Got GPS?

by Jared Bancroft & Gérard Lachapelle Ph.D.

Everybody seems to be using the Global Positioning System (GPS) these days. Geo-caching is taking people to new places, climbers and hikers seem to be trading their compasses in for small handheld receivers, drivers are swapping paper maps for in-car navigation systems, and cell phones and PDAs (Personal Digital Assistant units) are more often attracting new buyers with their GPS features.

So, what's all the fuss about? How does GPS actually work? How accurate is GPS really? Is it of any use to Scouting youth and leaders? Read on and you will be able to impress your youth with your GPS knowledge next time you are on the trail. Not to mention you won't get lost… provided you relate GPS readings to maps and traditional orienteering.

Is GPS Here to Stay?

Absolutely. The multibillion dollar industry has proven its use significantly. More and more countries are contributing to a market with incredible growth, much more than just recreational handhelds. Global Positioning System receivers are currently used to track assets during shipment (e.g. diamonds and other precious cargo), manage fleet vehicles (e.g. taxi services), locate vehicles after theft, aid law enforcement vehicles and of course, continue its original use in complex military applications.

Global Positioning System receivers are used extensively in land surveying and numerous other applications (such as measuring continental drift and mountain heave), where they use sophisticated receivers and methods to achieve cm to mm level positions. These systems can cost upwards of a hundred thousand dollars and take trained technicians to operate.

How Does GPS Work?

All receivers use approximately 30 satellites orbiting 20,000 km above the earth, although only a portion of them are simultaneously visible to a user. The key to the system is that each satellite uses an atomic clock, which keeps time between satellites within seven nanoseconds! Satellites then synchronously and repeatedly send their own unique code on electromagnetic radio waves, allowing GPS receivers to lock onto the numerous signals and track them. The satellite's code serves a dual purpose; it allows the receiver on the earth to measure the distance to each visible satellite. Additionally, the satellite

Using GPS while at camp or in the outdoors, adds a new "techno" skill that Scouts enjoy.

Photos: Jared Bancroft

sends an encoded message with parameters that allow the receiver to calculate where the satellite was when it sent the code. With all this information, we now have a high school math problem; three known points (the satellites) and three distances from the satellites (to the receiver). The mathematics is known as trilateration. (See figure 1.)

However, there lies a critical problem with the GPS receiver to measure the distances to the satellites. In reality, the distance is never really measured; it measures the time it takes for the signal to travel from the satellite to the receiver instead. Because we know how fast the signal is going (the speed of light), it is possible to calculate the distance with the time of travel. However, the handheld GPS receiver doesn't keep time as precisely as the satellites and is offset by small amounts. Therefore, the receiver measures travel times (to all the satellites) that are biased by one unknown time. Receivers then solve for this unknown time bias by observing yet another satellite (at least four in total). Thus, for any receiver to compute its position (and time), it will need to track at least four satellites. Global Positioning System receivers must always determine an incredibly precise time to determine your position. Therefore, they not only provide positions, but time with a very high accuracy. A GPS receiver is practically a perfect watch for many applications!

How Accurate is GPS?

A typical handheld GPS receiver (e.g. Garmin or Magellan) can reach a maximum horizontal accuracy of *about* 5-10 metres (within a 5-10 m radius circle 95% of the time). This may sound a bit vague, but in reality the accuracy of the GPS varies with several factors.

Figure 1

Shows how trilateration is the intersection of three spheres to calculate a position.

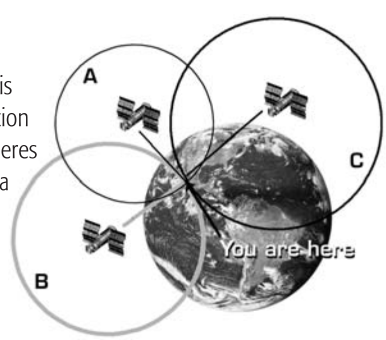
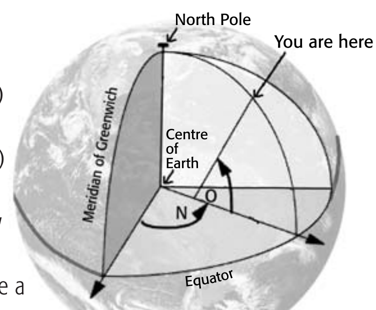


Figure 2

Longitude (shown as N) and latitude (shown as O) are angles showing how they can be used to locate a point anywhere on the earth.

