# *Geomatics Education and the Global Spatial Data Model*

Earl F. Burkholder, PS, PE
Surveying Engineering Department - 3SUR
New Mexico State University - Las Cruces, NM 88003

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## Abstract

The global spatial data model (GSDM) is defined elsewhere in terms of its functional model (Burkholder 1998) and its stochastic model (Burkholder 1999). After briefly summarizing those features, this paper looks at how the GSDM accommodates spatial data in geomatics-related disciplines such as surveying, engineering, geodesy, photogrammetry, remote sensing, mapping, and GIS. With that as background, it is suggested that the GSDM is an appropriate tool for handling vast quantities of digital geospatial data and for describing spatial data accuracy. Finally, questions are asked if, and to what extent, the GSDM should be part of a geomatics-related curriculum. A separate issue, acknowledged but not emphasized in this paper, is the storage and organization of 3-dimensional spatial data in a BURKORD® 3-D database.

## Introduction

An appropriate introduction to the global spatial data model (GSDM) might be to list several challenges facing geospatial data users as the world heads into the decade of the "naughts" and the next millennium. According to Vice President Al Gore (1998) in a speech titled, The Digital Earth: Understanding our planet in the 21st century, "the hard part of taking advantage of this flood of geospatial information will be making sense of it - turning raw data into understandable information." The following challenges all come under the umbrella of Gore's statement, but are listed separately for purposes of this discussion. Challenges for spatial data users include:

- Handling vast amounts of 3-dimensional (3-D) digital spatial data efficiently.
- Describing spatial data accuracy without ambiguity.
- Finding the best (appropriate) combination of tools, talents, and resources to accomplish the task at hand.

The third challenge is very open ended and relies heavily on seasoned professional judgement, but the first two challenges are addressed specifically by the GSDM and an underlying BURKORD® database. The functional model portion of the GSDM includes geometrical equations which permit each user to work with local coordinate differences while preserving true geometrical integrity on a global scale. The stochastic model portion of the GSDM includes rigorous error propagation procedures which accommodate input of measurement uncertainties and provide output of standard deviations of each 3-D coordinate position and/or other derived quantities. It has been said, "No job is difficult if you have the right tools." The implied part of the quote is also important, "and know how to use them." The goal of this paper is to examine features of the GSDM with the idea of finding better tools for handling digital spatial data. If the GSDM is an appropriate tool, then the larger issue, which goes far beyond this campus, this week, or this conference, is becoming more familiar with the fundamental concepts, using and building on those concepts, and sharing that knowledge with others. As Al Gore concluded in his speech, "Working together, we can help solve many of the most pressing problems facing our society..."

## Definition of the Global Spatial Data Model (GSDM)

The GSDM is a collection of existing mathematical concepts and procedures which can be used to manage spatial data both locally and globally. It consists of a functional model which describes the geometrical relationships and a stochastic model which describes the probabilistic characteristics--statistical qualities--of spatial data. The functional part of the model includes equations of geometrical geodesy and rules of vector algebra (solid geometry) as related to various coordinate systems, see Figure 1, Diagram Showing Relationship of Coordinate Systems. The primary system used by the GSDM is the earth-centered earth-fixed (ECEF) geocentric X/Y/Z coordinate system as defined by the Department of Defense (DMA 1991). The GSDM is also intended to be consistent with the 3-D Geodetic Model described by Leick (1995) with the following exception; the GSDM, being strictly spatial, does not include gravity measurements, but presumes gravity affects are accommodated before data are entered into the spatial model.

The stochastic model component of the GSDM uses fundamental error propagation concepts as described in Chapter 4 of Mikhail (1976) and Chapter 5 of Wolf/Ghilani (1997). The GSDM stores stochastic information in the variance/covariance matrix associated with each point defined by ECEF coordinates and in the correlations between point-pairs. The local perspective (e/n/u) covariance values and standard deviations need not be stored but are computed upon demand from the geocentric values. The accuracy defined by each point covariance matrix, whether geocentric or local, has been called **datum accuracy**. A BURKORD® 3-D database accommodates storage of both the geocentric covariance values for each point and the point-pair correlations. That capability supports and allows one to exploit the rigorous mathematical definitions of **local accuracy, network accuracy,** and **P.O.B. accuracy** when computing a 3-D inverse between points (Burkholder 1999).

