the satellite to reach the receiver. The satellites and receivers both contain accurate clocks (the satellites contain an atomic clock that is much more accurate than the receivers' clock, however), and periodically they both generate a signal that begins at the same time. When the signal from the satellite is received, however, it appears to begin later than the signal generated by the receiver because of the time required for the signal to travel from the satellite to the receiver. This time delay is proportional to the distance between the satellite and the receiver. It is similar to someone clapping their hands in front of a large building: The person hears the echo from their clap after the sound of the clap itself because of the time required for the sound waves to travel to the building and back again. As the distance from the building increases, so does the time delay between the original sound of the clap and the echo. The receiver calculates the time difference between the two signals, and then converts this to a distance measurement. The signal from the satellite also contains information about its position, as well as the time of the signal's transmission as determined from the atomic clock. For more information, visit *http://www.trimble.com/gps/index.html*.

Four satellites are typically used to determine the three-dimensional position of a location on Earth. One reason for this is that three satellites actually establish two possible positions for an object; but since one of these is usually impossible (e.g., a position that is inside the Earth or out in space), the true position can often be worked out from three satellites alone. A fourth satellite, though, eliminates the "untrue" position, and also provides a way to correct for errors in the receiver clock, and thus improves the accuracy of the computed position. If more than four satellite signals are available, the accuracy of the computed position can be improved further. Visit *http://oceanservice.noaa.gov/education/kits/geodesy/geo09_gps.html* for additional discussion of this concept.

The elevation of a specific location on Earth is usually given as the height of the location above global mean sea level, or orthometric height. Global mean sea level is defined by an imaginary shape called the geoid. Elevation measured by GPS is not referenced to the geoid, but instead to another mathematically defined shape called a reference ellipsoid. The reference ellipsoid is an approximation of the geoid, so elevation measured by GPS is an approximation of orthometric height. Visit *http://www.oceanservice.noaa.gov/education/kits/geodesy/geo03_figure.html* for additional discussion of the geoid.

Along with a multitude of practical uses, GPS technology has become the foundation for a new generation of outdoor games. "Geocaching" (pronounced "geo-cashing") is basically a classic "treasure hunt" game in which the object is to use a GPS receiver to navigate to the specific latitude and longitude of a hidden container (or sometimes, just a specific location). Since its beginning in 2000, geocaching games have sprung up in all 50 states and over 100 countries (visit the official geocaching Web site at *www.geocaching.com* for more information). One of the many variations of geocaching is a game known as "benchmarking."

Benchmarks are objects that mark reference points on the Earth's surface. These reference points are part of a national coordinate system known as the National Spatial Reference System (NSRS). Developed and maintained by NOAA's National Geodetic Survey (NGS), the NSRS provides the foundation for transportation, communication, mapping, and a multitude of scientific and engineering activities. Key components of the NSRS include:

- A consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States;
- A network of permanently marked reference points;
- A network of continuously operating reference stations (CORS) which provides up-to-the-minute information on movements of the Earth's surface; and
- A set of accurate models that describe dynamic geophysical processes that affect spatial measurements.

In benchmarking games, players search for NSRS benchmarks. The most familiar types of benchmarks are bronze disks set into concrete casings, but navigation lights, water towers, church spires, and many other objects may be benchmarks as well. The object of the game is to find a specific benchmark and take a digital picture to post on the official geocaching website. The NGS maintains data for each benchmark that includes detailed information on its precise location, history, and many other technical details. Benchmarks in a particular area can be located using a search engine on the same website (*www.geocaching.com/mark*). To recover the entire datasheets for benchmarks, use the NGS Datasheet Retrieval Page at *http://www.ngs.noaa.gov/* and click on "Datasheets." Note that a GPS receiver is useful for getting in the general vicinity of a specific benchmark, but the actual "find" is usually accomplished using very detailed location descriptions from the benchmark's datasheet.

In this lesson, students will locate geographic sites on a map using the same methods used by the Global Positioning System.

Learning Procedure

Notes:

- Portions of this lesson are adapted from a GPS learning activity prepared by the CHICOS (California HIgh school Cosmic ray ObServatory) project, in which schools in the Los Angeles, CA area participate in a network of sites for the detection of ultra-high energy cosmic rays (*http://www.chicos.caltech.edu/classroom/GPS/GPSActivity1.html*).
- Since the techniques used in this lesson can be applied to any location in the United States, you may want to create your own worksheet using geographic features from your local community or other location with which students are familiar.

1.

