The Role of a Model for Geospatial Data

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Note to Readers (feedback to eburk@globalcogo.com is welcome):

Following several unsuccessful attempts to get this article peer reviewed and formally published, it is being circulated to colleagues, posted on the Global COGO, Inc. website, and filed with the U.S. Copyright Office. Possibly, "You can't beat City Hall" is a matter of timing.

I. The logical basis for the 3D global spatial data model (GSDM) promoted herein includes:

   A. Functional model: Start with the origin at the Earth's center of mass (CM) and use rules of solid geometry for subsequent geometrical computations within the Earth-centered Earth-fixed (ECEF) reference frame (in the context of a named epoch).

   B. Stochastic model: Invoke standard rules of error propagation applied to independent observations and derived measurements (including correlations) to compute uncertainties (standard deviations) of subsequent intermediate and final quantities.

II. The goal is to provide spatial data end users with standardized procedures and tools which can make the entire workflow more efficient (from data collection to final result).

Abstract:

Born of the digital revolution, the spatial data infrastructure is the foundation for location on or near the Earth's surface and is integral to spatial data practices in various disciplines. Associated developments have given rise to a plethora of measurement sensors and data collection practices (including GNSS, LiDAR, etc.) and digital spatial data storage requirements have grown exponentially. While management and organization of large data sets are well studied, a rigorous spatial data model which serves users across the spatial data spectrum (from local GIS to navigation and military applications) is needed. This article highlights advantages of the 3D global spatial data model (GSDM) first by discussing characteristics of an appropriate model, then by looking at examples illustrating the role of a model (hypothesis/falsification/adoption) in various applications. Although the timeline for adoption of a model can be lengthy, the geometrical integrity of spatial data as used worldwide is paramount. The goal is algorithmic integrity and standardization in applications utilizing spatial and/or geospatial data. As highlighted in the examples, the GSDM fulfills those requirements, improves efficiency of spatial data workflows, and supports underlying algorithmic integrity for all spatial data applications – including AI. The GSDM also includes tools for handling spatial data accuracy.

Introduction:

Models are used to enhance human understanding of abstract concepts. A well-formulated model contains rules and guidelines which serve to eliminate ambiguity and support concise communication between various users of the model. Of the models available for a given circumstance, the preferred model is one that is, simultaneously, both adequate and simple. A model is adequate to the extent it accommodates and describes what is needed (e.g., geometry and observed phenomenon). The advantage of a simple model is that it is easier to understand and use while providing better workflow connections between data and solutions.

While a model for a given application may be both adequate and simple, trade-offs exist. If a model is inadequate (falsified for whatever reason), the defect might be remedied by choosing a different model or by increasing the level of complexity in the existing model. But increasing the complexity of a model tends to limit its use or utility. In rare cases, the adequacy of a model can be enhanced (without sacrificing rigor) while making it easier to use – a win/win case.

Scope:

The 3D global spatial data model (GSDM) [1] is an example of such a win/win case. Spatial data are used to express the geometry of location. A consequence of the digital revolution is that spatial data are digital and three-dimensional (3D) or 4D when time is included. A point of clarification is that spatial data are generic while geospatial data are spatial data referenced to the Earth. In practice, the words spatial and geospatial might be interchangeable (the difference is due to gravity), but the following distinction is made. In the mathematical context, geospatial data are a subcategory of spatial data while in the context of geography, spatial data are a subcategory of geospatial data.

Traditional models for geospatial data used by scientists, geodesists, engineers, and others include separate origins for horizontal and vertical data and are, by comparison, rather complex. However, as spatial data applications continue to expand, the user community needs a better model that is both adequate and simple. The GSDM is concise, rigorous, less complicated, and more efficient because it is based on the assumption of a single origin for 3D data and uses rules of solid geometry to compute positions in 3D space. Bonus - the stochastic component of the GSDM includes an efficient algorithm for handling spatial data accuracy.

