If You Can't Afford a Nailgun, Will a Hammer Do?

Tapping the Miracle of GPS on a budget. . . .

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Oshkosh '96 was wonderful. In spite of warm humid weather, seeing old friends and getting down-n-dirty with airplane talk was great. I wasn't out of the booth much but I did make a quick tour through the commercial exhibit buildings and Fly-Market. Even did some shopping and got a bargain set of ni-cads for the lap-top. Thinking back over past years at Oshkosh, one group of products is remarkable for its explosive growth: GPS receivers.

Five years ago, they were almost nonexistent. Now, everyone in the avionics business offers several models. Recent additions include TSO'd products for IFR service in certified airplanes. The GPS receiver phenomenon exhibits some curious attributes. I observed many vendors who have never before offered any kind of avionics now sell GPS receivers. I also noted that prices varied by more than 10:1 which produced another question. Over the range of $300 to $3,000, what does one get for the money?

A brief review of GPS navigation technologies will help us get a handle on cost-benefit tradeoffs in GPS products. First, the hardware responsible for listening to satellites is a small part of the total package. Further, the receiver portion of a GPS can accomplish but one task . . . . . it reads time-of-day from three or more satellites with sub-nanosecond precision.

All of the satellites broadcast time-of-day from very precise clocks along with ephemerus and almanac data. Without the extra information, we cannot locate each satellite in three-dimensional space with respect to time of day. We know that radio waves travel at the speed of light (161,526 nautical miles per second or about 6.1909 microseconds per nautical mile). When a time update is received from any given satellite, we know the value received is "early" with respect to true time. A similar effect is in force when we observe the sun . . . it takes just over 8 minutes for light from the sun to reach earth. So, it stands to reason that position of the sun at sunrise and sunset are events that really occurred over 8 minutes earlier than when we observe it.

Let's assume that we also possess a clock precise as those aboard the satellites. Let us also assume that the received time from satellite A is 440.86 microseconds "early" which yields a distance from the satellite of about 72.21 nautical miles. Now we can deduce all of the solutions which satisfy a distance of 72.21 miles from satellite and find that there's a whole lot of them. In fact, the whole family of solutions describe a sphere-of-position (SOP) 144.42 miles in diameter with the satellite at its center. Hmmmmm . . . not very helpful.

If we assume that we're on the surface of the earth, and assume the earth to be a smooth sphere, the intersection of the 144.42 diameter SOP and the surface of the earth would describe line-of-position (LOP) wrapped into a circle. Hmmmm . . . better; at least we know that we're somewhere on that circle. Suppose we getting a second time value from another satellite? Okay, the second satellite SOP describes another LOP circle which will intersect the first LOP on the earth's surface in only two points. Aha! If we've just left Chicago and the two LOP intersections call out Peoria, IL and Lubbock, TX it's pretty safe to assume that we're over Peoria! However, this still doesn't work well if the receiver doesn't know where we left from and it still assumes that we're on the surface of a smooth earth! Okay, how about a third satellite? Sure enough, this does the trick. Three spheres-of-position will generate three line-of-position circles which may have multiple intersections between

pairs but only one intersection between all three! Guess what? If we know where the three satellites are with respect to each other and to the surface of the earth, we can now deduce our location both in terms of latitude-longitude AND altitude above the surface as well.

Lines-of-position locating is not a new concept . . . in fact, celestial navigation is based on the same idea. For example: a family of locations where a star sighting will produce any given angle with respect to the horizon describes a circle on the earth's surface. Two stars gets you two intersecting circles and two possible locations. A third star sighting resolves the ambiguity between the original pair of possibilities. This technique assumes that you have a good handle on time-of-day. First because finding a particular star in the sky is aided by checking time-of-day against almanac data for the star and second because time passes between sightings. At the equator, the earth's surface moves under the star canopy at 900 nautical miles per hour or a quarter of a mile per second! Corrections for earth motion with respect to latitude must be a part of good navigation. Timekeeping at sea was a serious problem until about 1750. Pendulum based clocks, no matter how accurate, were useless aboard a pitching and rolling ship!

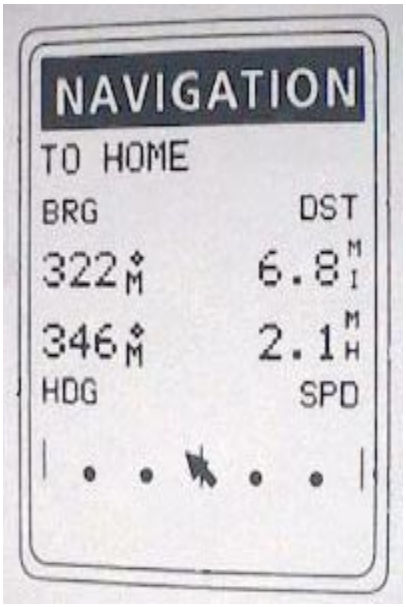
Practical celestial navigation at sea was not possible until clock maker John Harrison used Huntsman's spring grade steel and Earshaw's escapement to develop mechanical clocks with seconds per day accuracy in the late 1700's. Depending upon latitude, an error of 1 second will produce an error of up to one-fourth nautical mile. It wasn't until the early 1900's that quartz- crystal clocks and stationary radio transmitters were combined to provide the first versions of LORAN which allowed shipboard navigators to plot three LOPs to deduce present location from known references (stationary radio transmitters). Nowadays, still more accurate clocks are needed to deduce position to within a few meters of true using transmitters that whiz about the earth at thousands of miles per hour!