To prepare for this lesson:

- Review information about the Global Positioning System at *http://oceanservice.noaa.gov/topics/navops/positioning* and *http://www.sco.wisc.edu/gps/index.php*; you may also want to review information about coordinate systems (*http://oceanservice.noaa.gov/education/kits/geodesy/lessons/geodesy_meet.pdf*; 263 kb, 20 pages) and the National Spatial Reference System (*http://www.geodesy.noaa.gov/INFO/OnePagers/One-Pager_NSRS.pdf*; 1.5 Mb, 1 page);
- Copy the "GPS Coordinate Grid" onto clear acetate (overhead projector transparency), one copy for each student or student group.

  If time is limited or students will not have internet access, you may also want to make copies of topographic maps (Part A on the "GPS Challenge Worksheet").

2.

Briefly review the concepts of the Global Positioning System. Be sure students understand the distinction between triangulation and trilateration, and how latitude and longitude are used to describe the location of specific points on Earth's surface. Discuss the idea behind geocaching games, and be sure students know what "benchmarks" are.

3.
Give each student or student group a copy of the "GPS Challenge Worksheet," the "GPS Coordinate Grid," and "Table 1." Tell students that their assignment is to use the basic principles of GPS to locate specific features on a topographic map.

4.
Review students' answers to questions on the worksheet. The correct answers are:

- Point 1 is at or near the Triumph Mine.
- Point 2 is at or near the Old Triumph Mine.
- Point 3 is at or near the North Star Mine.
- Point 4 is at or near the Courier Mine.
- Point 5 is at or near the town of Triumph.
- Point 6 is at or near the Reservoir adjacent to the Lucky G Mine.
- Point 7 is at or near a pile of mine tailings.
- The elevation of Point 8 is 6617 ft.
- A benchmark located at Point 9 would be in the middle of a tailings pond (a pond that contains liquid mining waste).
- The elevation of Point 10 is 7749 ft.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Human Activities," then "Technology," for links to other resources about Satellites & Remote Sensing.

The Me Connection

Visit *http://cfa-www.harvard.edu/space_geodesy/ATLAS/applications.html* for a worksheet that asks students to design a system that incorporates GPS receivers, and encourages students to consider how GPS might be integrated into their daily lives (a component of Project ATLAS (Assisted Transnational Learning using Artificial Satellites), a multidisciplinary, international educational outreach project in which students in the age range of 12—14 years from around the world use satellite and Internet technologies to learn about the world in which they live.

Extensions

1. Have students prepare a "Benchmarking Challenge" game to be solved by other students:
   a. Use resources described in "Background" to retrieve information for benchmarks near a specific area;
   b. Locate these benchmarks on a suitable topographic map prepared as in worksheet Part A;
   c. Use a "GPS Coordinate Grid" to find satellite distances for the location of several benchmarks;
   d. Challenge other students to find the latitude and longitude of the benchmarks given their distance data and an appropriate map.

2. Have students find out about "Travel Bugs" (see *http://www.geocaching.com/track*).

Resources

http://oceanservice.noaa.gov/education/kits/geodesy – "Geodesy Discovery Kit" from NOAA's National Ocean Service

http://oceanservice.noaa.gov/topics/navops/positioning – NOAA's National Ocean Service webpage on the Global Positioning System

http://www.ngs.noaa.gov/PUBS_LIB/develop_NSRS.html – Article by David R. Doyle on development of the National Spatial Reference System

http://www.wcrl.ars.usda.gov/cec/java/lat-long.htm – calculates distance between two points given lat & long

http://www.pbs.org/wgbh/nova/longitude/gps.html – "GPS: The New Navigation," a shockwave game that explains how the Global Positioning System (GPS) works *http://www.pbs.org/wgbh/nova/shackletonexped/navigate/find.html* – "Find Your Longitude Shockwave Learning Activity;" another shockwave game from PBS

http://www.nasm.si.edu/exhibitions/gps/ — A visual introduction to GPS from the Smithsonian Institution's National Air and Space Museum

http://sciencespot.net/Pages/classgpslsn.html – GIS & GPS Resources & Lesson Plan Links from The Science Spot

http://www.trimble.com/gps/index.html – GPS tutorial from Trimble Navigation, Ltd.

http://www.unavco.org/edu_outreach/resources.html – Web site for UNAVCO, a consortium of research institutions whose mission is to promote Earth science by advancing high-precision techniques for measuring and understanding crustal deformation. with links to educational activities using GPS and GPS tutorials

National Science Education Standards

Content Standard B: Physical Science
- Motions and forces

Content Standard D: Earth and Space Science
- Origin and evolution of the Earth system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

National Geography Standards

Standard 1: How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information.

