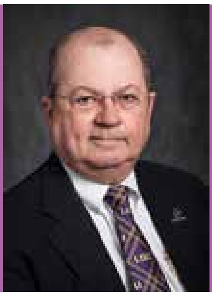

GRIDS & DATUMS

GRIDS & DATUMS of THE WORLD

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The U. S. Global Positioning System (GPS) satellites have revolutionized surveying and mapping activities. First-order astronomical theodolites are now used as bookends or displays in museums. Little classical triangulation is done outside of academic instruction because of the enormous cost-savings afforded by differential GPS techniques. However, the fruits of centuries of detailed *and largely reliable* classical surveys are the basic foundation of today's national topographic maps existing in every country throughout the world. When we venture into a "new" mapping project, there is some pre-existing survey data that will have to be incorporated into that data set. Although a GPS-controlled project is largely free of systematic error when properly executed, the prospect of quantifying the systematic error of an older data set and incorporating that older data into the new system can be daunting. A successful mapping project depends on the merger of the old with the new. An understanding and knowledge of past practices, techniques, and reference systems is the pre-requisite to that success.

The primary coordinate reference system of interest is the DATUM. The classical geodetic horizontal datum starts at a particular point. The North American continent has one major classical horizontal datum, which is the North American Datum of 1927. The starting point is defined at Meades Ranch, Kansas. Most datums have their historical origins at an astronomical observatory, mainly because when geodetic reference systems were originated, the best-known position in a region was at that observatory. That observatory also had a "mire" or reference point on the horizon with a known azimuth from true north (North Celestial Pole). With a known direction reference and a known position, physically measuring a distance to another point on the ground allowed the computation of another known position (latitude and longitude) with reference to the starting point or datum point. That's how all datums started. The observatory for NAD 1927 was not in Kansas but on the East Coast, and was used for earlier datums that included the New England Datum. Many of these classical origin points were also Prime Meridians (zero longitude) because these observatories established an *ephemeris* of their own for predicting positions of heavenly bodies with respect to their own reference meridian. For instance, classical horizontal datum origins that had their own Prime Meridians include: Amersfoort Netherlands, Bogotá Colombia; Dehra Dun India; Tokyo Japan, Madrid Spain; Athens Greece, Quito Ecuador, Ferro Canary Islands, Singkawang Borneo, Potsdam Germany and Greenwich England.

When we map an area, we first establish control points that encompass the entire area. We interpolate – not extrapolate – when we map, and we use a coordinate reference system of some sort. The establishment of a datum from a starting point required many points to be determined in order to provide control for a national or regional mapping program. The electronic distance meter was invented in the late 1940's almost simultaneously in Sweden and South Africa. Prior to that, steel tapes were used, commonly made of a quench-annealed nickel alloy called invar. Geodetic surveyors of the late 18th century did not have that technology available, and had to use other types of length-measuring devices. Measuring distances was extremely difficult and time-consuming. Triangulation baselines sometimes involved entire seasons for dozens of surveyors and helpers in the determination of a single 20–30 kilometer distance. Needless to say, after a baseline was determined to be reliable by several separate independent measurements, the last thing those geodetic surveyors wanted to do was to measure another baseline anytime soon. Triangulation techniques were developed to minimize the need for physically measuring distances on the ground. The basic mathematical formula they used for this purpose was the Law of Sines:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Of course, there are many corrections for systematic error that need to be made, but the basic principle of classical triangulation is just this simple. These points were observed as part of basic figures called quadrilaterals (four-sided) with all points being visible and all angles observed from all other points in the quadrilateral. Within each quadrilateral, there is an over-determination of lengths, which can be used in a least-squares solution. Tens of thousands of quadrilaterals observed throughout the world were run predominantly in North-South directions to obtain a best-fitting figure of the earth for the region under observation. Because we had many starting points (datum origins) with hundreds of crews and thousands of different instruments and length-measuring devices, we wound up with many different determinations of the size and shape of the earth (ellipsoids). Over time, many of the various ellipsoids never got past a single publication while a couple dozen became commonly used for actual mapping in different parts of the world. Ellipsoids were usually named after the geodesist that computed and published the values along with the year of the publication such as Clarke 1866, Everest 1830 and Bessel 1841.

Datums evolve with time and some ellipsoids have been modified as a result of a re-computation or re-adjustment of an older datum. In some cases, ellipsoids have been changed as a result of the adoption of new length standards such as new "meter bars". Classifying data types and coordinate systems in terms of specific map projections and ellipsoids is a common mistake; the most important classifier is the datum and its adjustment date. Therefore, once the specific datum is identified, all other parameters follow by definition. Datums vary in accuracy and reliability according to how various points were surveyed. The classical triangulations have evolved in accuracy as a result of improvements in instrumentation, field procedures and adjustment techniques. Furthermore, intersection points were observed as invaluable reference points for topographic mapping, but at a drastically lower level of accuracy than the basic quadrilaterals. Many intersection points could not be realistically occupied such as church spires, roof finials and water tanks. Although a datum defines the basic control for a region or continental area, accuracy varies according to the "order" of the original survey. Relating two datums to each other is valid only when we can identify common points that are part of main triangulation arcs. We cannot develop a meaningful transformation between datums when we are indiscriminate in our choice of common points. The chains of quadrilaterals represent the actual observations made over decades of datum development. Transformations are valid only when we relate chains of like accuracy or "order" for a given region. The larger the region for which we attempt to develop a relation, the larger the uncertainty we obtain for our relation. We sometimes use additional parameters to define a relation so that we can decrease the uncertainties for a region or given data set. When we establish control for a mapping project with GPS receivers, eventually we will have to relate old data to our new maps. If we undertake this task in the United States, it's a pretty straightforward and well-documented procedure thanks to the National Geodetic Survey. However, the datums and grid systems that exist in the world are myriad; there are over 1,100 classical horizontal geodetic datums existing in the world, and over 3,200 known grids. Last summer, I keyed in the classical geodetic coordinates of several dozen Datum origins into Google Earth™. Of course, when the software scrolled over to those parts of the world, the old origin points were not immediately apparent since Google Earth™ is referenced to the WGS84 Datum and ellipsoid. However, many, if not most are easily located based on their descriptions especially when the origin points are observatories. Most can be found within a kilometer or so, primarily in an East-West offset.