# The BURKORD™ 3-D Diagram

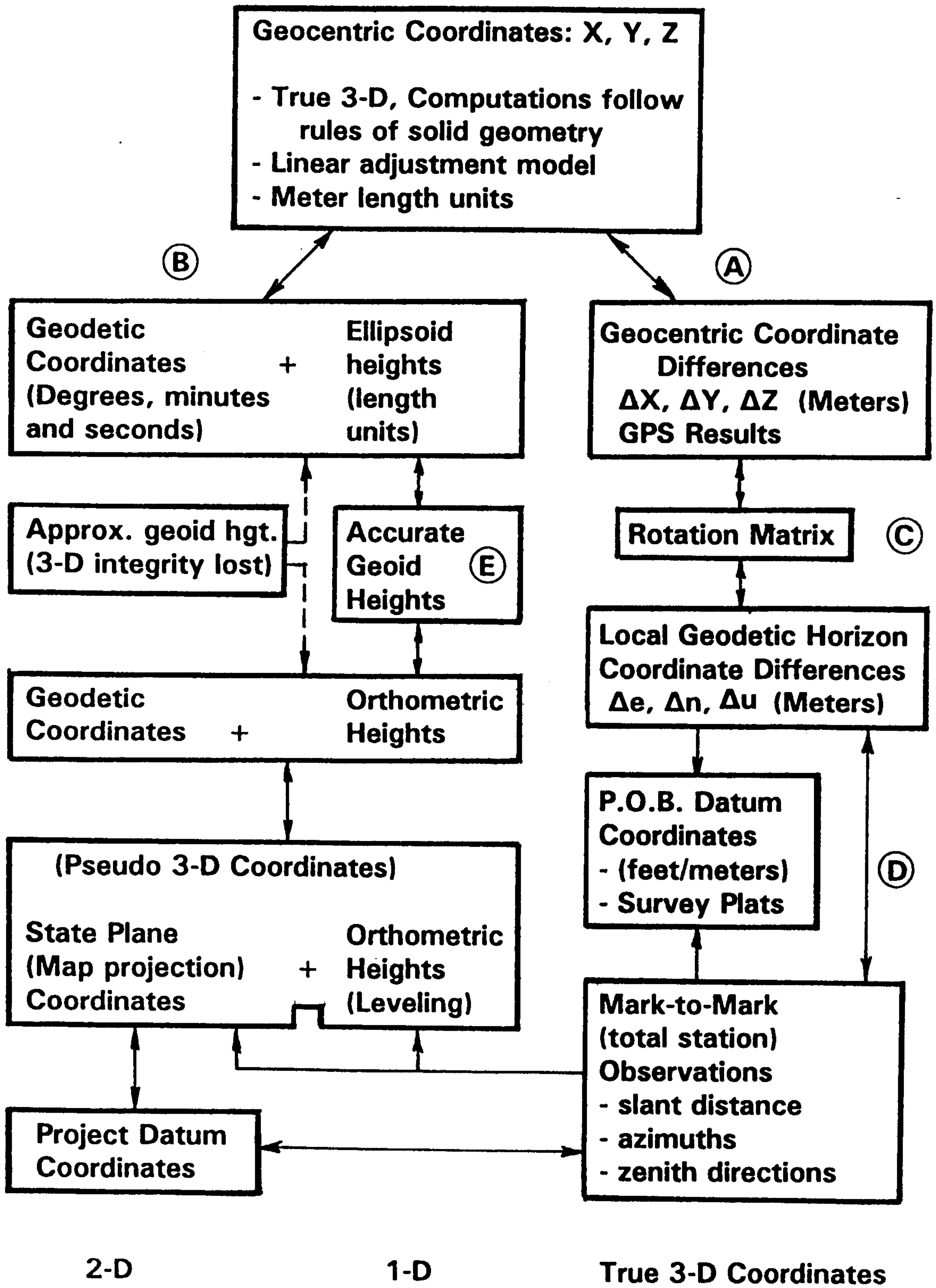


Figure 1 Diagram Showing Relationship of Coordinate Systems

A general description and details of the GSDM are contained in a series of three articles by the author published in the *Professional Surveyor* magazine:

- October 1997: The Global Spatial Data Model: A Tool Designed for Surveyors
- Nov/Dec 1997: Using the Global Spatial Data Model (GSDM) in Plane Surveying
- Jan/Feb 1998: Positional Tolerance Made Easier With the GSDM

Two other articles which describe the functional and stochastic components of the GSDM more rigorously are:

- "A Practical Global Spatial Data Model (GSDM) for the 21st Century" presented at, and included in the proceedings of, the National Technical Meeting of the Institute of Navigation, Long Beach, CA, January, 1998.