Examples:

1. Claude A. Pruneau [2] is a high-energy physicist who wrote a comprehensive book based, in part, on his work at CERN. In chapter 1 Pruneau discusses models within the context of the scientific method, explains the role of “hypothesis falsification," and notes the importance of simplicity (Occam’s Razor) when choosing between the two competing alternatives. The GSDM fulfills the requirements of the scientific method, has survived repeated falsification attempts, and qualifies as Occam’s Razor choice for a spatial data model.

2. Wikipedia hails publication of Thomas S. Kuhn's [3] book, *The Structure of Scientific Revolutions*, as "a landmark event in the history, philosophy, and sociology of science." In the Preface Kuhn describes the interaction of disciplines as "paradigms" and devotes the entire book to showing how, why, and under what circumstances, revolutionary science displaces normal science, resulting in a new paradigm. In Chapter 1 Kuhn defines normal science (where scientists spend most of their time) as ". . . predicated on the assumption that the scientific community knows what the world is like. Much of the success of the enterprise derives from the community's willingness to defend that assumption, if necessary, at considerable cost." Many parallels can be drawn between the concepts described by Kuhn and the challenges of adopting the GSDM which is based on a single origin for 3D geospatial data. Kuhn includes particularly insightful discussion on pages 84 and 85 and says that reorientation by "paradigm change" is as simple as "picking up the other end of the stick."

3. Prior to the advent of reliable clocks, finding the longitude at sea was a challenge. Dava Sobel [4] chronicles John Harrison's (1693-1776) development of the chronometer and the triumph of his time-keeping solution over the astronomical solution favored by the scientists and astronomers of the day. Efforts to falsify Harrison's solution ultimately failed and Harrison, a talented clockmaker, is credited with solving the longitude problem.

4. Jennifer A. Doudna and Samuel H. Sternberg [5] describe development of the CRISPR gene editing process. This technology has already had profound impact worldwide. Development of CRISPR would not have been possible without prior work documenting the DNA model of genetics. This is not to suggest that either the DNA model or the CRISPR model is "simple." But the process of gene editing has been greatly simplified by using CRISPR techniques.

5. A history of the conception, beginning construction activities, and termination of the Superconducting Super Collider (SSC) project in Texas was written by Riordan, Hoddeson, and Kolb [6]. The standard model for particle physics is a paradigm developed by theorists in the second half of the 20th century. Scientists envisioned building a machine, the superconducting super collider (SSC), to test their theories. Championed by then President Reagan and funded by the U.S. Congress in the 1980s, the SSC project was terminated in 1993 due to cost overruns, mismanagement, and other reasons. The resulting loss of scientific competitive edge by the United States was highlighted by the discovery (proof) of the Higgs Boson by the CERN Large Hadron Collider in 2012. This book documents many lessons related to science and models.

6. Legend has it that Columbus was the first to "discover" the New World in 1492. However, Menzies and Hudson [7] document a body of contrary evidence. What does it take to dislodge long-accepted "facts"? It is the prerogative of each reader to evaluate the evidence and to reach their own conclusion. But falsification of a hypothesis can also be time consuming and messy. Furthermore, it is not unheard of for two experts to consider the same evidence and reach different conclusions. Notwithstanding non-Euclidean geometry and the curvature of space time, it is reassuring that rules of solid geometry as espoused by Descartes in 1637 and embodied in the GSDM are fundamental and reliable.

7. Nicolaus Copernicus wrote a book, *De revolutionibus*, on the heliocentric model of planetary motion, which was published in 1543 - at the very end of his life. It took many years for the Copernicus model to be accepted and one writer, Arthur Koestler (in his book *Sleepwalkers*), referred to the Copernicus book as "the book nobody read." Owen Gingerich [8] (1930-2023), Professor Emeritus of Astronomy at Harvard University, became fascinated by that claim and embarked on quest (lasting over 30 years) to locate all known copies of the first edition of the Copernicus book. Gingerich collected sufficient evidence to dispute Koestler's claim and shares insights into related issues such as antique book collecting, manuscript thefts, and the progress of science – truly a fascinating read.

