GPS – Is it really that complicated?

By Chris Hope, Master CFI

A fact of human nature is that we take for granted those things in our life that we have grown up with, while those inventions that have come along after adulthood continue to amaze. Kids think that cell phones are normal – older adults remember the amazing Dick Tracy two-way wrist radio. All of us think nothing about electricity – my grandparents were thrilled when it actually was available in their rural home. And so it is with GPS.

Like many items in our life with a lot of technology in the background, we read and understand the promises of the sales team, but we don't read the fine print. We tend not to read the "how this works" part, and so we don't know when, where and why the system doesn't work. The system just works, and we assume that it always will.

GPS has become part of life very quickly. In less than ten years, the system has moved from a system found only in the very expensive airplanes to installations in the smallest object. Want to know where your daughter's bag pack was left? Check the GPS readout on your computer (oops – iPad).

The GPS is so ubiquitous that we fail to realize that it has some shortcomings. After all, in our car or boat, when we are hiking, when we are walking around downtown Chicago, we just push a button to tell the system where we want to go, and then we read the instructions. What could be easier? And it is because of this simplicity and easy use that I find a lot of pilots don't understand why the aviation world puts restrictions on GPS use in IFR operations. (When operating under Visual Flight Rules the FAA assumes that pilots will look outside to see discrepancies.) So maybe we need to know a little bit more about it.

That little device that slips into the airplane instrument stack, or that we lay on the glare shield or hold in our hand, is really four separate devices, bundled together. First, we have a satellite radio receiver. Next, we have a base map with its display with geographic (latitude / longitude) coordinates. Then, we have a long list of mapped items, all with their lat-lon coordinates. And finally, we have a really fast computer to analyze where we are located relative to those satellites and therefore to all of the other items that we have mapped.

So first, the receiver. In one sense, there is not too much difference between this receiver and a radio receiver (does anyone still remember VOR?) In the not too distant past, we pilots learned to determine our position by triangulating two or three VOR stations. We learned that we could tune a VOR to the appropriate frequency and determine the line that would take us to or from that station. And if we tuned into a second VOR transmitter, we could find a second line, and we could determine our position by where those two lines intersected. But fairly quickly, we figured out a couple of shortcomings. Our VOR receiver can be off as much as six degrees and still be legal for navigation. Secondly, if the two lines intersected at 90 degrees or so, we could put some reliability into the answer we got, and we would see our position somewhere in the area shown in figure 1. But if the two VORs were closer together, our position would fall into the area shown in figure 2.

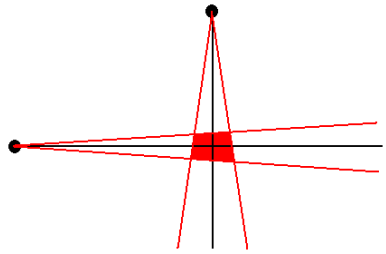

fig. 1

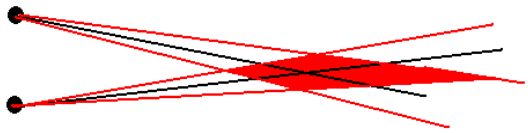

fig. 2

So, we figured that if we threw one more VOR into the mix, we could get this area of "we are in here somewhere" down to something more manageable. And our area of "we are in here somewhere" did become smaller, as shown in figure 3.

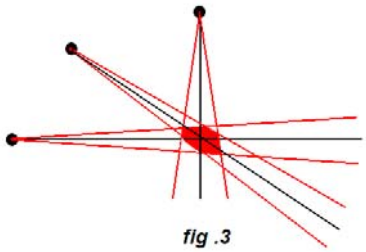

fig .3

But there are still two problems here. If we use more VORs, we need to either install more VOR receivers in the aircraft, or we need to retune the one that we have a whole lot quicker. And all the time we are doing this re-tuning, we are moving along the ground. But, in concept the system works. If we can only make the system more accurate so that that cone is smaller, and if could add one or two more transmitters at the proper angles we could make this "we are in here somewhere" area smaller and smaller.