- "Spatial Data Accuracy as Defined by the GSDM," *Surveying and Land Information Systems*, Vol. 59, No. 1, March 1999, pp 26-30.

Additional information on the GSDM is found at URL: **www.zianet.com/globalcogo.**

## Application to Geomatics-Related Disciplines

It is not possible in one short presentation to discuss adequately the manner in which the GSDM supports the use of spatial data. The following examples are highlights and somewhat obvious. There are many others which will be discovered, discussed, and documented in the months and years to come.

<u>Plane Surveying:</u> Plane surveyors have worked with latitudes and departures for generations. Local rectangular flat-earth relationships, including 3-D, are handled with aplomb by the GSDM. The rules for working with local coordinate differences match existing land surveying practice very well. Admittedly, special attention must be given to elevations because the $\Delta u$ component as used in the GSDM is the perpendicular distance from the forepoint to the tangent plane, not an elevation difference. $\Delta u$ does not include curvature and refraction (c+r). When working over short distances at a nominal level of accuracy, c+r is insignificant. But, the c+r correction can be added to $\Delta u$ to obtain local elevation differences as needed.

<u>Engineering Surveying:</u> It is an artificial distinction to say that engineering surveying is more precise than plane surveying but several features of the GSDM can be associated with such a distinction. First, the GSDM preserves 3-dimensional geometrical integrity in a global sense. In this environment, geoid heights become critical because they are the link between ellipsoid heigths and reliable elevations. Geoid modeling and on-going research are both critical. Second, when using the GSDM, the adjustment of control networks, GPS or otherwise, is linear and avoids complex issues associated with linearization and iteration. Finally, the concept of local accuracy of directly connected measurements is valuable in many applications.

Geodesy: In one sense, the art of geodesy involves documenting the location of points while the science of geodesy (gravity) helps explain why a point is where it is. In the past, primary location has been defined in terms of horizontal position (latitude/longitude) and height (ellipsoidal or orthometric). With implementation of the GSDM, horizontal and vertical datums are replaced by a 3-D datum of X/Y/Z coordinates and orders of accuracy (first-, second- etc) are replaced by standard deviations--component by component. Traditional values of latitude/longitude/height and their accuracies can be derived from primary X/Y/Z coordinates and their associated covariance matrices. Research into the gravity field and geoid modeling is still important but it is generally acknowledged that GPS technology has solved the location problem. And, the GSDM defines the unique location of points - globally.

Photogrammetry: Photogrammetry has been defined as the science of making measurements from photographs. The geometrical interpretation of those measurements has been used to develop photogrammetric mapping to a very sophisticated level. With development of computers and digital technology the state-of-the-art is now referred to as softcopy photogrammetry in which the spatial location of a point is computed with respect to some coordinate system and stored digitally in a computer file. In this environment, the photogrammetrist (spatial data user) is free to construct a digital terrain model to represent the ground surface or other feature being mapped. Options for plotting and data visualization are numerous. But, even with elaborate manipulation and presentation of digital spatial data, the fundamental determination of spatial location is the intersection of rays in 3-D space from separate exposure stations of the camera. That geometry, especially when constructed in terms of coordinate differences, is naturally and fully supported by the GSDM.

Remote Sensing: Remote sensing is similar to photogrammetry but with important differences. The goal here is not to define exclusive differences, but to acknowledge that remote sensing, "implies the study of images...rather than merely to determine their size or position" (Bethel 1995). More than the geometrical information contained in a photograph or image, remote sensing records interpretative data in several spectral bands which are organized and stored pixel by pixel. Without being specific, the difference is raster as opposed to vector. That is not to say raster data are without geometrical characteristics. To the extent it is desireable or practical, the GSDM could be used to define the unique location (and accuracy) of each pixel. Yes, data storage requirements are enormous. A technique which might reduce storage requirements is to determine and store an algorithm (for each image) by which the X/Y/Z location of each pixel in the image is computed as needed. If that were to happen, the difference between raster and vector would become less distinct. It has been suggested that too is a solved problem.

