3-D Potpourri

Earl F. Burkholder, PS, PE, F.ASCE
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In 1977 I was newly licensed and soaking up "interesting" information related to the surveying profession. I came across an article, "Geodetic Potpourri," by Joe Dracup and enjoyed reading it. As many readers may know, Mr. Dracup was a colorful geodesist employed by the National Geodetic Survey (NGS) who made many contributions to the surveying profession. One of his more popular articles is posted at http://www.history.noaa.gov/stories_tales/geodetic1.html.

His potpourri article provided me an opportunity to learn a new word and to gain more insight into the larger world of geodetic surveying – that of the NGS and other related geodetic surveying activities. Of course, I "saved" the article, but my current filing system did not support its re-discovery. So, I did a web search. No, I did not find the actual article, but I did find a reference to it. I just hope that some of my articles will be viewed similarly by surveying professionals – young and old alike.

Those who follow my writing know that 3-D digital spatial data are my primary focus. Yes, 3-D offers a "new" way of looking at many problems but, over time, "new" will lose its luster and using 3-D will be more commonplace. Given the existing rate of change, that may happen sooner than later.

Glen Schaefer, a geodetic engineer retired from the Wisconsin DOT (also retired as a Captain in the NOAA Commissioned Corps), sent me a "teaser" from the December issue of the Wisconsin Professional Surveyor Newsletter. The "teaser" was posted by Jerry Mahun who asked for the shortest distance between two ends of a tunnel proposed (tongue-in-cheek) to be built by Elon Musk from Las Vegas, NV to a point in Wisconsin. With the information provided, Glen and I both concluded (somewhat facetiously) that the easiest way to answer the question is to compute Earth-centered Earth-fixed (ECEF) X/Y/Z coordinates for the end points and to compute a straight-line distance using

$$Distance = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2}\ .$$

Now, I've known Jerry as a fellow surveying educator for many years and have high regard for his contributions to surveying. But I'll admit that I have not asked him if that is the answer he was expecting – I presume it was not. Why not? Well, a professional is expected to provide "reasonable" solutions to a problem and I doubt that Jerry would accept an answer that burrows so far into the Earth. Yes, using any of several methods, one can come up with a reasonable answer that does not ignore Earth's curvature. Incidentally, if one goes to the half-way point of our "straight line" (the means of the X/Y/Z coordinates of the endpoints), then computes latitude/longitude/ellipsoid height of that midpoint, the surprising value of ellipsoid height (depth of a ventilation shaft) is a rather large negative number – much too large for any known tunneling operation! Yes, it is a long way from Las Vegas to Wisconsin and the distance between arc and chord gets to be quite large – in this case over 100 km.

Which brings me to the real point I wanted to raise – what are the reasonable options for "shortest distance"? Is it a horizontal distance, a slope distance, an arc distance, or a distance at a specified elevation? I am making no attempt to answer that here, but I am working on a more comprehensive article to examine the options – stay tuned.

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On to another item as reported in the February 4, 2018, issue of the New York Times. It seems that the nation of Nepal plans yet another GPS survey to determine the height of Mount Everest.

https://www.nytimes.com/2018/02/03/world/asia/mount-everest-how-tall-nepal.html

The summit of Mount Everest has been surveyed in the past but, national pride being what it is, Nepal plans to determine their own result rather than accepting answers from other nations such as China, Denmark, Italy, India, and the United States. The Times article mentions the dilemma arising from different definitions of "highest" mountain. Is the number to represent distance from sea level or distance from the center of the Earth? If distance from the center of the Earth is the criterion, then Mount Chimborazo in Ecuador surpasses Mount Everest. That is because, as most surveyors know, the Earth is flattened at the poles and the peak of a mountain near the equator could be declared the highest even though its height above sea level is significantly less than, say, the height of Mount Everest.

The issue of different definitions is easily handled by declaring sea level (really the geoid) as the reference for height – after all, it is more intuitive. That introduces additional considerations - sea level is easy to see if you are standing at the coast, but it is difficult to establish sea level without ambiguity. Let's see, there is both a mathematical definition for the geoid and the physical location of the geoid. I leave it to the scientists and the physical geodesists to provide authoritative definitions but, for purposes of this article, let's say that the geoid is the equipotential surface that best approximates the size and shape of the Earth. Simple enough. Now, what about the location of the geoid? This is where it becomes challenging. Dissertations and books are written to describe the theory, many physical measurements are observed and recorded, and extensive computations are performed to find the location of the geoid. In this case, where is the geoid under the peak of Mount Everest? Unless one reliably knows the location of the peak and the location of the geoid under the peak, it is difficult (if not impossible) to find the elevation of the peak.

