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Vincent Pica
District Commodore, First District, Southern Region (D1SR)
United States Coast Guard Auxiliary

Coast Guard Aux NEWS February 06, 2013

Preventing Collision at Sea: Gee, How Does GPS Do It?

In 1951, a Raytheon PhD, Dr. Ivan Getting, born in New York City in 1912, suggested to the US Government that satellites could be used for navigation and positioning. The concept was developed only from a laboratory stand-point for many years – until October 4, 1957.

Sputnik sent shock waves through the defense establishment when it became immediately apparent that its radio signal was a lighthouse in outer space.

By 1960, the US Navy had a working model and it went live with Transit in 1965 for the Polaris fleet. By 1973, the Navy wanted a reliable global system for all vessels and what we now know as "GPS" was borne in a brain-storming session at the Pentagon over the Labor Day weekend.

By 1978, the skeleton of GPS was aloft and reached operational status with 24 satellites in 1993. (There are now 31 such satellites aloft.) Around that time, the US Government turned over GPS technology, that we paid the estimated $12 billion it took to build, to the private sector and said, 'Have at it!' We did and companies and divisions of even bigger companies were created.

Along with the jobs and the benefits to so many that were derived from that act, there came one little wrinkle – "Selective Availability." The designers of GPS noted to President Bill Clinton that such technology could eventually be used by our enemies to target us. "For $500, some Russian spy drives up alongside a missile base, or the White House, and now has the exact position of where it is."

This was deemed, "Not such a good idea." So, the government intentionally degraded the quality of the system to the degree that "PO'GPS" (Plain Ol' GPS) was accurate to within roughly a football field.

In one of his final acts as President, Mr Clinton turned off Selective Availability, correctly reasoning that with nuclear weapons as powerful as they were, you didn't exactly have to hit the White House on the roof for the bomb to be effective in its mission. The only people being disbenefited by Selective Availability were the people who had paid for it – us.

How Does It Work?

The easiest and most reliable measurement we can make with current technology is time itself.

Everyone has heard of "atomic clocks," where we can measure time to within billionths of a second by counting the vibrations of the atoms themselves.

So, if we put enough atomic clocks in orbit and measure the time it takes, at the speed of light, for the signal of three of those clocks/satellites to reach our $300 GPS unit in the cockpit of our boat, we must know where we are. It is coastal piloting to the nth degree.

Akin to using a handheld compass to find the angle from our boat to three landmarks and drawing the lines back to the boat to find the boat's location relative to those objects, the GPS uses time differences to do the same thing. It can even tell your elevation should you be using a handheld GPS while hiking or hunting. But there are a couple of wrinkles in this simple model and it demonstrates the genius of the designers.

Forgetting about the "Doppler effect" (why a car's horn sounds differently as it approaches and then moves away from you), which is easily compensated for, the first wrinkle was thrown in by Albert Einstein. Under the Theory of Relativity, objects traveling at high speeds actually distort time itself. So, with the satellite traveling around the Earth at a distance of 11,000nm twice a day, "relativistic effects" have to be accounted for or the system would be absolutely useless.

In fact, if it wasn't for Einstein's work in 1905, there would be no GPS, period. The second wrinkle was cost – to us. To make the system work, all the clocks have to be accurate to a couple of billionths of a second of each other. Such clocks cost about $100,000.

Such an expense hardly stops a government project – but all the clocks have to be that accurate. That means the one in your GPS too . . . and the clock in your GPS is no more accurate (nor expensive) than your quartz-wristwatch. So, how does it work?

When my children confront me with some fantastic fact, I answer with this bit of logic: "If that were true, what else would have to be true to make it so?" This usually shortens the debate about Martians populating early Earth. But the designers of the GPS system used essentially the same logic to replace a $100,000 atomic clock with a cheap quartz wristwatch. They take the signal from a fourth satellite.

If our GPS clock was as accurate as the ones in the satellites, the redundant signal from the fourth satellite should give the same position as was calculated by the other three satellites. Once the GPS knows the difference in the calculated positions, it knows the error factor built in by the cheap quartz watch and it then compensates for it – giving you atomic clock accuracy on your boat!

How Accurate?

In the days of Selective Availability, commercial GPS accuracy was good to within the length of a football field. Now, it is accurate to within 30+/- feet. How come, with all this fantastic technology, it can't be more accurate? The answer is time again.

Light travels at about 1 billion feet per second. If light travels at a billion feet per second, this

means that it travels one foot in one-billionth of a second. While that is incomprehensibly fast, think of it this way: if you could drop this newspaper, travel 10 times around the world, you'd be back just before it hit the floor – about one second later. Fast, no doubt, but now conceivable. So, every clock in the system has to be accurate to each other by that same one-billionth of a second or there is a built-in one foot error. DoD is working to get them all accurate to each other to within a few billionths of a second on a daily basis as they pass overhead - until then, we'll have to be happy getting to within 10 meters of where we are on Earth!

BTW, if you are interested in being part of USCG Forces, email me at JoinUSCGAux@aol.com or go direct to the D1SR Human Resources department, who are in charge of new members matters, at DSO-HR and we will help you “get in this thing…”