Building on Hazelton's Surveying Revolution Articles

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Hazelton's Part I and Part II:

Dr. N. W. J. Hazelton wrote several scholarly articles on The Surveying Revolution that were published in the Surveying & Land Information Science (SaLIS) Journal. Taken together, the articles present a comprehensive overview of surveying technology since about 1550 and describe the inevitable impact that "going digital" will have on the surveying profession (and society at large).

Hazelton, N.W.J., 2012, "The Surveying Revolution of 1550-1650: Implications for the Current Geospatial Revolution – Part I," Surveying & Land Information Science, (SaLIS), Vol. 72, No. 3.

Hazelton, N.W.J., 2024, "The Surveying Revolution of 1550-1650: Implications for the Current Geospatial Revolution – Part II," Surveying & Land Information Science, (SaLIS), Vol. 83, No. 2.

Examined in the larger historical context, Part I of Hazelton's visionary articles shows that the pattern of change in the surveying profession shares many of the characteristics of other historical revolutions and lays the foundation for many of the "disruptive innovations" described in his Part II.

Burkholder's Part I, Part II, and Part III:

Independent of and less scholarly than Hazelton's articles, the author wrote and posted several items (called Parts I, II, and III, http://www.tru3d.xyz 2024) that focus on "using a 3D model for 3D data." It seems that these developments serve to document the realization of Hazelton's vision.

Part I begins by listing factors and circumstances relevant to changes already realized and those forecast by Hazelton. Many challenges of "going digital" can be met by adopting the 3D global spatial data model (GSDM) which forms a rigorous concise bridge between the real physical world and its digital representation in a computer database (also called digital twins).

Part II – Benefits of a Standard, summarizes issues related to spatial data and lists particulars associated with the advent of the digital revolution. The discussion highlights examples of standards development and associated benefits. Part II closes by looking forward to the future, summarizing the issues, and acknowledging objections to implementing the GSDM. Finally, the question is, "Will the Genie ever return to the bottle?"

Part III, still in draft form, is planned to have four sections – sections 1 and 2 will focus on characteristics of Process and Content. Section 3 will discuss the importance of transparency while Section 4 will look at geometrical integrity. Section 4 is particularly important when anticipating the use of artificial intelligence (AI) in the context of spatial data applications

Chronology of author's involvement:

1. The author studied Dr. Hazelton's articles carefully and found many reasons to support the points he made. Hazelton's resource materials are extensive and are used effectively to explain "how we got to where we are" with regards to the use of digital spatial data.

2. The conceptual foundation for ideas espoused by the author was laid in the 1970s by Professor Ralph Moore Berry at the University of Michigan – there is no substitute for building on proven fundamentals. Berry (at Michigan) and, later, McEntyre (at Purdue) both indulged in abstraction when discussing surveying and land data systems in professional practice.

3. After graduating from Michigan, responsibilities at Commonwealth Associates, Inc., Jackon, Michigan, included performing mapping and engineering layout computations on a high-voltage transmission line project for the Detroit Eidson Company. Computations were based on the elevated Michigan Coordinate System as designed by Professor Berry. That procedure worked as intended and was used by various disciplines involved in the project. But surveyors, vendors, and others often mis-used it. See the abstract http://www.globalcogo.com/MichGSF80.pdf.

4. Professional activities within ASCE over the past 50 years, in professional practice, research, and teaching come under the umbrella of the convergence of abstraction/technology/policy/practice – see Part I. Implementation of "a 3D model for 3D data" grew out of that thought process.

5. It would be a mistake not to acknowledge the value of the 1990/91 sabbatical at the University of Maine. Dr. Leick (and others) shared their knowledge and provided lots of inspiration. "Using GPS Results in True Coordinate System" grew out of that experience – see True 3D versus Pseudo 3D.

6. Facing the datum transition, NAD 27 to NAD83, Dr. Kurt Bauer, Executive Director of the SE Wisconsin Regional Planning Commission (SEWRPC), wanted to develop reliable datum transformation procedures for the SEWRPC area. The concept of using an integrated 3D datum in place of separate horizontal and vertical datums was presented. It was a short discussion. Although Dr. Bauer listened carefully, he was not swayed. Two separate transformation projects were completed – one for horizontal and one for vertical. However, acknowledging the possible benefits of a 3D system, SEWRPC commissioned a study to incorporate horizontal and vertical spatial data into one system – see Definition of 3D model. Dr. Bauer retired at the end of 1996. The 3D report, published in January 1997, was shelved and "forgotten."

7. The formal definition of the Global Spatial Data Model (GSDM) includes both functional and stochastic models for spatial data and was filed with the U.S. Copyright Office in 1997.

   a. All equations and procedures included in the GSDM are in the public domain.
   b. The GSDM uses a single origin for 3D data. Computations are performed in 3D space.
   c. Local accuracy procedures defined by the stochastic model portion of the GSDM have been challenged in technical literature – but, to date, successfully defended.

8. The first Edition of the book, "The 3-D Global Spatial Data Model: Foundation of the Spatial Data Infrastructure," was published by CRC Press in 2008. The 2nd Editon, "The 3-D Global Spatial Data Model: Principles and Applications," was released in July 2017 (copyright 2018). Although the original subtitle remains valid, CRC Press marketing insisted on the change.