Mapping: Traditionally a map is a graphical or pictorial representation of a portion of the earth's surface. In many cases, the map served both as the end product of a survey and as the primary storage medium for the data. Since the earth is round and a map is flat, map projections were devised to define a specific relationship between ordered pairs of latitude/longitude and plane coordinate (x/y) positions. There are many kinds of map projections which serve many purposes and, for given purposes, map projections remain as valid as ever. But, even though contours on a topographic map depict elevations, a map projection is strictly a 2-dimensional mathematical model and we use 3-dimensional data. With the advent of digital spatial data storage and visualization practices, a hardcopy map is no longer the storage medium nor is a map necessarily the end product of a survey. Instead, a map, whether hardcopy or electronic, is now used as a disposable means of communicating spatial information to humans in analog form. Primary data storage (both position and accuracy) is a computer file and rules for making maps (projections) haven't changed but, when using the GSDM, spatial data users world-wide will enjoy enormous benefits of a common (standard) database and each cartographer (user) will have unlimited freedom in designing displays of spatial data.

GIS: Geographic information systems (GIS's) have been adopted and are being used by many segments of society. In addition to faster computers, larger capacity data storage devices, and more literate users (both in terms of numbers and level of knowledge), two factors driving implementation and use of a GIS are the uniqueness of spatial location and the ability to share compatible spatial data between users, agencies, disciplines, and applications. Issues specifically related to using a GIS beneficially are:

- global uniqueness (state plane & UTM values may repeat from zone to zone).
- compatibility of datums and coordinate systems (geometrical integrity).
- building a 2-D database with 3-D data (or the impossible inverse).
- getting a handle on the issue of spatial data accuracy (meta data are good, but somewhat unwieldy).

Modern GIS's have evolved from 2-dimensional databases (state plane coordinates) to 2.5-dimensional systems where elevation is an attribute of location to pseudo 3-D systems in which state plane coordinates are used with elevations (called pseudo because elevations are referenced to an irregularly curved surface - the geoid). The next step is to use a truly 3-dimensional system, such as the GSDM, which accommodates each of the four issues listed above.

## The Global Spatial Data Model (GSDM)

Figure 2 is a diagram of the GSDM which lists the core concepts surrounded by various disciplines which, to one degree or another, use geographic information systems utilizing the National Spatial Data Infrastructure (NSDI) as defined by President Clinton (1994) in Executive Order 12906 signed April 11, 1994. The GSDM is intended to support fully and be compatible with details of that order and the NSDI.

# Global Spatial Data Model - GSDM

*(A Universal 3-D Model for Spatial Data)*

The Global Spatial Data Model provides a simple, universal 3-dimensional mathematical foundation for the National Spatial Data Infrastructure (NSDI) which supports Geographic Information System (GIS) database applications in disciplines such as:

