Spatial Data Considerations for Civil Engineers

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ASCE Texas Section Fall Meeting

Camino Real Hotel

El Paso, Texas

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Earl F. Burkholder:

- **Member of ASCE since 1972.**
- **Taught surveying at NMSU 1998 to 2010.**
- **Editor ASCE Journal of Surveying Engineering,**

  1985 to 1989 and 1992 to 1996
- **Wrote "The 3-D Global Spatial Data Model"**
- **Current Secretary of Geomatics Division ASCE**
- **2010 ASCE Surveying & Mapping Award**

  - October 22, 2010

  - ASCE Annual Meeting, Las Vegas, Nev.

Meeting Theme - Mission Possible:

- Sustainability in the Desert Southwest
- Permanence of location is related to:

  - Geography, knowing where things are.
  - Geometry and geometrical relationships.
  - Geodesy and spatial data accuracy.
  - Measurement; technology and tools.
  - 3-D digital spatial data
  - bits, bytes, binary, ASCII, and www.

Mission Impossible:

- "Get it" all the first time.
- Arrive at a goal without benefit of the journey.

Assumptions:

- Civil Engineers need/use spatial data.
- Not everyone learns surveying in college.
- Engineers and technicians know geometry.
- New technology facilitates productivity.
- Learning can be enjoyable if resources are available and if information is well organized.

What does it take to increase productivity?

I need to gage the audience:

- What does it take to keep us on same page?
- I presume many are sophisticated users.
  - Technicians can be geometrical whizzes.
  - Professionals are more concept oriented.
- Talk is balance between abstract/practical.
- My comments may be impractical & futuristic.
- Web links are included for additional study.
- Full paper is printed in the proceedings.

Let's talk about SPATIAL DATA – Surveying

- Maps, geometry, and coordinates.
- Flat Earth and limiting assumptions.
- Datums – horizontal and vertical.

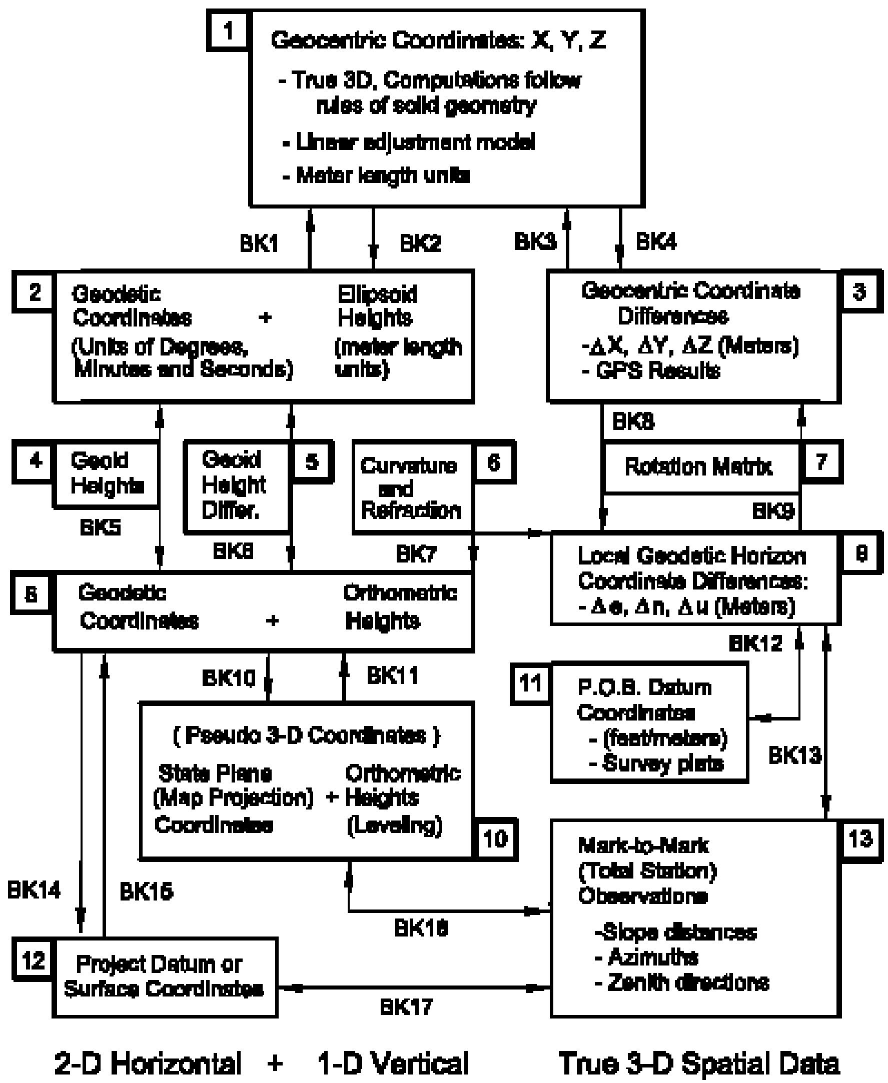
  "3-D Datum for a 3-D World" article in Geospatial Data Solutions, May 2004
- Geographic Information Systems (GIS).