8. Nicholas Crane [9] writes about Gerard Mercator (1512-1594) as the Man Who Mapped the Planet. Mercator was an early contributor to the age of enlightenment and is best known for his 1569 map of the world which later became known as a conformal map. Revolutionary spacing of parallels of latitude on a Mercator map enabled a mariner to plot a course across the ocean from one port to another following a constant bearing. This procedure was more efficient than sailing across the ocean at a constant latitude based on the observed altitude of the Sun or stars. A related feature of a conformal map, subsequently exploited in the US State Plane Coordinate System (SPCS), is that the distortion between distance on the ellipsoid and the projected distance on the map, at a given location, is the same in any direction.

   A map projection is strictly a two-dimensional model, but spatial data are 3D which begs the question, "shouldn't a 3D model should be used for 3D data?" The 3D GSDM does not distort a ground distance when shown on a map. The user chooses the elevation at which to compute a horizontal distance, $HD = \sqrt{(\Delta e^2 + \Delta n^2)}$ and, in terms of the GSDM, the 3D azimuth of a geodetic line from any point to any other named point is $\alpha = \arctan(\Delta e/\Delta n)$ with due regard to quadrant. A rotation matrix is used to convert ECEF vector components $\Delta X/\Delta Y/\Delta Z$ to local components, $\Delta e/\Delta n/\Delta u$ – see video clip example [10].

9. Private ownership of property (real estate) along with a democratic legal system are two fundamental characteristics of life in the United States. Andro Linklater [11] describes how the United States was shaped by the greatest land sale in history. Although the Metes & Bounds system of describing land predated development of the U.S. Public Land Survey System, both systems are still in use. Much has been written about the advantages of one model compared to the other and over the past 200 years, the stability of land conveyancing has been enormously beneficial. Although neither system is under attack, the digital revolution is driving enhanced efficiencies in the land conveyancing process. Underlying principles such as priority of calls, senior rights, and the sacredness of the original undisturbed monument (for defining boundaries) are enduring but the evolution of measurements, data processing, and principles of spatial data management are manifest in the proliferation of options – monument witnesses (bearing trees, fence lines, road centerlines, and coordinates); units of length (chain, foot, meter); and coordinate reference systems (local, state plane, UTM, ITRF). Anticipating the impact of artificial intelligence (AI) related to spatial data applications, there seems to be no end in sight. On the other hand, given the overarching concepts of the GSDM, existing practices and

procedures can be incorporated efficiently under the same umbrella. The GSDM provides a convenient meeting place from which users in various disciplines can tailor their own applications. Caveat – to preserve the integrity and benefits of using the GSDM, the rules for transformations must be provable and bi-directional. 1D and 2D data can also be accommodated in the GSDM if reasonable estimates of data accuracy are included.

10. Anthropologists and others go to great lengths to develop plausible explanations of human history based on evaluation of available evidence. Yuval Noah Harari [12, 13, 14] wrote a series of 3 books (all three were on the NY Times Best Seller List) which covers the entire span of humanity, from the Big Bang to the present. Each book contains extensive notes and some conjecture but, for the most part, each appears to be authoritative. Being on the NYT best seller list enhances credibility but does not guarantee the absence of "snake oil." Although each reader is responsible for what they believe, it seems that many choose to embrace the Simon/Garfunkel lyric which states, "a man hears what he wants to hear and disregards the rest." Under such conditions, legitimate evidence may not be given the weight it deserves.