Reasons that finding the location of the geoid under Mount Everest is so difficult include:

1. Mount Everest is far from the nearest ocean coastline. Extrapolation can be problematic.
2. Acknowledging the fact of global warming, the volume of water in the oceans is not constant and sea-level changes. According to NOAA, sea-level rise has been 3.4 mm/year from 1993 to 2016.

   https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

3. There are issues of isostasy. Land masses re-bound and oceans deepen as land-supported ice melts.
4. The physical environment dictates the shape of geoid. Gravitational attraction, centrifugal force, water temperature and density, and currents all affect sea level.
5. Angles, distances, gravity, and other elements need to be measured, modeled, and correlated.
6. Elevations in North America are based upon one "arbitrary" bench mark – Father's Point/Rimouski, Quebec, Canada. Is there a common bench mark and elevation applicable in Asia that all parties can agree upon?

Acknowledging the challenges of locating the elusive geoid, does it not make more sense to develop a comparison of ellipsoid heights (instead of elevations) from one GPS survey to another and from one mountain top to another? As a reference, Earth's center of mass is much easier to locate in terms of ECEF coordinates and is more stable than the geoid. Consequently, ellipsoid heights can be determined with much less ambiguity.

Yes, there is a lot of science and many interesting questions related to determining the location of the geoid but, from a practical perspective and acknowledging the importance of national pride, ellipsoid heights can provide a much better comparison. Mark it up as a benefit to be realized by using the global spatial data model (GSDM) – see www.globalcogo.com/gsdmdefn.pdf.

The GSDM also includes a stochastic model component which enables the user to track the standard deviations of measurements through various computations to provide the standard deviations of the computed quantities. Ellipsoid heights and their standard deviations can be used in hypothesis testing to determine various relationships between results from separate observing campaigns.

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The question of whether coordinates will ever be an acceptable substitute for monuments is another current topic. Traditional principles hold that the original undisturbed monument is sacred and is without error as defining a survey location. I too revere that legal principle and cannot be swayed from my conviction. But such a conviction should not preclude evaluation of new technology or procedures. We start down the "slippery slope" when the original monument has been disturbed or destroyed. That being the case, who has the authority or responsibility to re-habilitate the monument? Most licensed surveyors are experienced in the collection and evaluation of evidence and, given unambiguous evidence, are quite capable of replacing a monument.

But, we start down the slippery slope if and/or when a surveyor (or some administrator) who is dedicated to judicious use of resources makes the suggestion that since the location is already known, the time and expense of setting or replacing the monument can be avoided. After all, is that not standard practice when setting an offset monument to a corner that falls in the middle of a stream (or some other inaccessible point)?

I submit that the discussion should not center around whether GPS is used or not. The coordinate vs. monument discussions can be pushed to extremes and different viewpoints can be "legitimately" argued. On one hand, a missing monument is readily replaced from ties to local reference objects. If local ties are not available, a prudent surveyor may tie-in all other corners of a tract and (good intentions being what they are) may decide to come back next week to set the missing corner consistent with other found (and surveyed) corners of the parcel. Is the license of a surveyor who "forgets" to come back and set the missing corner to be revoked? It could be argued that the location of the missing corner is still valid even though it is not marked with a physical monument. Of course, the landowner who pays for a survey deserves to know where the corner is and to see it physically marked. But, again, what if the corner is out in the middle of a stream and what if the ground in the adjoining flood plain is not sufficiently stable to hold a reference monument position? How far can a reference monument be removed from the corner position without jeopardizing the integrity of a conscientious surveyor?

Now, given capability of existing technology and trending toward use of 3-D digital spatial data, how many dots must be connected before our process of rationalization will accommodate setting and replacing monuments in their "coordinated" position using local ties, traditional surveys, state plane coordinates, and even positions obtained from orbiting satellites? The discussion initiated by the Southeastern Wisconsin Regional Planning Commission is, in my opinion, entirely appropriate and demonstrates the need for all surveyors to be diligent in applying our talent to the protection of landowner rights in all cases.