  Universal data storage system – 3-D?
- Spatial data accuracy – How good (reliable) are the data? Consequences of bad data?

What is the Global Spatial Data Model (GSDM)?

- **The GSDM is an arrangement of existing geometrical elements and concepts.**
- **GSDM is based on the DoD Earth-centered Earth-fixed (ECEF) geocentric coordinates.**
- **GSDM is equally applicable:**
  - **Worldwide with same set of equations.**
  - **In any discipline using spatial data.**
- **Fully supports 3-D digital spatial data.**
- **The GSDM contains no secrets.**

The BURKORD™ 3-D Diagram



Three useful coordinate systems - I

- **Geodetic Coordinates:**
  - **- Latitude, angular distance from Equator.**
  - **- Longitude, angular value from Greenwich.**
  - **- Ellipsoid height above or below ellipsoid.**
- **Geocentric ECEF Metric Coordinates:**
  - **- Origin at Earth's center of mass.**
  - **- X & Y, plane of Equator, X at Greenwich.**
  - **- Z is parallel with spin axis of Earth.**
  - **- Rectangular coordinates & solid geometry.**
  - **- Work with coordinate differences.**

http://www.globalcogo.com/GM012.pdf

Three useful coordinate systems - II

- **Local – state plane or other well-defined:**
  - **- East/north/up is right-handed.**
  - **- North/east/up is left-handed. Either is OK.**
  - **- Be careful with flat-Earth assumption!**
- **Low distortion projection:**
  - **- Becoming popular, but not recommended because it is a 2-D model. Elevations need to be handled separately.**

http://www.globalcogo.com/CR002.pdf

Types of Spatial Data

- **Absolute values are coordinates in a well-defined system, X/Y/Z or east/north/up.**
- **Relative values are differences within the same system.**
  - **- GIS data bases use absolute coordinates.**
  - **- Engineers work with measurements and relative differences.**
- **Local accuracy is closely associated with relative values .**

Types of Spatial Data

- **Absolute latitude/longitude/ellipsoid height.**
- **Relative lat/long/height - $\Delta\varphi/\Delta\lambda/\Delta h$.**
- **Absolute ECEF geocentric X/Y/Z coordinates.**
- **Relative ECEF values, $\Delta X/\Delta Y/\Delta Z$.**
- **Absolute well defined (SPC) east/north/up**
- **Relative SPC $\Delta e/\Delta n/\Delta u$. Is it true 3-D?**
- **Arbitrary X/Y/Z values in an assumed system.**

See – http://www.globalcogo.com/BK001.pdf

National Spatial Reference System (NSRS)

- http://www.ngs.noaa.gov/INFO/OnePagers/NSRS.html (The NGS establishes and maintains the NSRS.)
- NAD 27 – horizontal datum, outdated.
- NGVD 29 – vertical datum, outdated.
- NAD 83 – horizontal only, big improvement.
- NAD 83 (XXXX) – 3-D since (2007)
- NAVD 88 – vertical based upon geoid & 1 BM.
- WGS 84 – is both an ellipsoid and a datum.
- ITRF – defined and supported by scientists.