11. In music, an octave is defined by doubling the frequency (2:1) from one "do" to another. Stuart Isacoff [15] explains that a piano is tuned by establishing 12 equal frequency intervals in an octave. It is well known that the frequency ratio of (3:2), known as a "fifth," produces a much desired harmonious sound. However, it is impossible to meet those frequency ratios perfectly across the range of keys on the piano keyboard. Although C (sharp) and D (flat) are represented by a single key on a piano, in theory they have slightly different frequencies. It is said that a person with perfect pitch can hear the difference but, for the most part, many people who enjoy music are oblivious to that difference. Even temperament has been passionately debated by musicians, mathematicians, and theologians for hundreds of years. Is everyone satisfied? No! Does even temperament work? Yes.

    Similarly, some insist that the geoid (sea level) is the best reference for elevation. Acknowledging the intuitive long-standing practice of referencing elevation to sea level, mathematical efficiency, driven by the digital revolution and other reasons, provides justification for using the ellipsoid as the reference for the third dimension. In general, ellipsoid heights can provide an acceptable approximation for elevation. Citing the direction "water will run," it is claimed that geoid heights combined with ellipsoid heights are required for computing hydraulic grade lines. But dynamic heights (requiring input of gravity values) are used in cases requiring ultimate precision for hydraulic grade lines. Issues include:

    - Height differences are critical for hydraulic grade lines. Elevations are arbitrary.
    - In many applications ellipsoid heights can be used in place of elevations. If really needed, dynamic heights are used to compute precise hydraulic grade lines.
    - Continuing improvement in measurements and concepts of gravity contribute to on-going improvements to the location of the geoid. Frequent upgrades to geoid models are costly for the end user.

The GSDM uses the Earth's CM, more stable and easier to locate than the geoid), as the reference for the third dimension. An authoritative study is needed which will document:

- Those cases for which a precise hydraulic grade line is actually required.
- The acceptable uncertainty permitted when approximating hydraulic grade lines.
- The anticipated frequency of updates to current geoid models.
- The economic impact of continuing use of separate horizontal and vertical datums.

Although the theoretical relationship between gravity, location of the geoid, and time (at the 10^{-18} second level) is also acknowledged, it appears that true 3D will be more beneficial to spatial data users than pseudo 3D for the foreseeable future.

In a parallel case, the equation-of-time (ET) defines the difference between mean solar time (widely used worldwide) and solar time (used by astronomers). The ET is known and used by those actually needing it. This is another example in which an approximation (mean solar time) is widely used but for which a correction is readily available if needed.

12. Sometimes, the scientific method can be "messy." Understanding reasons for extinction of the dinosaurs 65 million years ago required evaluation of evidence from a variety of sources worldwide and collaboration among knowledgeable professionals in multiple disciplines. Depending on one's perspective, different conclusions can be drawn from the same data. James Lawrence Powell [16] writes about the progress of discovery and relates his conclusions. The book describes ensuing disagreements and heated debates as being one of the all-time lows of scientific discourse. Eventually testable theories (e.g., finding evidence of the impact crater) lead to acceptance of the catastrophic demise of the dinosaurs. Regarding adoption of a universal 3D datum, respectful discussion should be part of "agreeing to disagree." While a transition to using a 3D model for 3D data might appear to be inevitable [17], such a transition will take time, and various challenges need to be met. A flip side question is, "Will the 3D genie ever be returned to the bottle?"

13. What existed in the universe before there was "something"? Lawrene M. Krauss [18] states that he is not sympathetic with the notion that creation requires a creator, and it seems that he, along with other notables such as Albert Einstein, Stephen Hawkings, and Richard Dawkins, is comfortable knowing that the existence of God can neither be proven or disproven. Highly regarded as a cosmologist, Krauss has written more than 300 scientific publications and compiles a plausible explanation of how the universe came to be. Will any of his conjectures ever be falsified and will there be consequences? Or did the universe really come from "nothing?"