Standard 15: How physical systems affect human systems.

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H3 – Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

GLOBAL POSITIONING WORKSHEET

GPS Challenge Worksheet

A. Get A Map

The first step is to obtain a topographic map of the selected geographic area. The U.S. Geological Survey's National Map Web site provides an easy way to obtain such maps, using the following steps:

1. Open the National Map Viewer Web site (*http://nmviewogc.cr.usgs.gov/*). The "Layers" menu on the right side of the page allows you to customize the map to show particular features. The tools on the left side of the page allow you to control the scale and location of the map displayed in the center window.

2. Use the "Find Place" tool to display a map for the vicinity of Triumph, Idaho:
   a. Click on the "Find Place" tool. A dialogue box opens that has several options for identifying the area to be displayed. You can zoom into a specified state and/or county, or to a particular address, or to a named feature (such as a mountain), or to a specific point whose latitude and longitude are known, or to an area enclosed by specified north-south and east-west boundaries. In this case, we will use the last method.
   b. Click on "Extent" to display the "Zoom to Bounding Box" window. In the "Select coordinate format:" box select "Degrees, Minutes, and Seconds."
   c. Next, enter the north, south, east, and west boundaries. In the "North" box, enter 43°39'44". In the "West" box, enter -114°16'59". Note that the Map Viewer tool uses a minus sign to name meridians of longitude that are west of the prime meridian (the one that passes through Greenwich, England). In the "East" box, enter -114°14'8". In the "South" box, enter 43°38'2". Click "Zoom to Extent." The map window should re-draw to show some named streets and "shaded relief" showing a rather mountainous terrain.

d. Customize the map further using the "Layers" menu: Click the triangle next to "Topographic Maps," and click in the box next to "USGS Raster Graphics (Topo Maps)." Click the triangle next to "Transportation." Scroll down and notice that the boxes next to "ROADS," "County Road Labels (USGS)," and "Idaho Roads (BTS)" are all checked. Click in the box beside "ROADS" to deselect roads and road labels. Click the "Refresh Map" button. Now you should see a topographic map with the town of Triumph (labeled, and indicated by several small black squares) near the center of the map, and a scale bar on the lower left corner that reads 0.3 mi (If your map does not show these features, you have have accidentally zoomed in. Try clicking on the "Zoom Back" tool. If you still don't see these features, click on the "Find Place" tool and repeat steps 2b and 2c). Hide the overview map in the upper left corner by clicking once on the "Overview" tool.

e. Save your map by clicking on the "Print" tool, then clicking "Create Printable Map" in the "Print" dialog box. Click "View Printable Map." Enter a file name when prompted, being sure to retain the ".pdf" suffix (the file will be about 750 kb). Click "Save" to download the map file in Adobe pdf format. Open the file with Adobe Acrobat or Acrobat Reader, and print the map.

B. Identify Features Located by Satellite Distances

Now, you will locate specific points on your map with the same methods used by the Global Positioning System.

1. Locate the point on the upper scale of your map that corresponds to longitude 114°14′30″. Lightly draw a vertical line on your map through this point. Locate the point on the right side scale of your map that corresponds to latitude 43°39′0″, and draw a horizontal line through this point. Now, lay the clear "GPS Coordinate Grid" over your map of the Triumph, ID vicinity. Position the Grid so that the "Align A" mark is on the vertical line, and the "Align B" mark is on the horizontal line. Tape the Grid to your map so the Grid will remain properly aligned.

2. Table 1 shows the distances to GPS Satellites #1, #2 and #3 from various points on the map. To locate a given point, use a drawing compass and the "GPS Coordinate Grid" to construct an arc that is centered on GPS Satellite #1 with a radius equal to the distance shown in Table 1. You can use the grid to set the opening distance of the compass (one small square on the grid is equal to 0.1 inch). If your compass won't open enough to set the given distance, you can use a piece of string tied between two pencils to draw the arc. Next, construct a second arc centered on GPS Satellite #2 with the radius shown in Table 1. Finally, construct a third arc centered on GPS Satellite #3 with the radius shown in Table 1. The intersection of the three arcs is the location of the given point. If the arcs do not coincide exactly (they usually don't), use the center of the overlap area as the approximate location of the point.