Models Used When Working with Spatial Data

- **Local – assumed origin and orientation.**
  - **Can be horizontal or vertical (2-D or 1-D)**
  - **Or, it could be 3-D. What about flat Earth?**
- **State Plane Coordinates (and Elevation)**
- **Geodetic latitude/longitude/ellipsoid height**
  - **Geometrical geodesy, on ellipsoid surface.**
  - **Physical geodesy and geoid modeling.**
- **Geocentric ECEF, true rectangular 3-D. In this environment, elevation is derived. That's OK.**

Advantages of using State Plane Coordinates

- **Used in many GIS data bases as absolute coordinates defining unique location.**
- **Computations use simple 2-D equations.**
- **One-way traverses are used instead of loops.**
- **Parallel grid meridians used in plane surveys.**
- **Elevations are added for third dimension.**
- **SPC have been standardized and accepted.**
- **Concepts integrated into commercial software.**

Disadvantages of using State Plane Coordinates

- **The map projection model is strictly 2-D.**
- **Distances are distorted in two ways:**
  - **- Grid scale factor (projection 3-D to 2-D).**
  - **- Elevation factor (horizontal not at sea level).**
- **Grid meridians do not portray true north.**
- **Elevations are used as third dimension but the reference surface for elevation is not flat.**
- **GIS needs unique designations. Many states have more than 1 zone. Texas has 5 zones.**

Advantages of Using the GSDM

- All the pieces are in place & in public domain.
- Equally applicable world-wide, all disciplines.
- Provides a standard for data interchange.
- Model does not distort survey measurements.
- Supports use of spatial data accuracy.
- Preserves character of 3-D measurements.
- Inverse gives ground distance & true azimuth.

Disadvantages of Using the GSDM

- **The concept is "new" and not widely used.**
- **Relies on understanding more than rote.**
- **Software options are, so far, limited.**
- **The GSDM supports too many options:**

  - Geocentric Coordinates.

  - Geodetic coordinates.

  - State plane coordinates.

  - Local & assumed coordinates.

Spatial Data Accuracy

- **Digital spatial data are not "exact."**
- **Consequences of bad data can be severe.**
  - **Mars probe crash $125 M – Sept. 1999**
  - **$110 M US submarine crash – Jan. 2005**

  http://www.globalcogo.com/sub.pdf
- **Current spatial data accuracy standards:**

  www.fgdc.gov/standards/standards_publications/index.html
- **Stochastic model (of GSDM) handles standard deviations and error propagation.**

Process and Content

- **This part is abstract but worthy of discussion.**
- **Doing things right (process) and doing the right thing (content) are both important.**
- **Some equate:**
  - **- Management with process and**
  - **- Leadership and vision with content.**
- **See http://www.globalcogo.com/process.pdf**

Conclusions - I

- **Many persons use spatial data.**
- **Technicians can do an excellent job of collecting data/making measurements .**
- **Professionals solve problems by generating creative solutions – often using spatial data.**
- **Logic – what happens if I start with a simple assumption (a single origin for 3-D data) and add components defined by solid geometry? You get the GSDM!**

Conclusions- II

- **Spatial data accuracy is huge issue!**
- **How good are the data?**
- **What is the cost of good data?**
- **What are the consequences of bad data?**
- **Who is responsible for writing/enforcing the standards and specifications?**
- **The GSDM provides tools for establishing, tracking, and using standard deviations.**

Additional sources of information

- Equipment vendors.
- Colleges and Universities.
- Other practicing professionals.
- Book – "The 3-D Global Spatial Data Model: Foundation of the Spatial Data Infrastructure"
- The Global COGO web site –

http://www.globalcogo.com/refbyefb.html

Seminars - various

Additional Opportunities – SPAR 2011

- See http://sparllc.com/spar2011.php
- 3-D imaging and 3-D laser scanning for engineers, surveyors, photogrammetrists, etc.
- 11th Annual Meeting, March 21-24, 2011, Woodlands, (Houston) TX.
- On March 19th (at the same place) ASCE Geomatics Division will host workshop on:
  - The Global Spatial Data Model (GSDM) 4 hr.
  - Real-time GPS Networks (RTN) 4 hr.

(Will qualify for continuing education credit.)