14. Regarded as one of the most brilliant theoretical physicists since Einstein, Stephen W. Hawking [19] describes efforts to find the ultimate unifying concept in particle physics. On page 69 he states, "most physicists hope to find a unified theory that will explain all four forces as different aspects of a single force." In the Introduction of the book, Carl Sagan, says that Hawking's book is about God – or about the absence of God. At the end of the

book Hawkings includes a summary of challenges faced (separately) by Einstein, Galileo, and Newton. “Science is messy,” is a common thread.

15. The ultimate “model” question, “If the universe is the answer, what was the question?” might be that associated with the origin and end of the universe as now perceived. Leon Lederman [20], retired Director of Fermi Lab, writes an understandable history of particle physics, development of the “standard model,” and, among others, the search for the Higgs Boson – discovered by the CERN Large Hadron Collider in 2012. He notes in the Preface that science is making great progress consistent with the Greek philosopher Thales (about 600 B.C.E.) who asked whether everything could be traced back to a simple overarching principle. The GSDM is viewed as a similar overarching principle in that the workflow process from spatial data collection to final solution is standardized and eliminates needless intermediate models such as map projections and geoids. Geometry and science support that hypothesis but additional study and discussion are needed prior to adoption of the GSDM as an international standard.

16. Without doubt, elevations constitute a critical physical feature of the global geospatial environment. The digital elevation body of knowledge is documented in a 2007 book edited by David F. Maune [21]. The book is comprehensive and includes numerous sources, including Wikipedia. Traditionally, elevation worldwide is referenced to sea level (more particularly the geoid). Past practice leads to the underlying question exacerbated by the digital revolution – since Earth’s CM is more stable and is easier to locate, should it be used as the reference for elevation instead of sea level (the geoid)? Stated differently, at what point should standard practice transition from pseudo 3D to true 3D? Here again, the GSDM defines the environment and provides specific procedures for implementing [22] the GSDM. An important postscript is that the GSDM provides an efficient common “meeting place” for generators of spatial data and users of spatial data.

17. Noel A.C. Cressie [23] states in the Preface that this book provides coverage of *geostatistical data, lattice data*, and *point patterns*. Written primarily for scientists and engineers involved in mining and geological operations, he discusses “spatial data” and “spatial data models,” while at times assuming that data and location are both random. Nonetheless, he introduces the use of sophisticated tools such as Kalman filtering and kriging for data analysis. Such tools are compatible under the umbrella of the GSDM. Without sacrificing rigor, the GSDM is intended to be easier to use for spatial data computations than traditional geometrical models for performing computations on the mathematical ellipsoid and referencing the geoid. Additionally, the GSDM uses standard deviation (and variances) to express uncertainties in the data. The point here is that Kalman filtering, kriging, and other sophisticated procedures do not falsify the GSDM. Use of such tools can be incorporated within the framework of the GSDM.

18. Joseph Zund [24] writes a book Intended for research geodesists, graduate students in geodesy, and theoretical geophysicists. This is another book that includes high-level mathematical tools for handling spatial data. For example, Dr. Zund introduces tensor calculus in Chapter 1 as being appropriate for various classes of high-level historical material. Without criticizing his work, the book appears to be more appropriate for theoretical considerations than for practical applications. One exception might be his

treatment of conformal differential geodesy. Mercator is credited with inventing the conformal map in 1569. Since then, numerous mathematical works have been written to incorporate conformal mapping concepts. Conformal mapping products remain useful for 2D visualization but, because computations are performed in 3D space. the GSDM does not need or use conformal mapping equations.

19. Similar to previous items, the book, *Spatial and Temporal Reasoning in Geographic Information Systems*, Edited by Max J. Egenhofer and Reginald G. Golledge [25], provides insight into "weightier" issues that should not be ignored. While additional evidence may eventually suggest otherwise, it is gratifying to realize that the simplicity of the GSDM is not falsified by spatial reasoning. On the contrary, it appears that the rigor of the GSDM is compatible with weightier mathematical concepts.

    Rather than stopping there, the question was put to Microsoft Copilot – "in what ways are spatial reasoning and abstraction of spatial data related?" The AI response was reasonable and thought provoking but demonstrated a disturbing absence of human insight.