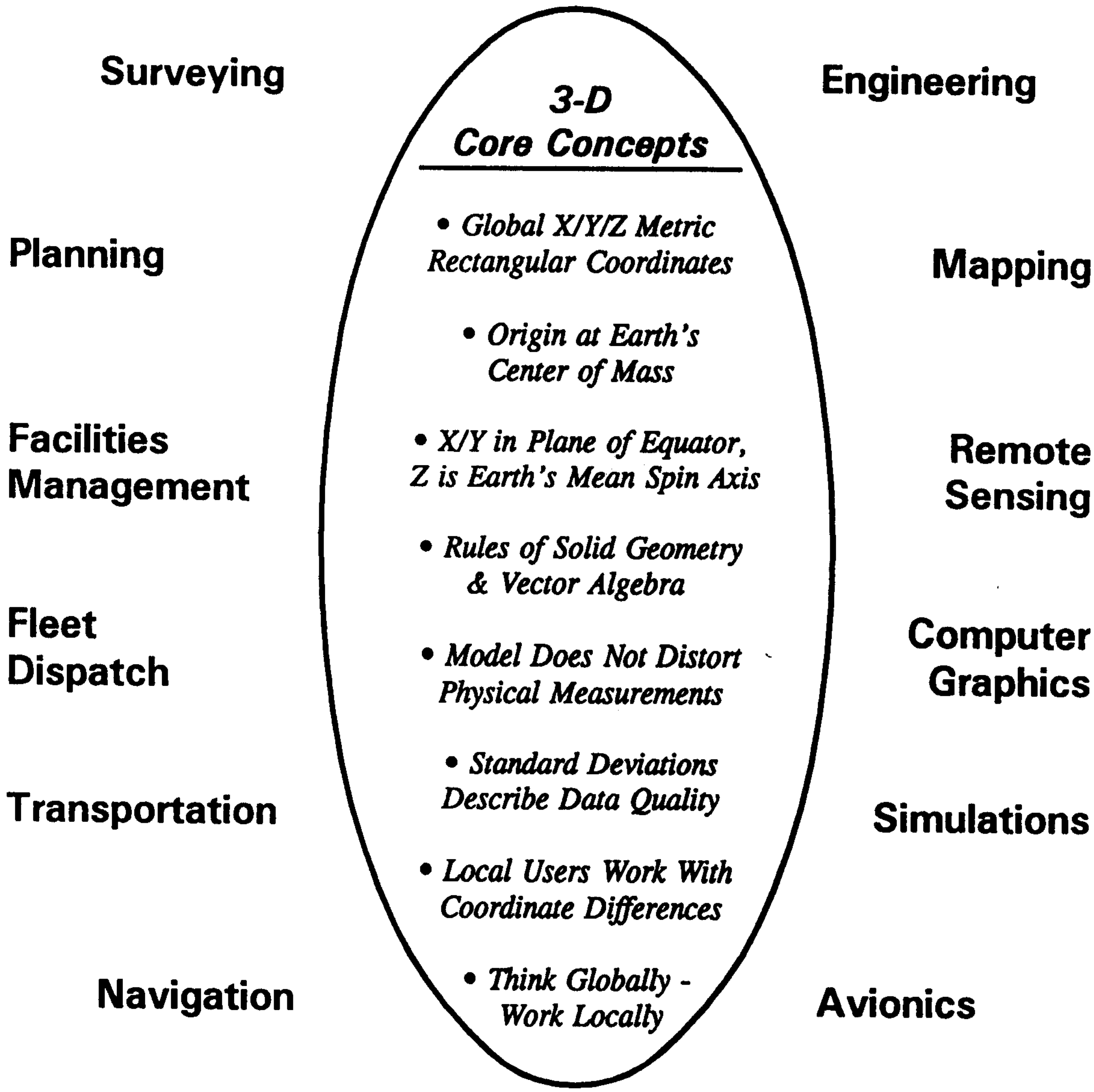


**Figure 2 The Global Spatial Data Model (GSDM)**





Circleville, Ohio 43113

## Issues & Questions for Geomatics Educators

### Issues:

- The Accreditation Board for Engineering & Technology (ABET) is committed to playing a key role "in the globalization of the engineering profession, and as part of this, the globalization of engineering education" (Proctor, 1998). Surveying programs are found in all three ABET commissions, the Engineering Accreditation Commission (EAC), the Technology Accreditation Commission (TAC), and the Related Accreditation Commission (RAC). Many surveying (geomatics) educators serve on the various commissions and even the ABET Board of Directors.

- The National Council of Examiners for Engineering & Surveying compiles exams for professional registration in the United States and is deeply involved in protecting the health, safety and welfare of the public by developing a model law for registration of various disciplines.

- Many people who generate, manipulate, interpret, and use spatial data (and the GSDM) do so outside the traditional definitions of surveying and/or engineering. Many are highly trained, competent, dedicated individuals who provide quality service and advice to end users. On the other extreme, some people, call them "opportunists", engage in activities which border on fraud by exploiting the public's fascination with razzle-dazzle high-tech gimmicks.

- The international reputation of U.S. surveying and surveying education was questioned by Cliff Wilkie (1998) writing in response to a paper presented by Dr. Hazelton (1997) at the 1997 Surveying Teachers' Conference, "Broadening Surveying into Geomatics: Are We Promoting Obesity, Fattening the Calf for Slaughter, or Living Off the Fat of the Land?"

- The North American Geomatics Educators' Conference is a forum which has earned the right to have well informed opinions on the following questions.

### Questions:

- What bearing should the issue of accreditation and ABET's goals for continuous improvement (or globalization) have on geomatics education?

- Does generation, evaluation, manipulation, and use of spatial data come under the definition of engineering or surveying? Are registration laws really needed to protect the public against the "opportunists"?

- At what point and to what extent should the GSDM be included in a geomatics educational curriculum?

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