3-D Digital Spatial Data, Time is 4th Dimension – Part I

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Convergence of abstraction/technology/policy/practice fosters a discussion of issues.

1. The digital revolution is driving the transition to the use of 3-D digital spatial data.

2. The geocentric Earth-centered Earth-fixed (ECEF) coordinate system is the primary reference.
   a. The origin is at Earth's center of mass (CM).
   b. Location anywhere in the world or near space is defined by rectangular X/Y/Z coordinates.

3. Rules of geometry do not change and include both solid geometry and plane geometry.

4. Mathematical relationships between rectangular and curvilinear systems are unambiguous.

5. Gravity is one of four fundamental physical forces and is. . .
   a. The subject of extensive research by the National Geodetic Survey (NGS) and others.
   b. Too small at atomic scales to be part of the standard model of particle physics.
   c. Infinitely large in regions of space known as black holes.
   d. Everywhere present in human experience in, on, or near the Earth.
   e. Manifest in "deflection-of-vertical," the difference between a plumb line and the normal.
   f. The reason for the difference between spatial data and geospatial data.

6. In the hierarchy of classifications,
   a. Although sometimes overlooked, a fundamental question is, "with respect to what?"
   b. Spatial data describes shapes and location of objects, typically rectangular flat earth.
   c. Geospatial data are spatial data that are referenced to the Earth – often curvilinear.
   d. In the context of mathematics, geospatial data is a subcategory of spatial data.
   e. In the context of geography, spatial data is a subcategory of geospatial data.

7. Spatial data and geospatial data both exist in three dimensions and can be reconciled.
   a. Horizontal data are 2-dimensional as experienced by walking erect on a "flat Earth." (Definitions of horizontal distance (HD) can be mathematically ambiguous.)
   b. Specificity for HD is assured by using a defined horizontal datum. (A simple widely used definition of HD is the right triangle component of a slope distance.)
   c. Vertical data are 1-dimensional, perpendicular to horizontal, and parallel to. . .
      i.) The plumb line at a point. It is called elevation or orthometric height.
      ii.) The ellipsoid normal. It is called ellipsoid height or geodetic height.
      iii.) The difference between normal and plumb line is due to gravity – item 5.e above.
      iv.) Unlike normals, plumblines at the bottom & top of a tall skyscraper are not parallel.
   d. Characteristics of spatial data are supported by separate horizontal and vertical datums.
   e. An integrated 3-D datum supports true 3-D while pseudo 3-D uses elevation, not height.

8. The digital revolution is driving convergence of abstraction/technology/policy/practice.
   a. Traditional practice implements horizontal and vertical datums separately.
   b. The NGS has a long history of providing end users reliable control coordinates for. . .

i.) Horizontal: latitude and longitude on NAD 27, NAD 83 etc.
ii.) Vertical: elevations referenced to mean sea level, NGVD 29, NAVD 88 etc.

c. The U.S. DoD and the scientific community have separately defined. . .
   i.) The WGS 84 ECEF reference system worldwide.
   ii.) The ITRF ECEF reference system worldwide.
d. Both are monitored and compared daily. Differences are statistically insignificant.
e. NAD 83 uses the GRS 80 ellipsoid and is tied to the global network at a given epoch.
f. The Earth is dynamic and gradual changes in the global network are monitored/modeled.
g. The location of Earth's center of mass (CM) is known better now than in the past due to. . .
   i.) Different and improved instrumentation.
   ii.) Larger data set - accumulation of observations over a longer period of time.
   iii.) Transfers of mass on, in, or near the Earth – earthquakes, melting of ice cap, etc.
h. The NAD 83 is referenced to a static location of the CM, WGS 84 is updated more often.
i. The NGS is modernizing (updating) our National Spatial Reference System (NSRS).
   i.) See www.ngs.noaa.gov (new datums) for information on replacing datums.
   ii.) Tectonic plate motions and other movements will be modeled.
   iii.) Earth's CM will be more closely aligned with WGS 84.
   iv.) The new datum will be 3-D but a separate vertical datum will also be published.

