Rationale for Supporting Low-Distortion Projections (LDPs)
As Stepping Stones to Adoption of the 3D Global Spatial Data Model (GSDM)

Earl F. Burkholder, PS, PE, F.ASCE
Global COGO, Inc. – Las Cruces, NM 88003
July 13, 2026

The traditional view:

1. The digital revolution is driving disruptive innovation in the use of 3D digital spatial data.
2. Solid geometry rectangular east/north/up (flat earth) relationships are 'standard' for local use.
3. The impact of gravity drives choices when working beyond limitations of flat earth assumptions.
    - A horizontal datum is defined by latitude/longitude positions on the ellipsoid.
    - A vertical datum defines distance above (or below) a reference surface (sea level or geoid).
4. Due to gravity, physical accommodations cannot be ignored when transitioning from 2D to 3D.
    - Except in special cases, plumb lines at two ends of a line are not parallel.
    - Except at the Equator, meridians of longitude are not parallel.
    - Sea level (the geoid) is the nominal reference for elevation. Research is ongoing/complex.
5. Methods have been devised to ease the computational burden imposed by physical constraints.
    - Extensive effort has been devoted to modeling distance between the ellipsoid and geoid.
    - Map projections support use of plane computational methods based on latitude/longitude.
        i.) Distances from ground to grid are distorted but controlled by limiting area of a zone. (Low-distortion projections (LDPs) have been devised for local coverage.)
        ii.) Map projections are strictly 2-dimensional while spatial data are 3-D.
6. National Geodetic Survey (NGS) is modernizing the National Spatial Reference System (NSRS).
    - Their project website is https://geodesy.noaa.gov/datums/newdatums/index.shtml.
    - The massive project is very comprehensive and nearing completion. Kudos to NGS!
    - The spatial data user community will enjoy enormous benefits from using the results.
    - Regretfully NGS is promoting two products/procedures as a carry-over of past practice.
        i.) Use of map projections for state plane coordinate systems.
        ii.) Promoting a new geoid model for computing orthometric heights.
        (Both can be obviated by adoption of the global spatial data model (GSDM)).

Background:

1. 3D concepts have emerged from convergence of abstraction/technology/policy/practice.
2. See, "Definition and Description of a Global Spatial Data Model (GSDM)," 1997 by Burkholder - http://www.globalcogo.com/gsdmdefn.pdf
3. Dr. N. W. J. Hazelton wrote several scholarly articles on The Surveying Revolution that were published in the Surveying & Land Information Science (SaLIS) Journal. Building.pdf
4. The Manual of Digital Earth (2020) is an 846 page volume published by the International Society of Digital Earth and Co-edited by Professors Huadong Guo, Mike Goodchild, and Alessandro Annoni. A very comprehensive volume, it contains 26 Chapters, written by 100 different authors from 18 countries. Manual of Digital Earth - International Society for Digital Earth.
5. Professor Goodchild also published "Reimagining the History of GIS" (2017) in which he identifies two options for development of GISs – a flat earth model and the globe. He continues by describing the benefits of the Discrete Global Grid for organizing spatial data.
6. As a follow up to Hazelton's and Goodchild's resource materials, Burkholder authored two articles published by the Journal of Geographic Information Systems (JGIS) which describe a third option – that is, performing spatial data computations in 3D space based on the GSDM.
7. An item posted at GSDM alternative provides links to the two JGIS articles and describes how the GSDM can be an alternative to conformal mapping – obviating the need for state plane zones.

Current:

1. To their credit, NGS is on the verge of publishing results for modernization of the NSRS. Many talented people have contributed to an enormously valuable asset for the end users.
2. Steps and procedures leading up to adoption of low-distortion projections (LDPs) are the result of careful planning and persistent promotions to the user public. “We are where we are because of where we came from.” A simple analogy to the title is, “we need to walk before we run.”
3. The reasons for developing state plane coordinates (making it easier and possible for local users to enjoy the advantages of using “big picture” survey control on local projects) remain valid.
4. Used properly, state plane coordinates & LDPs are enormously valuable to the user community.
5. An increasing pool of “sophisticated” users don’t need the “crutch” of a conformal projection.
6. Advancing technology (including AI) will increasingly rely on using “3D models for 3D data.”
7. Although the investment in existing SPCSs is huge, the AT&T Story will likely be repeated.
8. Viewed as a precursor to the current NSRS modernization project, NGS performed a nationwide adjustment of the network to bring consistency to various input types and reference frames for the results. Notably, the same results were obtained using both classical geodesy equations on the ellipsoid and ECEF vectors in 3D space. The ECEF adjustment involved one iteration of the linear network model and error propagation procedures are the same as used in the GSDM stochastic model. Seemingly, features of the GSDM are compatible with that 2011 adjustment.