20. Written over 20 years ago and drawing heavily on Kuhn's book, the article, "The Digital Revolution Begets the Global Spatial Data Model (GSDM)" by Earl F. Burkholder [26] is primarily a response to item (19) above. The GSDM facilitates several forward-looking concepts but the hypothesis in this article that vertical could ultimately be the strongest component of a GNSS solution remains a challenge. Regretfully, the EOS article did not generate sufficient traction to make a measurable impact. Since then, rather than making the GSDM obsolete, advancements in the use of 3D digital spatial data over the past 30 years highlight efficiencies that can be realized with adoption of the GSDM.

21. Currently CEO of Microsoft AI, Mustafa Suleyman [27] was previously affiliated with artificial intelligence (AI) start-ups, Inflection AI and DeepMind. He has also held several posts at Google and writes about the inevitable impact of AI and synthetic biology. Each topic carries enormous implications about the future and how we (mankind) should maintain control of our own future. It seems that Suleyman is of the opinion that ultimately, our future will be determined by personal resources and collective application of the human mind to solve our problems.

22. Following up his previous book listed in item (13), Lawrence M. Krauss [28] describes "*The Greatest Story Ever Told - So Far. . ."* Scientists know that any new idea, opinion, or interpretation of evidence may be subject to falsification or discredited. It seems that Krauss acknowledges possible falsification by adding the phrase, "So Far" to the title. He states in the Prologue that, "It is a story of science's quest to uncover the hidden realities underlying the world of our experience." Although the level of technical/scientific detail might overwhelm a casual reader (personal experience), the story is told with admirable patience. With careful reading, answering question, "why are we here?" comes through rather nicely. As an item of interest, what might it be like to read a similar treatise 25 to 30 years from now? Speculation suggests that it should prove to be a fascinating exercise.

23. Early versions of AI exploited facial recognition prematurely as described by Dr. Buolamwini [29], a dark-skinned person who championed “algorithmic justice” for persons victimized by premature use of the technology. She writes about the frustration of her personal experience with limitations of AI as applied to her research on facial recognition. She also writes about other misapplications of AI and highlights the importance of “algorithmic justice.” Like Suleyman in Item (21) above, Dr. Buolamwini advocates diligence and engagement as we (humankind) strive to enjoy benefits of using AI while avoiding detrimental consequences of AI applications.

Analysis:

Evaluation of spatial data models occurs against the backdrop of the digital revolution, expanding applications of 3D digital spatial data, and the inevitable impact of AI. The 3D Global Spatial Data Model (GSDM) is highlighted as being appropriate for use worldwide. The goal in practice is to do things correctly. Performance specifications are the essence of professional services (doing the right thing). Detailed specifications, while not a guarantee, provide guidance for achieving a stated objective (doing things right). Algorithmic integrity is essential, i.e., doing the right thing correctly, for successful integration of spatial data into any workflow, especially those workflows involving AI.

Conclusions:

- The best model is one that is simultaneously adequate and simple.
- An overarching innovative concept can lend clarity to a variety of problems.
- Using the GSDM can enhance workflow efficiency from data collection to final solution.
- The collective view of scientists provides a filter for eliminating “snake oil.”
    - Although not perfect, the peer review process is necessary and effective.
    - Innovations are often disruptive. As such, they risk being prematurely falsified.
- This article will be successful to the extent it fosters honest evaluation of options.

References:

1 Burkholder, E.F., 1997, “Definition and Description of a Global Spatial Data Model (GSDM),” available from http://www.globalcogo.com/gsdmdefn.pdf (cited 10/10/2025).

2 Pruneau, C.A., 2017, *Data Analysis Techniques for Physical Scientists*, Cambridge University Press.

3 Kuhn, T.S., 1962, 1970, 1996, *The Structure of Scientific Revolutions*, University of Chicago Press.

4 Sobel, D., 2005, *Longitude*, Walker & Company, New York. Video available from https://www.youtube.com/watch?v=--b0eaKGWwE (cited 10/10/2025).