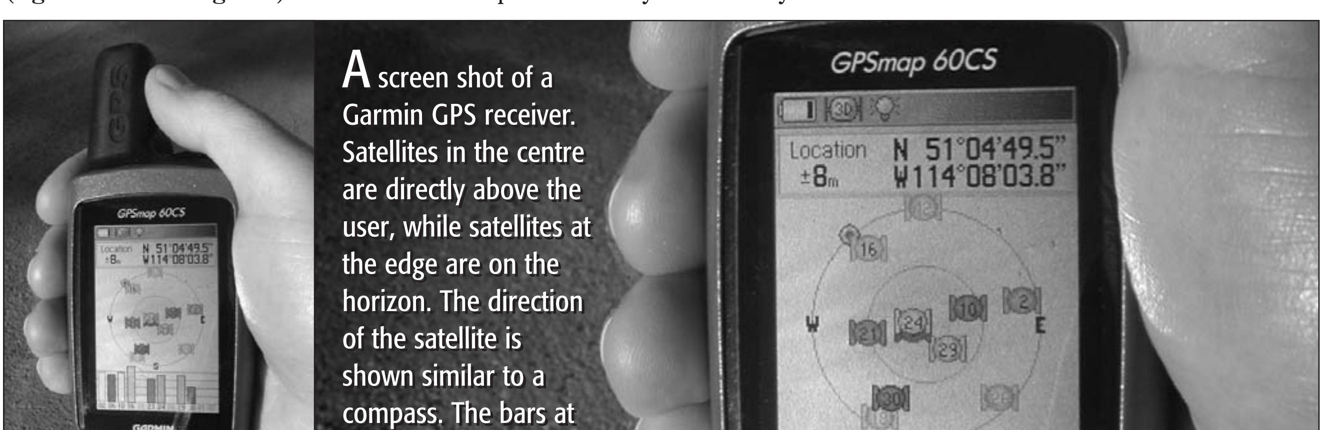


First, the number of satellites and their location in the sky is the largest contributing factor to accuracy. More satellites mean the position can be averaged (in complex mathematical processes known as Least Squares or Kalman Filtering), which becomes more reliable and robust. The satellite dispersion around the user, known as "satellite geometry" also affects accuracy. Satellites spread evenly across the sky will provide better positions than if all the satellites are to one side of the user (e.g. when on the side of a steep hill and only half the sky is visible). Satellites at the horizon must also travel through more atmosphere, which weakens signal power, delays the signal and provides comprised distance measurements.

Secondly, weak signal strength from the satellite makes the distance difficult for the receiver to measure and can provide poor distance measurements, thereby affecting the position it computes. Under regular open sky conditions, the signal strength is 10,000,000, 000,000,000 (10^{16}) weaker than when it was sent by the satellite. It's comparable to trying to measure a flickering 100 watt light bulb in Mexico City, while standing in Calgary! Even weaker signals occur indoors, under leafy trees, inside pockets, and near large buildings where the signal strength is reflected.

A new type of GPS receiver making its way into handheld models is called a High Sensitivity (HS) receiver. This is able to measure (with reasonable precision) very weak signals that previous models could not. Through some complex signal processing techniques, the receivers can usually operate under trees and achieve accuracy close to that under open sky conditions. A recent test we conducted showed that a HS Garmin receiver was able to provide tracking capabilities in a pocket, while in the mountains, under evergreen trees! If you are in the market for a GPS receiver for Scouting, High Sensitivity is the way to go.

There are many other aspects which degrade GPS accuracy, including atmosphere delays, large temperature variations, and other electronic interferences.



