HOW GPS WORKS

http://electronics.howstuffworks.com/gps5.htm

Our ancestors had to go to pretty extreme measures to keep from getting lost. They erected monumental landmarks, laboriously drafted detailed maps and learned to read the stars in the night sky.

Things are much, much easier today. For less than $100, you can get a pocket-sized gadget that will tell you exactly where you are on Earth at any moment. As long as you have a GPS receiver and a clear view of the sky, you'll never be lost again.

In this article, we'll find out how these handy guides pull off this amazing trick. As we'll see, the Global Positioning System is vast, expensive and involves a lot of technical ingenuity, but the fundamental concepts at work are quite simple and intuitive.

Photo courtesy Garmin
Garmin GPS 72 handheld

Trilateration Basics

When people talk about "a GPS," they usually mean a **GPS receiver**. The **Global Positioning System** (GPS) is actually a **constellation** of 27 Earth-orbiting satellites (24 in operation and three extras in case one fails). The U.S. military developed and implemented this satellite network as a military navigation system, but soon opened it up to everybody else.

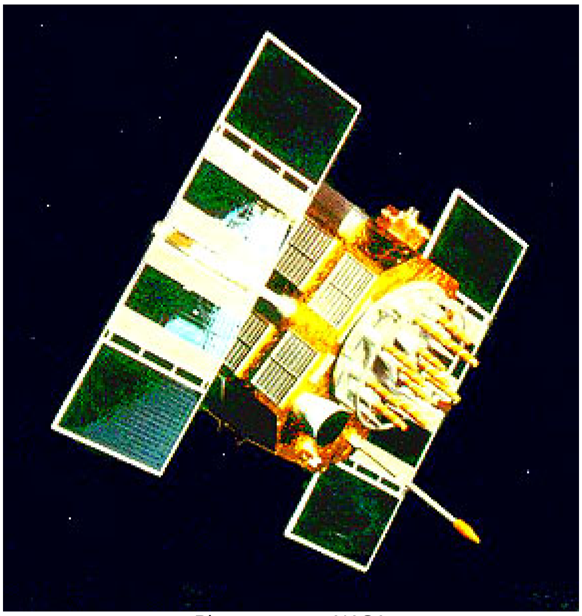


Photo courtesy NASA
NAVSTAR GPS satellite

Each of these 3,000- to 4,000-pound solar-powered satellites circles the globe at about 12,000 miles (19,300 km), making two complete rotations every day. The orbits are arranged so that at any time, anywhere on Earth, there are at least four satellites "visible" in the sky.

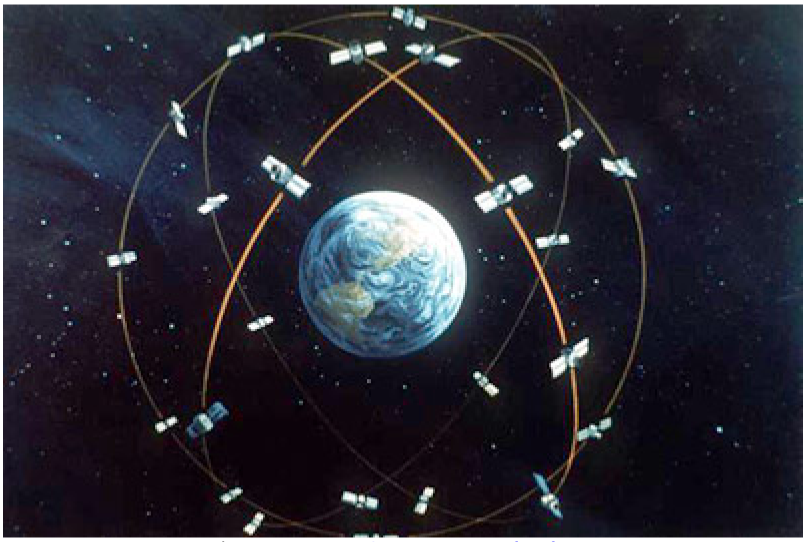


Photo courtesy U.S. Department of Defense

Artist's concept of the GPS satellite constellation

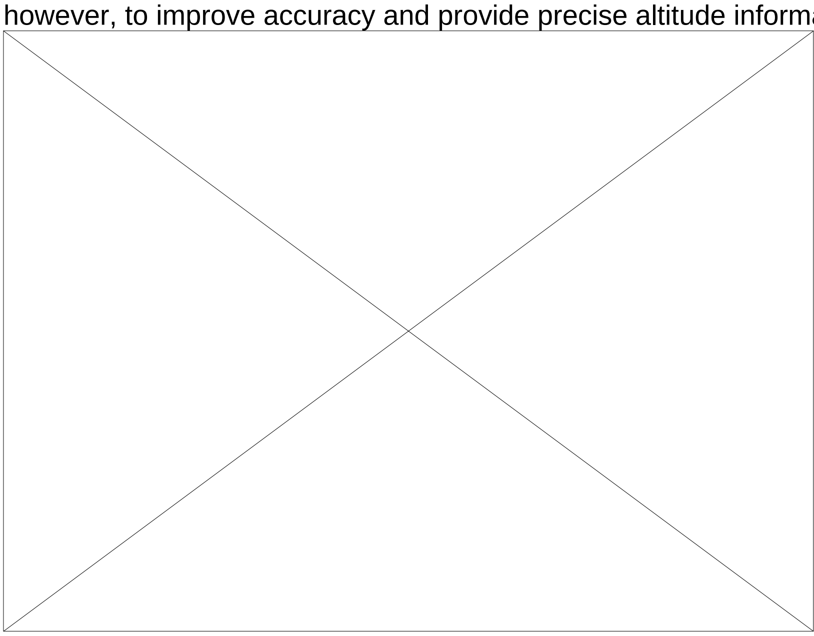
A GPS receiver's job is to locate four or more of these satellites, figure out the distance to each, and use this information to deduce its own location. This operation is based on a simple mathematical principle called **trilateration**. Trilateration in three-dimensional space can be a little tricky, so we'll start with an explanation of simple two-dimensional trilateration.

3-D Trilateration

Fundamentally, three-dimensional trilateration isn't much different from two-dimensional trilateration, but it's a little trickier to visualize. Imagine the radii from the examples in the last section going off in all directions. So instead of a series of circles, you get a series of spheres.

If you know you are 10 miles from satellite A in the sky, you could be anywhere on the surface of a huge, imaginary sphere with a 10-mile radius. If you also know you are 15 miles from satellite B, you can overlap the first sphere with another, larger sphere. The spheres intersect in a perfect circle. If you know the distance to a third satellite, you get a third sphere, which intersects with this circle at two points.

The Earth itself can act as a fourth sphere -- only one of the two possible points will actually be on the surface of the planet, so you can eliminate the one in space. Receivers generally look to four or more satellites, however, to improve accuracy and provide precise altitude information.



In order to make this simple calculation, then, the GPS receiver has to know two things:

- The location of at least three satellites above you
- The distance between you and each of those satellites

The GPS receiver figures both of these things out by analyzing high-frequency, low-power **radio signals** from the GPS satellites. Better units have multiple receivers, so they can pick up signals from several satellites simultaneously.

Radio waves are electromagnetic energy, which means they travel at the speed of light (about 186,000 miles per second, 300,000 km per second in a vacuum). The receiver can figure out how far the signal has traveled by timing how long it took the signal to arrive. In the next section, we'll see how the receiver and satellite work together to make this measurement.

When you measure the distance to four located satellites, you can draw four spheres that all intersect at one point. Three spheres will intersect even if your numbers are way off, but *four* spheres will not intersect at one point if you've measured incorrectly