Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *GPS*

OK – If you don't have one, you know someone who does, so let's skip the introductions and get straight down to the astronomy.

A standard GPS configuration is a constellation of 24 GPS satellites. The satellites are all at an altitude of 20,200 km with an orbital period of 11 hours and 58 minutes – which means they do exactly 2 orbits for each time the Earth spins once on its axis.

Four satellites each follow six orbital planes separated by 60 degrees which surround the Earth in an (airquotes) 'birdcage' of criss-crossing orbits. There a link to the relevant Wikipedia article from the Cheap Astronomy podcast page which has a nice animation of a GPS satellite constellation.

At last count, there were actually 31 actively transmitting GPS satellites – with these extra number increasing location accuracy and redundancy. There's been some recent media regarding a growing risk of dropping below the minimum 24 active satellites required to make GPS work effectively, but it remains to be seen if this risk will be realised in the face of the increasing economic importance of maintaining a working GPS system (and yes I do appreciate that saying GPS system is kind of like saying ATM machine).

A GPS satellite broadcasts a signal indicating where it is and the time the signal was broadcast – your receiver then determines, from the time it receives that signal, the distance travelled by the signal, knowing that, being a radio transmission, the signal travels at the speed of light.

By making just four calculations from four satellites in the sky, your GPS receiver can then establish its position with respect to latitude, longitude and altitude.

It's all about the conjunction of spheres. Imagine one satellite broadcasting a radio signal. If you pick up that signal and determine it's a 100 km away, all you really know is that you are somewhere on a surface of a sphere with a 100 km radius that has the satellite at its centre.

If there's two such satellites then you'll know you are somewhere on the circumference of a circle representing the plane where the two spheres of radio broadcast overlap. Introduce a third satellite and you can narrow down your location to just two points in space which are the points where two differently orientated circle circumferences intersect.

Potentially this may be enough to roughly determine your position since you can anticipate you will be on the one of those two points corresponding to the surface of the Earth. But for strictest accuracy – including accuracy in determining your altitude above sea level, the signal from a fourth satellite is required.

And that is the idea of the constellation of GPS satellites. Keeping 24 satellites moving in the same orbit, tracing a birdcage of divergent paths around the globe ensures there will always be four satellites in the sky wherever you happen to be on Earth.

Now when I say GPS satellites just have to broadcast where they are – actually knowing where they are is a whole separate operation, While the orbital period is predictable, knowing at what point they are on that orbit requires some very accurate time keeping – for which reason each satellite has an atomic clock.

Nonetheless, even this isn't enough, as the orbital paths of the satellites are subject to slight shifting due to the gravitational influence of the Sun and the Moon. To keep track of these changes the satellites are monitored from a fixed, known location on the Earth's surface – a function currently managed by the 50th Space Wing of the US Airforce Space Command – seriously.

Now, given that your GPS receiver is working out its distance from each of four satellites based solely on the time lag of a signal moving at the speed of light from a satellite just over 20,000 kilometres away – there is considerable potential for a margin of error that could see you driving over the embankment into a river when that sexy voice says 'turn left now'.

There are a range of methods to deal with various sources of error. Firstly your GPS receiver carries an electronic almanac of which satellite should be where since confusion can arise when the satellite radio signals get reflected off surroundings, such as tall buildings.

This electronic almanac is constructed from calibration data received from the GPS satellites, although these data are generally relayed from a ground-based source – such as Airforce Space Command. The almanac helps your receiver distinguish between garbage signals and genuine GPS signals.

The receiver also receives time checks from the satellites since, most GPS receivers determine time from a cheap (not that there's anything wrong with that) quartz clock rather than the ultra-accurate atomic clocks of the satellites. Clock error is probably the biggest potential source of GPS error, which is why, even though you could almost get away with determining your position from just 3 satellites, it is the fourth reading (which we might call quadrangulation) that ensures the poorer accuracy of the GPS receiver's clock is effectively accounted for.

Interestingly, there's also relativistic effects to account for, since the satellites move in a weaker gravity field (meaning by general relativity their clocks run faster), and they move at speed relative to the surface of the Earth (meaning by special relativity their clocks run slower). It turns out that the nett effect is that the satellites' clocks run about 38 microseconds per day faster than they would at the Earth's surface. To account for this, the clocks are actually set to run at a slightly lower rate, to keep pace with clocks running on the Earth's surface.

In the world of atomic clocks, various time keeping callibrations are also required to account for changes in the rotation of the Earth – which is influenced by the tidal drag of the Moon , the inertia of the Earth's molten interior and even the melting of glaciers. Overall, the Earth's rotation is slowing leading to a lengthening of a solar day.

Consequently a leap second must be introduced to atomic timepieces which measure Universal Coordinated Time (known as UTC – because of the French). In fact, a leap second is required to be added to UTC every 18 months or so because each year (on average) the length of a solar day increases by about 0.002 seconds.

The atomic clocks of GPS satellites were aligned to UTC in 1980 – but as of 2009, these atomic clocks in orbit now vary by 19 seconds and to keep it simple we just say they are running at GPS time.

Various under-the-hood adjustments are made along the way so that your GPS receiver can tell you the local time wherever you happen to be – as well as telling you where you are of course to within… well, within 10 metres is the general benchmark, although this takes a few minutes to establish after the unit is turned on and the accuracy will degrade with tall trees or buildings around. So, you know, it's a guide – not an absolute – it's still a good idea to keep one eye on the road.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where you can't put a price on space. No ads, no profit, just good science. Bye.