The GPS system follows this logic. We take the line of position from three satellites, not two, because we are seeking to position our self vertically as well as horizontally. And because we need a higher degree of accuracy and reliability, the system actually insists on at least five satellites. And not only does the system need to receive at least five satellites, it needs to have them geometrically correct. It does not do much good if they are all in the same line.

When we navigated by looking outside and comparing our progress to a map, we were using the next two parts of the system. We had a lat-lon set of coordinates and we had a myriad of mapped items, all shown on the map with the correct relationship to one another. Then, using the VORs and the map, the computer in our head compared what we saw on the map with what we saw on the ground.

So why can't the GPS do the same? Well, usually it can. Which is why we depend on it so much. But if we are going to bet our lives on the information we see on the screen, we need to be really sure that it is correct. And there are several reasons why the data we see on the screen might not be accurate.

The first is that little computer that analyzed those satellite signals is comparing our lat-lon with all of the mapped items that exist in the database. Are those items are listed correctly? (In the map-using world, how many times did you look at the ground and see particular road but not find it on the map? Early on we learned that not every item on the ground was shown on the map.) We as pilots control this to a large extent by ensuring that we have a current database of information installed. The data on that little card or on the internal memory includes not only the aviation information but the location of rivers, highways and other physical elements. Using an out-of-date data card voids all guarantees that all of the mapped elements are included and correct.

When using a slide-in card to update the data, is the card electronically correct? Has it been corrupted in any way by heat, magnetic fields or maybe just being a bad disc? Having a card that puts the airport in the wrong location and us in the correct location still puts us in the wrong location. The Aeronautical Information Manual (AIM) Section 1-1-19 reminds us that it is up to us as user-pilots to check the information we see displayed on the GPS screen matches the information that we see on published charts.

Secondly, do we have adequate signals from the satellites? Here is the biggest difference between the IFR and VFR units. Satellites are essentially radio transmitters which can and do become unusable for our use. Sometimes they are unusable due to their own internal faults. If there is a known problem, there will be a NOTAM to that affect.

Sometimes the problem is due to the geometry of the satellite location relative to the aircraft antennas. In any case, an IFR-certified GPS includes a way to continuously monitor all of the incoming signals and predict that they will or will not continue to provide adequate satellite coverage. This system is called the Receiver Autonomous Integrity Monitoring system (RAIM). This circuitry, which is not included in VFR-only units, provides assurance that the unit is receiving acceptable signals from the minimum number of acceptable satellites and it can therefore determine its position in space with the desired accuracy.

Then we have the computer that ties it all together. Is it really analyzing all of those little bits of information and tying them together and displaying them correctly? If there is a problem with the screen display, all of the correct data is useless.

And finally, there is us, the pilots. Do we really understand which buttons to push to find the information that we want? And are we able to interpret the information that we see? For VFR use, the underlying assumption is that our primary method of navigation is still map reading – look out the window and compare the scenery with the map (on paper or iPad). And if we get engrossed with the electronics and forget to look outside? Well, as soon as we look outside we can level the wings and come back to the correct heading.

Under IMC, that luxury is missing. Not only are there a lot more buttons and knobs involved with setting up a route and instrument approach, the consequences of spending too much time looking at the equipment and turning knobs can be disastrous. Therefore, the last and equally important piece of “equipment” in the GPS system is the pilot and our commitment to knowing the equipment.

Fly safe.

Chris Hope has taught fledgling and experienced pilots for more than 35 years, mostly in the Kansas City area. Chris holds flight instructor certificates for single engine land and sea airplanes and multi-engine land planes, as well as for instrument training. He holds ground instructor certificates for advanced and instrument training. Chris is an FAA Gold Seal Instructor and a Master Certified Flight Instructor. Chris serves as a member of the FAASTeam in the Kansas City area. His website is www.ChrisHopeFAAFlightInstructor.com