3. Repeat this process to answer the following questions: What features are shown near the following points:

Point 1: ______________________

Point 2: ______________________

Point 3: ______________________

Point 4: ______________________

Point 5: ______________________

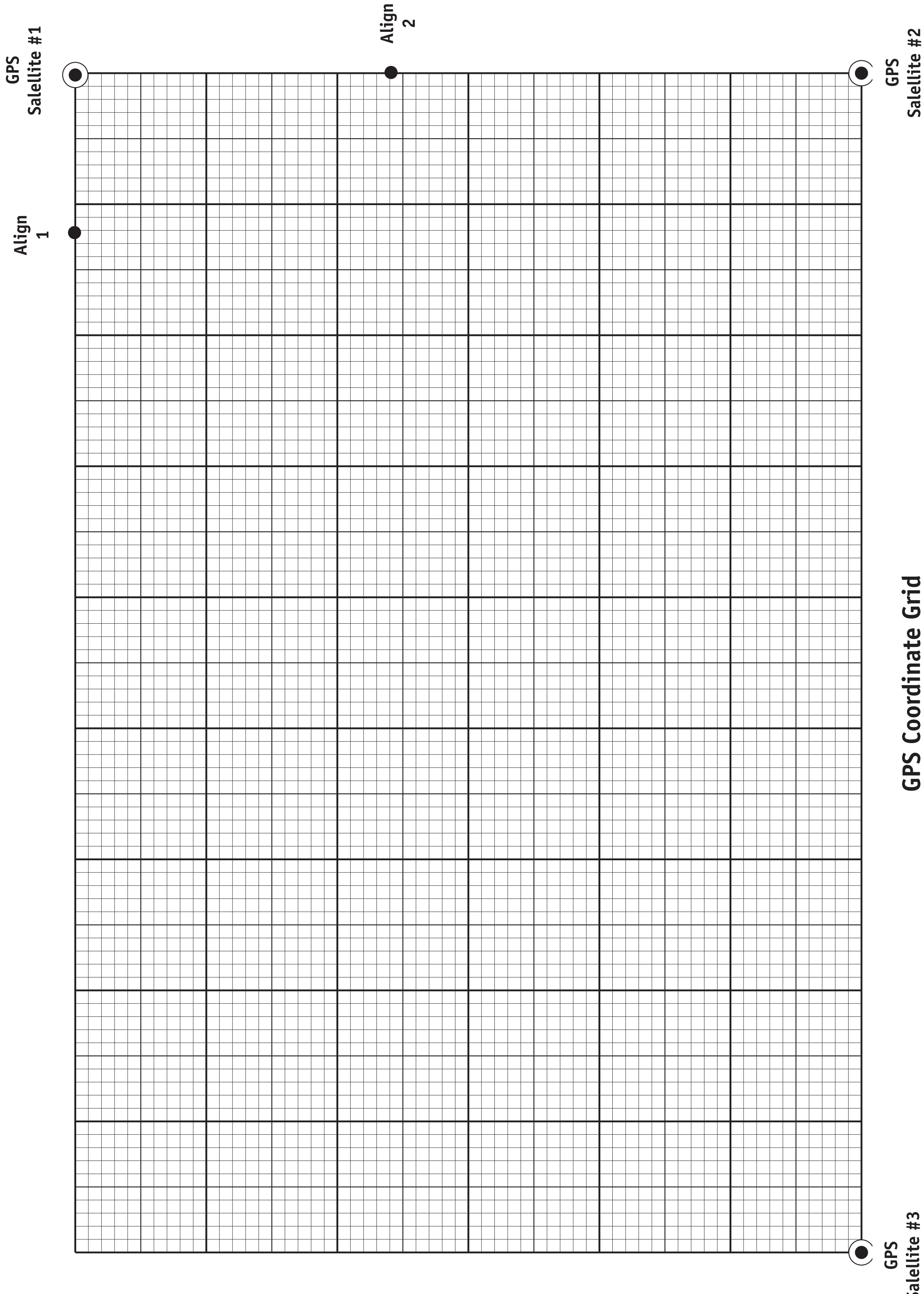
Point 6: ______________________

Point 7: ______________________

What is the elevation of Point 8: ____________________

You are looking for a benchmark whose location is supposed to be Point 9. Why may this benchmark be difficult to recover? ____________________________________

What is the elevation of Point 10: ___________________



GPS Coordinate Grid

Table 1

Location	Distance from GPS Satellite #1 (inches)	Distance from GPS Satellite #2 (inches)	Distance from GPS Satellite #3 (inches)
Point 1	6.1	5.7	4.6
Point 2	8.3	9.9	5.4
Point 3	6.9	8.1	5.0
Point 4	4.7	6.1	6.3
Point 5	5.1	4.7	5.8
Point 6	3.6	3.4	7.8
Point 7	5.4	4.6	5.5
Point 8	7.5	7.1	3.5
Point 9	6.3	5.1	4.6
Point 10	6.6	8.6	6.0