Localization – Making it Easier to Understand and Use GPS Data

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This article was originally written in response to an October 2014 thread on the Surveyor Connect Bulletin Board asking "Exactly what is localization?"

Bulletin board thread: http://surveyorconnect.com/index.php?mode=thread&id=285796
Response by EFB: http://www.globalcogo.com/localization.pdf

My response was limited to horizontal considerations and was posted using the link above. This follow-up article expands the original response because other persons posting to the thread described various aspects of "localization" from different perspectives. It is a bit like the blindfolded men describing their experience of touching an elephant – none of their descriptions was wrong but they were quite different. With additional context, such disparate views might be less confusing. The goal in this expanded article is to provide context in terms of the global spatial data model (GSDM) – i.e., a well-defined model for 3-D digital spatial data. This article discusses "3-D localization" and considers both horizontal/vertical issues. Several posts in the Surveyor Connect thread extol the virtues of using a 7-parameter transformation for localization. That can be appropriate or it can be over-kill. This article stops short of a comprehensive discussion of 7-parameter transformations. If a detailed example of 7-parameter solutions is needed, see www.globalcogo.com/sewrpc49.pdf.

The web-posted response noted that "localization" can be variously described as:

- Finding a way to use 3-D geospatial data on a 2-D plane of the user's choice.
- Using 3-D geospatial data within an acceptable approximation of a flat earth.
- Using plane surveying latitudes/departures within the context of the global "cloud."
- Other . . .

The end result of "localization" is obtaining ground level horizontal distances/directions and using those vector components as plane surveying latitudes and departures. The user is responsible for choosing the point about which to localize. With due diligence, the value of the third dimension can also be preserved. There is no one "correct" mathematical procedure for localization due to many factors – often involving the choice of a map projection. In that regard, it helps to understand that a map projection is strictly a 2-D model which means that, in localization, the third dimension of spatial data must be handled separately.

Using standard solid geometry equations, the GSDM provides all the benefits of localization and low distortion projections (LDPs). Furthermore, the three-dimensional integrity of 3-D geospatial data can be readily preserved when using the GSDM. The GSDM equations are all public domain and easily programmed – spreadsheet or otherwise.

Information on how to use the GSDM is readily available and the following 3-D diagram (Fig 1) illustrates the relationship between various coordinate systems used. The author is happy to answer email inquiries – especially from the self-learner. Oh yes, although information on the GSDM is available at www.globalcogo.com/refbyefb.html, it is organized better in the book, "The 3-D Global Spatial Data Model" by Earl F. Burkholder.

