**WHAT IS GPS?**

The **Global Positioning System** (GPS) consists of 24 earth-orbiting satellites. These satellites allow any person who owns a **GPS receiver** to determine his or her precise longitude, latitude and altitude anywhere on the planet. For as little as $100, you can know exactly where you are and where you have been.

**Trilateration:**  is a basic geometric principle that allows you to find one location if you know its distance from other, already known locations. The geometry behind this is very easy to understand in two-dimensional space.

This same concept works in three-dimensional space as well, but you're dealing with spheres instead of circles. You also need 4 spheres instead of three circles to find your exact location. The heart of a GPS receiver is the ability to find the receiver's distance from 4 (or more) GPS satellites. Once it determines its distance from the four satellites, the receiver can calculate its exact location and altitude on Earth! If the receiver can only find three satellites, then it can use an imaginary sphere to represent the earth and can give you location information but no altitude information.

For a GPS receiver to find your location, it has to determine two things:

1. The location of at least three satellites above you
2. The distance between you and each of those satellites

**MEASURING**

GPS satellites send out radio signal that your GPS receiver can detect. A GPS receiver measures the amount of time it takes for the signal to travel from the satellite to the receiver. Since we know how fast radio signals travel -- they are electromagnetic waves and so (in a vacuum) travel at the speed of light, about 186,000 miles per second -- we can figure out how far they've travelled by figuring out how long it took for them to arrive.

Measuring the time would be easy if you knew exactly what time the signal left the satellite and exactly what time it arrived at your receiver, and solving this problem is key to the Global Positioning System. One way to solve the problem would be to put extremely accurate and synchronized clocks in the satellites and the receivers. The satellite begins transmitting a long digital pattern, called a **Pseudo Random Code**, as part of its signal at a certain time, let's say midnight. The receiver begins running the same digital pattern, also exactly at midnight. When the satellite's signal reaches the receiver, its transmission of the pattern will lag a bit behind the receiver's playing of the pattern. The length of the delay is equal to the time of the signal's travel. The receiver multiplies this time by the speed of light to determine how far the signal traveled. if the signal traveled in a straight line, this distance would be the distance to the satellite.

The only way to implement a system like this would require a level of accuracy only found in atomic clocks. This is because the time measured in these calculations amounts to nanoseconds. To make a GPS using only synchronized clocks, you would need to have atomic clocks not only on all the satellite, but also in the receiver itself. Atomic clocks usually cost somewhere between $50,000 and $100,000, which makes them a little too expensive for everyday consumer use!

The Global Positioning System has a very effective solution to this problem -- a GPS receiver contains no atomic clock at all. It has a normal quarts clock. When you measure the distance to four located satellites, you can draw four spheres that all intersect at one point. Four spheres of this sort will not intersect at one point if you've measured incorrectly. Since the receiver makes all of its time measurements, and therefore its distance measurements, using the clock it is equipped with, the distances will all be proportionally incorrect. The receiver can therefore easily calculate exactly what distance adjustment will cause the four spheres to intersect at one point. This allows it to adjust its clock to adjust its measure of distance. For this reason, a GPS receiver actually keeps extremely accurate time, on the order of the actual atomic clocks in the satellites!

One problem with this method is the measure of speed. As we saw earlier, electromagnetic signals travel through a vacuum at the speed of light. The earth, of course, is not a vacuum, and its atmosphere slows the transmission of the signal according to the particular conditions at that atmospheric location, the angle at which the signal enters it, and so on. A GPS receiver guesses the actual speed of the signal using complex mathematical models of a wide range of atmospheric conditions. The satellites can also transmit additional information to the receiver.

From this discussion you have learned several important facts about the Global Positioning System:

1. The Global Positioning System needs 24 satellites so it can guarantee that there are at least 4 of them above the horizon for any point on earth at any time. In general there are normally 8 or so satellites "visible" to a GPS receiver at any given moment.
2. Each satellite contains an atomic clock.
3. The satellites send radio signals to GPS receivers so that the receivers can find out how far away each satellite is. Because the satellites are orbiting at a distance of 11,000 miles overhead, the signals are fairly weak by the time they reach your receiver. That means you have to be outside in a fairly open area for your GPS receiver to work.

**FINDING THE SATELLITES**

The other crucial component of GPS calculations is the knowledge of where the satellites are. This isn't difficult because the satellites travel in a very high, and predictable orbits. The satellites are far enough from the earth (11,000 miles) that our atmosphere does not affect them. The GPS receiver simply stores an almanac that tells it where every satellite should be at any given time. Things like the pull of the moon and the sun do change the satellites' orbits very slightly, but the Department of Defense constantly monitors their exact positions and transmits any adjustments to all GPS receivers as part of the satellites' signals.

**GPS IN MOTION**

A standard GPS receiver will not only place you on a map at any particular location, but will also trace your path across a map as you move. If you leave your receiver on, it can stay in constant communication with GPS satellites to see how your location is changing.

A receiver can use all of this basic data to give you several pieces of valuable information:

1. How far you've traveled (odometer)
2. Your current speed (speedometer)
3. Your average speed
4. How long you've been traveling