5 Doudna, J.A.; Sternberg, S.H., 2017, *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Creation*, Mariner Books, Boston.

6 Riordan, M.; Hoddeson, L.; Kolb, A.W., 2015, *Tunnel Visions: The Rise and Fall of the Superconducting Super Collider*, University of Chicago Press.

7 Menzies, G.; Hudson, I., 2014, *Who Discovered America? The Untold History of the Peopling of America,* William Morrow, an imprint of HarperCollins Publishers, New York.

8 Gingerich, O., 2004, *The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus,* Walker & Company, New York.

9 Crane, N., 2002, *Mercator, the Man Who Mapped the Planet,* Henry Holt and Company, New York.

10 Burkholder, E.F., 2025, Video clip of ECEF components converted to local components, available from, http://www.globalcogo.com/XYZ-to-enu.mp4 (cited 10/11/2025).

11 Linklater, A., 2002, *Measuring America: How the U.S. Was Shaped by the Greatest Land Sale in History,* Penguin Group - PLUMB.

12 Harari, Y.N., 2015, *Sapiens*, Harper Perennial; New York.

13 Harari, Y.N., 2017, *Homo Deus*, Harper Perennial; New York.

14 Harari, Y.N., 2018, *21 Lessons for the 21st Century*, Spiegel & Grau, New York.

15 Isacoff, S., 2001/2003, *Temperament, How Music Became a Battleground for the Great Minds of Western Civilization,* Vintage Books.

16 Powell, J.L., 1998, *Night Comes to the Cretaceous,* Harcourt, Brace & Company, San Diego.

17 Burkholder, E.F., 2023, AT&T experience as described by Walter Isaacson, available from http://www.globalcogo.com/ATandT-Story.pdf, cited 10/11/2025).

18 Lawrene M. Krauss, 1988, *Why is there Something Rather Than Nothing – A Universe From Nothing,* Free Press, New York.

19 Stephen W. Hawkings, 1998, *A Brief History of Time From the Big Bang to Black Holes*, Bantam Books, Toronto.

20 Lederman, L. with Tersi, D, 1993, *The God Particle: If the Universe is the Answer, What is the Question?* Houghton Mifflin Co. – A Mariner Book, Boston.

21 Maune, D.F.,2007, *Digital Elevation Model Technologies and Applications,* ASPRS, Bethesda, MD.

22 Burkholder, E.F., 1997, “Implementing the GSDM – Part I, Part II, Building, and Common,” available from http://www.globalcogo.com/Implementation.pdf (cited 10/10/2025).

23 Cressie, N.A.C., 1993, *Statistics for Spatial Data,* John Wiley & Sons, NY.

24 Zund, J. 1994, *Foundations of Differential Geodesy,* Springer-Verlag, Berlin.

25 Egenhofer, M.J.; Golledge, R.G, Editors, 1998, *Spatial and Temporal Reasoning in Geographic Information Systems*, Oxford University Press.

26 Burkholder, E.F., 2003, “The Digital Revolution Begets the Global Spatial Data Model (GSDM),” *EOS,* Transactions, American Geophysical Union, Vol. 84, No. 15, 15 April 2003, PP 140-141. New links, 2009 http://www.globalcogo.com/gsdm-eos.pdf (cited 10/27/25).

27 Suleyman, M., with Bhaskar, M., 2023, *The Coming Wave: AI, Power, and Our Future,* Crown, New York.

28 Krauss, L., 2017, *The Greatest Story Ever Told – So Far*: *Why are We Here?* Atria Books (Imprint of Simon & Schuster), New York.

29 Buolamwini, J., 2023, *AI Unmasked: My Mission to Protect What is Human in a World of Machines,* Random House, New York.