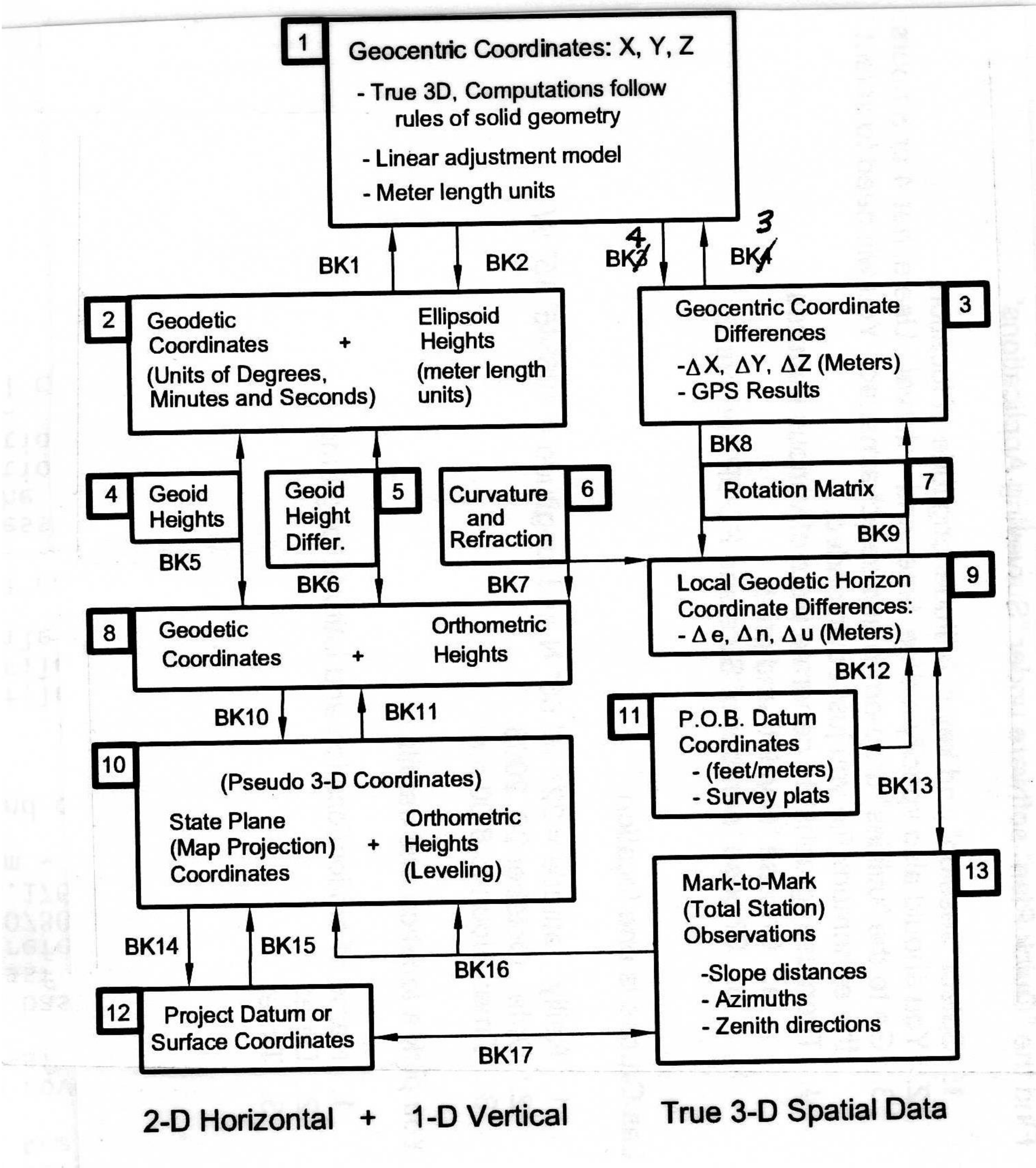

Fig 1, 3-D Diagram for the Global Spatial Data Model (GSDM)

In particular:

- Spreadsheet programs (www.globalcogo.com/BKpgms.html) can be used along with the 3-D diagram shown in Figure 1. The "BK" programs are keyed to the "BK" links between boxes on the 3-D diagram.
- Article #7 at www.globalcogo.com/refbyefb.html contains mapping equations for one of several methods for computing LDPs.
- Article #19 on the same list is a series of articles appearing in Professional Surveyor in 1998 and 1999. They were written specifically for surveyors.
- Article #20 on the same list is a rigorous summary of GSDM equations.

Notes with regard to using the GSDM include:

- Box #12 on the 3-D diagram shows project datum (LDP) coordinates.
- Box #9 on the 3-D diagram includes the 3-D local coordinate differences – $\Delta e/\Delta n/\Delta u$.
- Box #11 on the 3-D diagram shows P.O.B. Datum coordinates. The P.O.B. can be any point in the project (or cloud of points) and is selected by the user for convenience.
- When local coordinate differences are attached to the P.O.B. then the project has been "localized." The user may select any coordinate values for the P.O.B. Meter units are standard, but foot units can be used on a project if foot units are assigned to the P.O.B. and local coordinate differences are converted from meters to feet before being attached to the P.O.B. It should never be necessary to convert geocentric coordinates or geocentric differences to foot units.

