The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

How it works:

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude).

How accurate is GPS?

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. The 12 parallel channel receivers used by Tripmaster are quick to lock onto satellites when first turned on and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. These GPS receivers are accurate to within 15 meters on average.

The GPS satellite system:

The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. These were developed by Rockwell International, starting back in the 1970's. They are constantly moving, making two complete orbits in less than 24 hours. These satellites are traveling at speeds of roughly 7,000 miles an hour.

GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there's no solar power. Small rocket boosters on each satellite keep them flying in the correct path. Here are some other interesting facts about the GPS satellites (also called NAVSTAR, the official U.S. Department of Defense name for GPS):

- The first GPS satellite was launched in 1978.
- A full constellation of 24 satellites was achieved in 1994.
- Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.

- A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
- Transmitter power is only 50 watts or less.

What's the signal?

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signals travel by line of sight, meaning they will pass through clouds, glass and plastic but will not go through most solid objects such as buildings and mountains.

A GPS signal contains three different bits of information — a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information.

Ephemeris data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

Sources of GPS signal errors:

Factors that can degrade the GPS signal and thus affect accuracy include the following:

- Ionosphere and troposphere delays — The satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.
- Signal multipath — This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.
- Receiver clock errors — A receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.
- Orbital errors — Also known as ephemeris errors, these are inaccuracies of the satellite's reported location.
- Number of satellites visible — The more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.
- Satellite geometry/shading — This refers to the relative position of the satellites at any given time. Ideal satellite geometry exits when the satellites are located at wide angles relative to each other. Poor geometry results when the satellites are located in a line or in a tight grouping.
- Intentional degradation of the satellite signal — Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defense. SA was intended to prevent military adversaries from using the highly

accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

The basis of GPS is "triangulation" from satellites:

1. To "triangulate," a GPS receiver measures distance using the travel time of radio signals.
2. To measure travel time, GPS needs very accurate timing which it achieves with some tricks.
3. Along with distance, you need to know exactly where the satellites are in space. High orbits and careful monitoring are the secret.
4. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

***By very, very accurately measuring our distance from three satellites we can "triangulate" our position anywhere on earth*.**

First consider how distance measurements from three satellites can pinpoint you in space. Suppose we measure our distance from a satellite and find it to be 11,000 miles. Knowing that we're 11,000 miles from a particular satellite narrows down all the possible locations we could be in the whole universe to the surface of a sphere that is centered on this satellite and has a radius of 11,000 miles. Next, say we measure our distance to a second satellite and find out that it's 12,000 miles away. That tells us that we're not only on the first sphere but we're also on a sphere that's 12,000 miles from the second satellite. Or in other words, we're somewhere on the circle where these two spheres intersect. If we then make a measurement from a third satellite and find that we're 13,000 miles from that one, which narrows our position down even further, to the two points where the 13,000 mile sphere cuts through the circle that's the intersection of the first two spheres. So by ranging from three satellites we can narrow our position to just two points in space. To decide which one is our true location we could make a fourth measurement.

But for the triangulation to work we not only need to know distance, we also need to know exactly where the satellites are. That 11,000 mile altitude is actually a benefit in this case, because something that high is well clear of the atmosphere. And that means it will orbit according to very simple mathematics. The Air Force has injected each GPS satellite into a very precise orbit, according to the GPS master plan. On the ground all GPS receivers have an almanac programmed into their computers that tells them where in the sky each satellite is, moment by moment. The basic orbits are quite exact but just to make things perfect the GPS satellites are constantly monitored by the Department of Defense. They use very precise radar to check each satellite's exact altitude, position and speed. The errors are usually very slight but if you want great accuracy they must be taken into account. Once the DoD has measured a satellite's exact position, they relay that information back up to the satellite itself. The satellite then includes this new corrected position information in the timing signals its broadcasting.

The same government that spent $12 billion to develop the most accurate navigation system in the world intentionally degraded its accuracy. The policy was called "Selective Availability" or "SA" and the idea behind it was to make sure that no hostile force or terrorist group can use GPS to make accurate weapons.

Essentially, the DoD introduced some "noise" into the satellite's clock data which, in turn, added noise (or inaccuracy) into position calculations. The DoD may have also been sending slightly erroneous orbital data to the satellites which they transmitted back to receivers on the ground as part of a status message.

Together these factors made SA the biggest single source of inaccuracy in the system. Military receivers used a decryption key to remove the SA errors and so they're much more accurate.

On May 1, 2000 the White House announced a decision to discontinue the intentional degradation of the GPS signals to the public beginning at midnight. Civilian users of GPS are now able to pinpoint locations up to ten times more accurately. However, the DoD may still introduce errors or even turn off GPS in certain parts of the world if it is in the interest of national security.

The following are some sites of interest on the internet concerning GPS:

- US Coast Guard Navigation Center http://www.navcen.uscg.gov/
- Interagency Executive GPS Board http://www.igeb.gov

For more information, contact Joel Beal at jbeal@gpsgateway.com. Or, you can visit the Gateway Professional Services web site at www.gpsgateway.com.