9. Which leads to the question, "Under what circumstances will the spatial data user community be better served by using a 3-D datum rather than separate horizontal and vertical datums?"
   a. Stakeholders should be discussing spatial data issues and developing policies.
      i.) International agencies. A complete list would include all who use spatial data.
         - United Nations.
         - International Standards Organization.
         - Others.
      ii.) Federal agencies. A complete list would include all who use spatial data.
         - National Institute of Standards and Technology.
         - National Geospatial Intelligence Agency.
         - National Geodetic Survey.
         - United States Geological Survey & Federal Geographic Data Committee.
         - Others (NASA, FHWA, FEMA, FAA, NSF, etc.).
      iii.) Professional associations. A complete list would include all who use spatial data.
         - World Geospatial Industry Council
         - American Society of Civil Engineers
         - American Society of Photogrammetry & Remote Sensing
         - National Society of Professional Surveyors
         - Others (NCEES, aerospace, unmanned vehicles, etc.).
      iv.) Other organizations. A complete list would include all who use spatial data.
         - Manufacturers, vendors, and service providers.
         - City, county, state, and agencies.
         - Utilities, independent commissions,
         - Corporations, businesses, consultants.
         - Consumers (Should the list include everyone who uses a cell phone?)
         - Others.
   b. Topics to be discussed related to using a 3-D datum include:
      i.) Technical. . .
         - Geometry – true 3-D versus pseudo 3-D.
         - Gravity – relative/absolute, coverage (local, regional, global etc.).

- Modeling – trade-off between adequate/simple (tolerances).
- Spatial data accuracy (with respect to what?).

ii.) Administrative/legal. . .
- Responsibility and enforcement.
- Legislative – various levels
- Intellectual property issues.
- Education, promotion, permanence/sunset.

iii.) Economic/political. . .
- Consequences and cost of not adopting 3-D.
- Benefits (to various sectors of global economy).
- Capitalization and development of timelines for transition.
- Budgeting/cost recovery.

iv.) Policy
- Standards
- Contracts

v.) Practice
- Specifications
- Common procedures
- Interoperability

10. Spatial Data Models
    a. Characteristics – a "universal" spatial data model should be. . .
        i.) Applicable worldwide.
        ii.) Appropriate for use by all spatial data disciplines.
        iii.) Immediately and readily available.
        iv.) Rigorous and Simple.
        v.) Transparent with all equations in the public domain.
        vi.) Able to track spatial data accuracy.
        vii.) Adopted as the standard for moving 3-D spatial data epoch to epoch.
        viii.) Compatible with the concept of digital twins.
        ix.) Supportive of definition and use of high-definition maps.
        x.) The undisputed foundation for AI applications involving use of spatial data.
    b. The Global Spatial Data Model (GSDM):
        i.) Was formally defined in 1997 - http://www.globalcogo.com/gsdmdefn.pdf
        ii.) Fulfills all characteristics in "a" above – especially for spatial data accuracy.
        iii.) Emerged from abstractions considering applications of technology.
        iv.) Has survived repeated challenges in technical literature.
        v.) Enables digital transition not unlike experiences of AT&T and Kodak.
        vi.) Greatly reduces the need for geoid modeling and low-distortion projections.
        vii.) Has an infinite shelf-life, avoiding obsolescence.
    c. Considerations – impact:
        i.) With the publication of the new 3-D datum, elevations will change.
        ii.) With few exceptions, elevation can be approximated by ellipsoid height.
        iii.) Corrections, like equation-of-time and polar motion, can be used if needed.
        iv.) User-selected "filter" can be applied to values drawn from 3-D database.
        v.) A "3-D model for 3-D data" will obviate the need for low-distortion projections.
        vi.) Algorithmic justice/integrity is needed – www.globalcogo.com/3D-and-AI.pdf.
        vii.) Existing datum values will become "legacy" – similar to the successful deprecation of the U.S. Survey Foot.