An example project is http://www.globalcogo.com/3DGPS.pdf – see Plat in Fig. 2:

- The survey is "localized" on the SW Corner of Section 31 (selected as the P.O.B.).
- All courses on the plat give 2-D latitudes/departures with respect to the SW Corner.
- "Localized" distances are horizontal in the tangent plane at the SW Corner.
- Units of feet and meters are both used on this project. Note, in the article that the geocentric coordinates and geocentric coordinate differences are meters. Foot units are used to express the horizontal distances shown on the final plat.

Advantages of using the GSDM include:

- All points are geo-referenced with complete geometric integrity.
- Courses on a plat are in terms of local tangent plane latitudes/departures.
- No grid scale factors and no elevation (or combined) factors are involved.
- No state plane coordinates, no zones, and no map projections are needed.
- The user views all points from the user-selected P.O. B. – distortion free.

Now, what about those "tilted planes" discussed in the Surveyor Connect thread?

So far, this discussion is primarily concerned with plane coordinates – no elevations. Other issues must be considered when bringing elevations into the discussion. First and foremost, map projections are strictly two-dimensional models and elevation must be handled separately - meaning that there is no mathematical foundation for true 3-dimensional computations since the earth is not flat and elevation has its own reference surface.

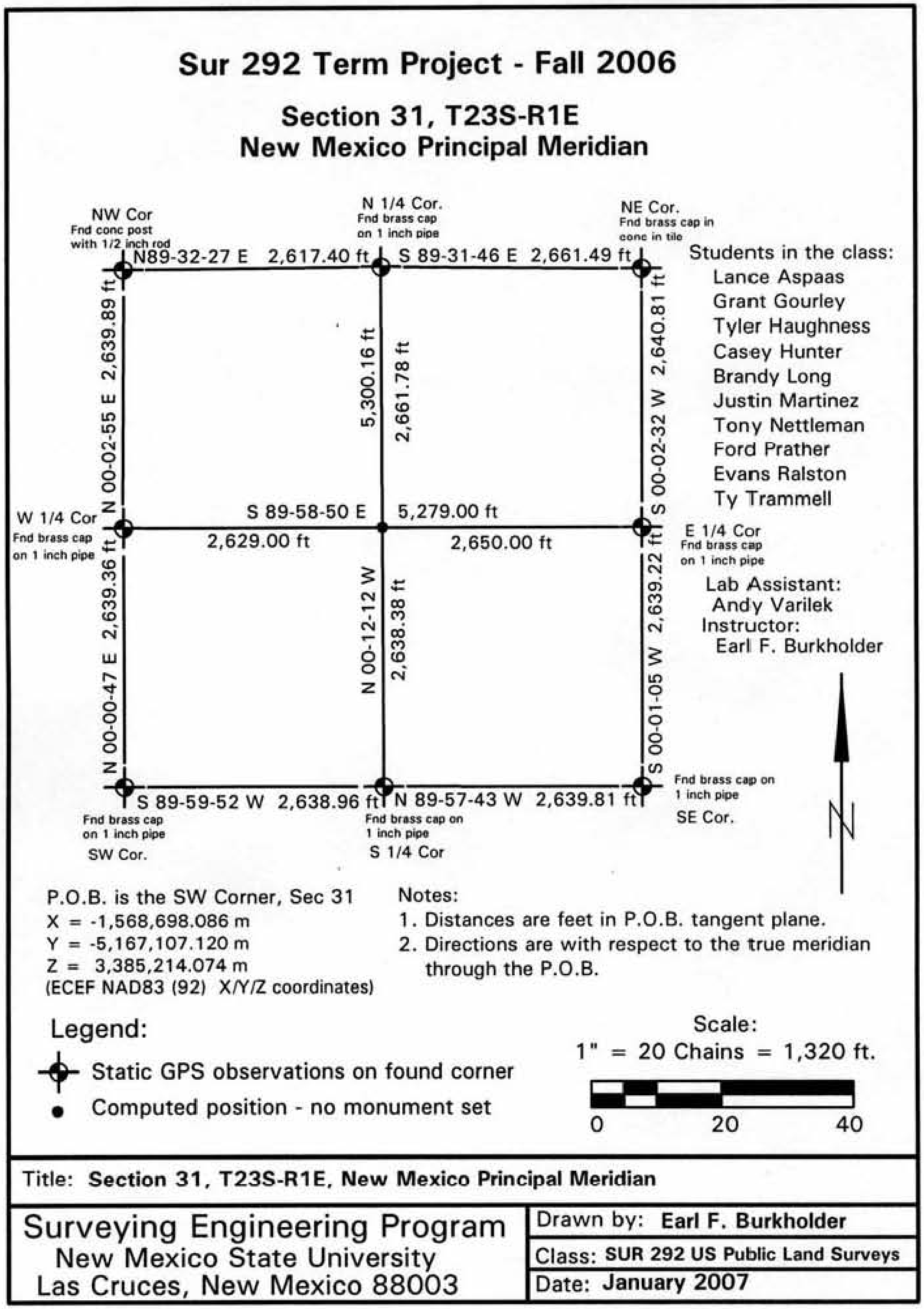

FIG 2 Plat of Survey – Section 31, T23S-R1E, New Mexico Principal Meridian

It is possible to preserve the 3-D integrity of the data when using a 7-parameter transformation to establish a local 3-D reference frame. The procedures are not trivial. In that case, the question becomes "What application is the "localization" to be used for and what does the software do with the data provided?" Many answers are possible and professional judgment is needed to assure the client is being well-served.