It follows that if a position fix later in time differs from a previous location, we must be in motion. It's a straightforward calculating task to figure out direction and velocity of travel. Further, the speed can be given in statute miles per hour, nautical miles per hour, kilometers per hour, etc. If we know where we are, then magnetic variation can be part of a built in data base so current course can be displayed in either magnetic or true degrees. If we know the location of a place we wish to visit, then further calculations will yield a best course to fly. With a little more number crunching, we can deduce distance yet to travel and time to cover that distance at present speed. Given current state of the art in hand-held electronics, adding moving maps and airport databases is just a matter of taking the time to do it. The ability to deduce present location is the real miracle of GPS. All the rest is just a whippy pocket calculator and "Gameboy" graphics.

I suppose now is a good time to get down to the reason for writing this piece! Allow me to explain: A few months ago, I began planning for a series of weekend seminars on aircraft electrical systems and thought it would be nice to offer a really useful door prize. Why not a hand-held GPS receiver? Why indeed. Having at least the spirit if not the substance of Scotch blood in me, I was interested in finding the least expensive product I could buy that would be useful to an airborne pilot. I dug through a number of catalogs and found a Magellan GPS2000 receiver for under $200! Problem was, the catalog catered to a different population of money-pit prisoners - BOATERS. Hmmmm . . . would this little feller be worth a hoot in an airplane? Only one way to find out.

A few weeks later, I began playing with the GPS2000 in a variety of places including wheeled vehicles and airplanes. Having NO database, the device wasn't in danger of becoming obsolete! It would hold hundreds of waypoints (I've never needed more than a dozen or so in all my years of flying). It tracked ground speed to over 200 knots. It features a POSITION screen displaying waypoint name, pointer showing direction turn toward waypoint, current position, altitude above sea level (disregard this display in an airplane!!!!) and time-of-day to nearest second (derived from satellites of course).

A mini HSI type POINTER display shows pointer to waypoint relative to compass points, digital bearing value (actually, the term BEARING with this GPS is a misnomer. Bearing is a direction relative to the airplane i.e. an object at 2:00 o'clock has a BEARING of 60 degrees to the right of our current heading. The numbers they give for bearing are really COURSE to MAKE GOOD or desired ground track . . . but given what this thing will do for the money, I'll forgive them a few idiosyncracies in terminology. A distance-to-go and time-to-go indicators are included in digits. The lable in the upper left corner is the waypoint name you're steering to. A small circle with a cross in it is the relative bearing of your waypoint. The arrow is a suggestion that a left turn is in order. Compass points are displayed around the perimeter of the arc . . . Hmmmm . . . just noticed an error in the the published figure . . . The first compass point clockwise from North is East . . . not West.



A third NAVIGATION screen displays digital bearing (course to make good). Here's another variant with the navigation terms. The GPS 200 displays HEADING but we know that is really present COURSE or ground track, we'll have to forgive them one more time. Anyone out there know the boating business well enough to tell me if the GPS 2000 terminology for vectors is okay for boats? I was under the impression that aviation derrived most of it's navigation terms from marine definitions) Distance to waypoint and Speed (over the ground of course). A pointer at the bottom of the screen shows left-0-right (displacement from desired ground track) combined with an arrow showing which way to turn to capture desired course. Further, it has a nicely back-lighted display for a dark cockpit and runs 20 hours plus on 4 AA cells. In short, the GPS2000 does about 99% of everything I ever wanted a nav system to do!

Hmmmmm . . . why didn't I see devices like the GPS2000 at OSH? I suspect that they're not very popular with vendors. If your mark- up is only 20% or so, you can do MUCH better selling $500-1000 devices than $200 ones. Besides, how can a little box like the GPS2000 compete toe-to-toe with all the moving map and database machines? To my way of thinking, it competes very well! First, a moving map display does not negate the requirement to have a current paper map in the cockpit. Looking up and entering waypoints for new places to visit is a trivial task . . . one of my favorite books in the flight bag is AOPA's Aviation USA directory with lat-lon of every place I'd ever want to find!

Avionics, particularly large volume avionics, is marketed like cars and laundry soap, "My product is (bigger, better, longer, faster) that the other product because. . . . ." You've all heard the pitch. The most disappointing statements by OSH attendees I spoke with went something like, "I'm not buying a GPS this year because I can't afford the one I want." Upon hearing that, I pulled the 7-bit boater's model out of my hip pocket and asked, "suppose you could get what you NEED for about $200?" They were all quite surprised and asked, "Does it have moving map? How about hooking it up to my PC? Can it find the nearest five airports when my engine catches fire?" Of course the answers were, "No, no and no." But I continued, "It will take you there and get you back with a level of precision and convenience never before offered at so low a cost. Some people were impressed, others poo-pooed it as "toy" compared to the "real" GPS products being offered at OSH. Allow me to suggest: Until you can afford the one you WANT don't forget that what you NEED may cost a lot less. Besides, when you finally do buy the panel mounted, full-color model with built in cellular phone, automatic flight plan filer and coffe machine, the "toy" can retire to your flight bag as a tried, proven and well understood back-up.

Happy flying!

I've received more response for this artical than in all others combined. Since it was originally published, the GPS2000 has been on sale at Walmart sporting goods departments for as low as $149.00! I've never before seen so much bang-for-the-buck in a piece of "avionics". At the time this article was posted to our website, I believe the GPS2000 has been upgraded and/or even replaced by newer versions. Given Walmart's generous return policy, there's no reason not to try this technology out for yourself . . . Keep all the wrapping in good shape and if you don't like it, take it back . . . I'm betting you'll keep it! Comments and alternative views welcome!

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