9. Although the GSDM includes concise procedures for spatial data computations worldwide, the user community has been reluctant to embrace a unifying spatial data model for many reasons. However**, Dr. Hazelton's comprehensive review of the Surveying Revolution and its impacts on modern practice provides context and justification for implementing the GSDM.**

10. Resources developed/provided by N.W.J. Hazelton:

    a. The Surveying Revolution of 1550-1650: Implications for the Current Geospatial Revolution – Part I. "The pattern of change, examined in the larger historical context, shows that the revolution of 1550-1650 has the same characteristics of many historical revolutions . . ." Many advancements in technology and methodologies are described and Hazelton notes that "major historical changes cannot be undone."

    b. The Surveying Revolution of 1550-1650: Implications for the Current Geospatial Revolution – Part II. This article attempts "to find parallels between that [historical] revolution and the current geospatial revolution that started about 1950." Those issues resonate well with many who have enjoyed a front-row seat to those changes.

    c. In email correspondence with author: Dr. Hazelton makes the following points:
        - Peter Medawar (1960 Noble Laureate in Medicine and Physiology) notes that as a science matures there are over-arching concepts that greatly simplify the subject.
        - Vectors, as defined by coordinate differences, provide a direct connection to the measurements used to compute a control network. Storing those measurement vectors supports re-computation of a network if/when needed.
        - Dr. Hazelton does not make this point, but vectors also facilitate efficient computation of directions/distances in 3D space when using the GSDM.

11. Resources referenced or developed by Earl F. Burkholder include:

    a. Structure of Scientific Revolutions, 3rd Ed. 1996, Thomas Kuhn. This book is highly regarded in scientific circles and describes many features associated with advancing knowledge, practices, and technology. It is a bit cynical to acknowledge that the process of adopting new technology is to wait until current leaders are retired. Although coming from different perspectives, Drs. Kuhn and Hazelton cover many of the same points.

    b. 3D Spatial Data – Time is 4th Dimension, Part I The purpose of this item is to list many of the "givens" associated with development of current systems being used. It also steps back and looks at "big picture" characteristics of spatial data before showing how the GSDM fulfills the requirements of a modern digital model for spatial data.

    c. Benefits of a Standard, Part II Disruptive Innovation is a consequence of the digital revolution and challenges many to look at new/better ways of achieving a goal. In keeping with the observation made by Peter Medawar (section 10.c this paper) the over-arching concept of the GSDM provides better tools for the spatial data user. After discussing particulars and benefits of adopting the GSDM, Part II includes examples (e.g., finding longitude at sea and adopting a standard meter or length) of the development of models and the benefits of standardization. Part II ends with a summary of issues in the context of forward-looking consequences of the impact of adopting the GSDM.

    d. Part III is a draft of "Challenges and Opportunities – Going Forward. This paper is only in the beginning stages of completion. The first section will look at how different perspectives of process and content contribute to future policies/practice. Some users are more adept at (focus on) content while others are more concerned with advancing user (administrative) accomplishments. In either case, a subsequent section will emphasize transparency of algorithms (suggestions are welcome) and the final section will highlight the importance of integrity. The book “Unmasking AI” by Joy Buolamwini provides a dramatic example of algorithmic justice (having to do with facial recognition) while algorithmic integrity is critical in spatial data applications. Maybe the best example for spatial data users is the difference between “true 3D” and “pseudo 3D.” Being transparent is essential and integrity suffers if/when concepts are mixed inappropriately.

e. “3D Imaging of the Environment: Mapping and Monitoring,” Edited by John Meneely, 2024, provides a valuable service to the spatial data community by identifying (among others) a “common data exchange point” that can be shared alike by generators and users of spatial data. Regardless of how spatial data are generated the GSDM provides a logical “handoff” point for archiving the data and/or as the basis for subsequent spatial data applications. Diagram 1.1 and Table 1.2 summarize those concepts.

f. M. Govorcin, D. Bekaert, B. Hamlingtoin, S. Sangha, and W. Sweet, “Variable vertical land motion and its impact on sea level rise projections,” Science Advances 11, eads8163 (2025), 29 January 2025. https://www.science.org/doi/10.1126/sciadv.ads8163. This article is relevant and important because:

- It is an example of a similar effort (study) needed to document issues, practices, consequences, and the economic impact of using true 3D compared to pseudo 3D, see http://www.globalcogo.com/3D-Development.pdf.
- Their results are reported in terms of relative vertical differences. Thus, the article avoids the question of referencing vertical motion to the geoid or the ellipsoid.
- It is authored by high-level professionals employed by the Jet Propulsion Laboratory, California Institute of Technology and National Oceanic Atmospheric Administration.
- Subsequent policy decisions related to sea level rise will be based on “solid science.”

12. The preceding material is summarized as part of a Vision (path forward) for implementation of the GSDM. Issues that need to be addressed include:

a. The Earth’s center of mass is more stable and is easier to locate than the geoid.
b. The importance of hydraulic gradients in the real world is undisputable. A high-level study needs to discuss “best” methods for computing gradients. The impact of gravity is huge!
c. The Scientific Method as discussed in Chapter 1, “Data Analysis Techniques for Physical Scientists,” Claude Pruneau, Cambridge University Press describes credible procedures. The proposed study needs to conform to the principles outlined in said Chapter 1.
d. As described in Chapter 1, “Normal” science uses models in computations. Corrections are applied to physical measurements to facilitate “working on the same page.” Two examples are equation of time and polar motion. Pruneau cites Kuhn frequently.
e. The costs and procedures for making the transition to using ellipsoid height for the third dimension need to be identified and the “way forward” needs to be planned carefully.

Many disciplines and organizations use digital spatial data and deserve a voice in future use. Some may justifiably choose to “go it alone” (the military, for example) but the advantages of commonality should ultimately prevail for spatial data users worldwide. What organization should be tasked with conducting such a study? This author suggested previously that NIST should conduct such a study. Might another option be more appropriate?