The attempt here was to describe two extremes. On one hand, a simple plane coordinate localization can be very valuable and useful. Simple 2-D localizations are used extensively. On the other extreme, with added effort and diligence, a strictly rigorous 3-D localization can be accomplished using a 7-parameter transformation. Regardless of the localization process used – whether at either extreme or somewhere between them – the fact is spatial data are not "exact" and nothing fits perfectly; meaning that the quality of a 3-D localization depends upon two separate factors – 1) the quality of the measurement data and 2) the appropriateness of the model being used in the software. For example, how does the software handle a non-flat earth?

Popular usage refers to "tilt of the plane" when judging how well elevations are modeled using a given localization procedure. It is true, reliable control points need to be dispersed beyond the boundary of a project in order to control such "tilt." But, unless appropriately qualified, such nomenclature can be misleading. The vertical reference used in localization is a plane only in the sense of "flat-earth." Otherwise the vertical reference for elevation is an equipotential surface. In that case, careful distinctions are appropriate and a sufficient number of well-spaced control points are needed to assure reliable results.

Rather than being critical of existing localization procedures being used, many persons utilizing GPS localization procedures are to be commended for due diligence, for testing their results, and for verifying the integrity of their answers project to project. In many cases, acceptable results can be obtained using simple localization procedures based on flat-earth assumptions. Depending upon the rigor needed, the elevations obtained from a given localization may or may not require use of more elaborate procedures such as those embodied in a 7-parameter transformation. For high-quality localizations, the GSDM used in conjunction with geoid modeling can be quite useful in obtaining quality results.

There is an ulterior motive for writing this article. CRC Press published the first edition of the book, "The 3-D Global Spatial Data Model" in April 2008. I've been asked to prepare a manuscript for the Second Edition of that book. In addition to material in the existing book, the Second Edition will contain additional material on least squares, spatial data accuracy, LDP's, and various applications such as drone navigation, intelligent vehicle guidance, underground mapping, localization, development of orthophotos, scale/elevation factors and others. Feedback on localization and other procedures for handling 3-D digital spatial data are welcome.