Features of the GSDM:

1. The GSDM, based on the Earth-centered Earth-fixed (ECEF) system, is defined and in place.
2. One set of public domain equations is applicable worldwide (no zones).
3. Local directions and distances are computed directly without distortion from ECEF values.
4. The stochastic portion of the GSDM is optional but if used, can handle spatial data accuracy.

Comparison and Notes:

The paper, “GIS distances and directions directly via the GSDM” shows that the same correct ground level distance can be obtained irrespective of the user’s choice of location for the project P.O.B. The P.O.B. Datum coordinates were computed as given in the project report and illustrated in a video. Subsequent computations were added in this article to compare local distances and directions for the same Section 31 based on the NM Dona low-distortion projection (LDP) and, separately, based on the anticipated SPCS2022 as defined by NGS. In all cases the results show that the GSDM derived distances (no distortion) can be used as a standard against which values obtained using other methods can be compared. Only the comparison results are shown in the Table on the following page. The underlying spreadsheets can be accessed here..

In addition to showing the ease with which local distances and directions can be obtained directly using the GSDM, the tabulation illustrates how well the distorted map projection distances match (or don’t match) the undistorted ground distance. Admittedly the comparisons, although similar, could be different depending on one’s location with a given map projection zone.

Computer printouts showing distortion at each point in the project for each projection (LDP and SPCS2022) are available distortion-SPCS2022 and distortion-Dona-LDP.

What are the consequences if the distortion correction is ignored? It depends on whether. . .

1. Ground distance is converted to grid distance. Computed coordinates are defective.
2. Grid distance (from GPS) is converted to ground distance. Distance on map is defective.

Comparison of Distances

Map Projection Results Compared to GSDM Results

Section 31, T23S-R1E, New Mexixo Principal Meridian

Earl F. Burkholder, PS, PE, F.ASCE
Global COGO, Inc. - Las Cruces, NM 88003

July 11, 2026

Column A	Line segment associated with Section 31, T23S-R1E, NMPM
Column B	Distances in meters obtained using the GSDM.
Column C	Distances in meters obtained using the Dona Anna LDP.
Column D	Difference of values in meters, GSDM – LDP.
Column E	Differences in parts per million (ppm).
Column F	Distances in meters obtained using the NGS defined SPCS2022 parameters.
Column G	Differences of values in meters, GSDM - NGS SPCS2022.
Column H	Differences in parts per million (ppm).

A	B m	C m	D m	E ppm	F m	G m	H ppm
SW Corner to W 1/4 Corner	804.478	804.476	0.002	2.49	804.534	-0.056	-69.6
W 1/4 Cor. to NW Corner	804.639	804.638	0.001	1.24	804.696	-0.057	-70.8
NW Corner to N 1/4 Corner	797.785	797.784	0.001	1.25	797.841	-0.056	-70.2
N 1/4 Cor. To NE Corner	811.224	811.224	0.000	0.00	811.281	-0.057	-70.3
NE Corner to E 1/4 Corner	804.92	804.919	0.001	1.24	804.975	-0.055	-68.3
E 1/4 Cor. to SE Corner	804.436	804.435	0.001	1.24	804.491	-0.055	-68.4
SE Corner to S 1/4 Corner	804.614	804.614	0.000	0.00	804.671	-0.057	-70.8
S 1/4 Cor. To SW Corner	804.355	804.354	0.001	1.24	804.412	-0.057	-70.9

Notes:

1. The GSDM distances agree with ground level geodetic distances within 0.001 meters.
2. All map projections distort distances. LDPs distort distances less than SPCS2022.
3. Corrections can be made to convert between grid and ground level distances.
   (The question is, "How much distortion can be tolerated before making a correction?")
4. 1:10,000 is 100 ppm. 1:50,000 is 20 ppm. 1:100,000 is 10 ppm.