How Did We Get from There to Here? Part 2

By Chris Hope, Master CFI

Last month we talked about the earliest methods that we pilots used to get us from there to here. And the most basic of navigation systems, map reading, is still prevalent today. But both map reading and celestial navigation required us to be able to see outside. And although ded reckoning, in theory, could be accomplished over long distances with no view of sky or earth, most pilots and navigators registered no small amount of surprise when they eventually found their expected position matching their actual position.

So how did we get to the point where we can fly long distances without ever seeing ground or sky, and have an assurance that we arrive at our planned destination? Three parts really make up the answer.

The first part of the answer was supplied by Elmer Sperry. Elmer was born in 1860 and lived until 1930. He noted that a spinning body, a gyroscope, tends to maintain a rigidity in space even if the structure that it is mounted on moves or rotates. And if a force is applied to a spinning gyroscope, it reacts in a predictable manner. Elmer Sperry was certainly not the first person to notice this phenomenon, but he was able to see the advantages of incorporating the principals into aircraft in a way which would allow a pilot to tell which way was up.

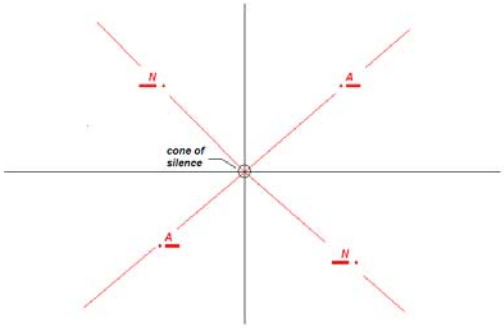
So now we can figure out how to keep the aircraft level. How to we actually navigate from place to place? Surprisingly, in concept, the engineers of pre- WW II got it right, and we have never changed. Oh, the details have changed, but the concept has proved to be rock solid.

Those early engineers knew that we pilots wanted some fixed reference points on the ground, points that we knew in reference to airports, cities and other landmarks. And they knew that only way that we pilots would know where those points were is if some type of radio wave could advise us.

The first radio system of navigation that came into wide-spread use was called the Adcock Radio Range or the A -N range radio.

The transmitter was placed at a known location, usually on the airport, and it broadcast two signals. On one axis, it broadcast the Morse code for the letter “A”, which is one short and one long sound (dit – dah). On the other axis, it transmitted the letter “N”, which is the opposite – one long and one short (dah-dit). On the axis midway between the two the axes, the sounds would merge into one solid sound. And when passing over the center point, the sound muted.

It was a good system, but not a great system. The pilot had to have some general idea of his location relative to the station. North and south sounded the same. East and west sounded the same. Once the sound came in fuzzy, he would turn either left or right to attempt to cross one of the main axis. At the point where the sound was most distinct, he knew that he was crossing an axis. And once he determined whether it was an A or an N, he would have a good idea of his direction from the station. (Unless, of course, he was on the totally wrong side.) As soon as he knew he was crossing a particular axis, he could turn to the station. When the sound suddenly disappeared, he knew that he was over the station. And then it was just a simple matter of flying away from the station on a predetermined leg for a set time at a set airspeed, and descending to an established altitude. Then, a course reversal, continue the descent and view the airport when descending out of the clouds. What could go wrong?



Well, there are some obvious challenges to the system. But one of the drawbacks was that the radio frequency range used was low frequency, essentially the AM radio that we still have. And radio waves in that frequency range are definitely affected by the weather. They bend, and they disappear when thunderstorms are near.

So, the next system was the Automatic Direction Finder. This system, also in the low-frequency range, allowed the pilot to tune to a particular frequency and watch a needle slowly turn and point to the station. A large improvement. Now the pilot could determine not just four legs, but 360 legs. And there was no longer any ambiguity between the two sides of the station.

The system had a couple more advantages. It was relatively cheap to install, and contrary to the thoughts of today’s instrument pilots, it was pretty easy to interpret. But although it was better than the Adcock Radio Range, it still had two large drawbacks. Even though it accurately pointed straight to the station in theory, in practice the needle would wander about ten degrees either side of an accurate track. And, as it used the low frequency radio, it was still very much influenced by weather (it would often point straight to the thunderstorms) and the vagaries of the night.

The fix to these issues was to change the type of radio signal. Instead of using low frequency signals that were easily distorted, engineers used Very High Frequency (VHF) signals, and thus the VHF Omni-directional Radio (VOR) was born. This solved the problem of wandering signal, but it still left two other problems unsolved. First, pilots knew the direction to the station, but not the distance. Second, the VOR signal was only strong enough to travel one hundred miles or so, and since it traveled lineof-sight, it wasn't much good in the valleys. So, while the VOR worked okay on land, it did not solve the over-ocean navigation issues.

The FAA went in two directions somewhat simultaneously to address this. First, the military had a system called Tactical Air Navigation (TACAN) that operated in the Ultra High Frequency Range (UHF), the frequency range above VHF. This system was providing both bearing and distance to a station. The solution? Physically locate the VOR and TACAN stations together, and broadcast the distance measuring equipment signal (DME) part along with the VOR signal. Thus did we get VOR-DME. So, we could now pinpoint our position relative to a series of fixed stations, but only over land.

About the time the engineers were looking at this solution, other engineers were looking at radio waves at the other end of the spectrum. Long Range Radio Navigation (LORAN) had been used for oceanic ship travel for some time. It used a low frequency signal (like the old short-wave radios) so its beams stretched for much longer distances. For airplanes, however, it had two big drawbacks. First, the equipment was bulky. The sets that I used during my ocean crossing days weighed around fifty pounds and were not "panel friendly". Secondly, they did not really display and data that was immediately usable by the pilot. Through some dial manipulations, a pilot or navigator could determine bearings to several distinct stations (a master station and two or three slave stations, making up a chain) and then he could plot those bearings on a map. If he was quick, he could determine where the plane was, five minutes in the past.

The advent of more compact circuitry solved the computation and display problem, and pilots loved the fact they could now determine a position relative to any point in space, and were no longer tied to the fixed positions of the VORTACs. Problem? The LORAN stations were focused for crossing the Atlantic and Pacific oceans, and coverage was not available over much of the central United States.

So while pilot groups were petitioning the FAA to build a chain of LORAN stations to cover the central US, avionics manufacturers were taking matters into their own hands. Their reasoning was, that if a VOR-DME unit could determine its bearing and distance from any station, it could establish any other point. Thus, one could name a point 40 miles east of a VOR as BEEFRIB, for example, and then find a distance and bearing relative to that point. And so for a while we had two complementary Area Navigation (RNAV) solutions. From a navigational point of view, the FAA did not care which solution a pilot used. Either system would provide a bearing and distance to an established point in space.

Ah, but the next step. Instead of fixing our position relative to some point on the ground, why not fix our position relative to some point in space? Of course, we needed to put some known points into space. And thus, satellite-based navigation was born.

The early GPS systems displayed their information exactly as the LORAN and RNAV systems had. There was a database of arbitrary fixed points, now known as waypoints, and one could select a waypoint and see the bearing and distance to that point.

But some clever engineer thought we could do better than that. Instead of compiling a list of all of the waypoints, why not use the tremendous computing power now available and list all of the roads, railroads, lakes and rivers as well? And then, why not show all of that information relative to the planes current position, and update it real often?

And thus the moving map, coupled with GPS positioning, and the end to map reading forever. Or not.

Don’t just practice until you get right. Practice until you don’t get it wrong

Chris Hope has taught fledgling and experienced pilots for more nearly 40 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