A screen shot of a Garmin GPS receiver. Satellites in the centre are directly above the user, while satellites at the edge are on the horizon. The direction of the satellite is shown similar to a compass. The bars at the bottom show the signal strength of the different satellites.

Photos: Jared Bancroft

The Wide Area Augmentation System (WAAS) is a feature now available on most handheld receivers. It was implemented in the United States to increase the accuracy of GPS receivers to assist with the landing of civilian airplanes. If accuracy is important, make sure it is enabled on your receiver.

The vertical accuracy of GPS is another story. Typically, vertical accuracy is two times worse than that of the horizontal component. Most handhelds report a horizontal accuracy, so for your elevation accuracy multiply the horizontal accuracy by two and you'll get a ballpark accuracy range. To counter this, numerous manufacturers now include a barometer inside the GPS receiver to improve the quality of the elevation. Wrist watch altimeters, which use barometers, can provide elevation gains over periods of several hours with accuracy better than five metres. The barometer is also a great tool to help predict the weather when camping, hiking or climbing.

Why Bother with Coordinate Systems?

GPS receivers can provide users with numerous types of coordinates. The most commonly used are latitude, longitude and elevation.

Another aspect of comparing maps and GPS receiver coordinates is the coordinate system used. There are typically two main coordinate systems that you will find on a map. These are latitude and longitude (known as geodetic coordinates) and UTM (Universal Transverse Mercator). Latitude is the angle extended from the equator to the user. Longitude is the angle from Greenwich Meridian, to the centre of the earth, to the user. (See figure 2.)

The UTM coordinate system was developed to simplify positioning. It divides the earth into 60 zones, creates a grid in each zone and adds a false easting and northing so as to avoid any negative coordinates. All the units are in metres, making for easy distance estimation while on the trail. Typically on maps, these are designated by light blue lines and show a grid pattern of 1000 by 1000 metres. These will provide the greatest resolution to find your GPS receiver's coordinates on the map.

GPS and Scouts

Because GPS is a tool more commonly used in outdoor activities, it is an important safety tool to teach Scouting youth. A GPS receiver is no substitute for compass navigation, but GPS can provide helpful information to leaders venturing off with their youth. Because GPS can calculate where you are, and a map can show you where you want to go, the combination is a powerful tool in teaching youth to navigate efficiently. Wasting time on the trail can be tiring and dangerous. Getting lost can be disastrous and catastrophic to even well prepared expeditions. To help, most receivers now include capabilities of including maps of roads and hiking trails. More web sites are appearing, allowing users to download specific routes others have logged while on the trail. Some advanced receivers even allow the user to know how far along the road/trail they are and how much further until their destination or next waypoint. However, always take a detailed paper map with you to provide more details and better orientation. And don't forget spare batteries for your GPS unit!

Geo-caching is a great activity to enjoy with Scouts. It's also a great way to reinforce what you taught them on mapping. For a challenge, see if the Scouts can find a cache without using a GPS receiver and only a compass! [See the *Leader Magazine,* Oct. 2005, April 2006 and April 2007 for more articles on Geo-Caching.]

A favorite activity, (especially on winter camps), is to have a GPS scavenger hunt. One morning, take a few hours to set up a series of waypoints and hide some prizes. Form the Scouts into teams and send them on their way to find each prize using their GPS receiver. The first team back wins and receives an extra prize for their expert navigation skills. It's a great activity to get them moving when they're cold! ⅄

– Jared Bancroft is the Scout leader for the 147th LDS Scout Troop in Calgary. He has been involved in Scouting for nine years as a youth and three years as a leader. He is currently a graduate student at the University of Calgary studying Geomatics Engineering. Questions and comments can be directed to Jared at: jbancroft@gmail.com.

– Gérard Lachapelle is professor of Geomatics Engineering at the University of Calgary and has been involved in advanced GPS research for nearly 30 years. He was a Scout leader with Strathcona 215 Group for eight years.

Interested in Learning More?

Jared and Gérard provided so much detail it wouldn't fit in one article! Visit Scouts Canada's web site, www.scouts.ca. Click on *The Leader*, and find the article titled, "**More GPS Information**."