Memo

Date: October 11, 2005

TO: ASPRS Panel on Digital Orthoimagery

FROM: Earl F. Burkholder, PS, PE
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RE: Review of ASPRS Panel Report to The U.S. Geological Survey on the National Digital Orthoimagery Program

Thank you for the opportunity to review the panel report on digital orthoimagery. The panel is to be commended for your dedicated effort and excellent work. The report is timely, succinct, and well organized. It addresses a number of fundamental policy and technical issues with regard to how spatial data are generated, manipulated and used.

I am not qualified to comment on the report in that there is so much I don't know about the science and technology involved in the various processes described in the report. Neither am I sufficiently familiar with management of government programs to offer constructive comment on those aspects of the report. On the other hand, I am qualified to ask questions and to comment on the report in that I have some insight into the geometrical environment and fundamental characteristics of spatial (or geospatial) data. Very briefly, spatial data are now characterized as digital and three-dimensional (3-D) and the traditional 2-D+1-D models commonly used are becoming obsolete. See Burkholder (2003) and Burkholder (2004a) (follow link to recent issues, May 2004).

Although these comments need to be evaluated in the context of the goals for the report, I sincerely believe that this different perspective may help bring greater clarity and focus to the existing report. But, I also suspect that some of the ideas offered herein will be too far out in front of existing goals to be implemented immediately. I say that because I believe ultimate implementation of a fully integrated 3-D spatial data model will take more time, testing, evaluation, discussion, and coordination of resources than can be achieved within the intended timeframe for this report. But, if the USGS is to provide overall leadership as recommended in the report, then long-range implementation of the global spatial data model (GSDM) should be brought into focus as soon as possible.

Characteristics of the GSDM

1. The GSDM (Burkholder 1997) is built on the earth-centered, earth-fixed (ECEF) geocentric rectangular coordinate system defined by the U.S. Department of Defense. In that environment, the rules of solid geometry and vector algebra are universally applicable. These procedures are proven and useful worldwide.

2. The GSDM supports a fundamental hierarchy of primary data versus derived secondary data. Measurements (Burkholder 2001) are primary data. However, once primary data are processed and added to the database, the coordinates and their standard deviations become primary data available to all users.

   Sidebar question/issue: We pay a lot of attention to generating spatial data and the question invariably is, "how good is it?" Meta data are often used to answer that question. Standard deviations can be used to provide a numerical answer. A related question that deserves equal attention is, "What causes spatial data to lose their value?" The typical answer has to do with availability, format, datum etc. But consider this; the value of spatial data is destroyed (or compromised) when it is replaced with similar position data having a smaller standard deviation.

   For example, given that the covariance of each point is also stored, then any derived quantity (distance, direction, area, volume etc) can also have a standard deviation associated with it. The GSDM provides a way to store and track the spatial data accuracy (Burkholder 1999) for any point or derived quantity.

   In addition, if the correlation between points is also stored, then it becomes possible to answer the question, "accuracy with respect to what?" (Burkholder 2004b). Spatial data users deserve and will find the concise mathematical definition of local accuracy and network accuracy to be very useful. These GSDM features can provide an enormous enhancement to use of metadata.

3. In an integrated 3-D system, elevations are a derived quantity. This is probably the area where the transition will be the most difficult to achieve and the area that has the potential to yield the greatest benefit (Burkholder 2002). In the subject report and in many other published papers, resolution of vertical with GPS is stated to be inferior to horizontal. That may be true if one uses only data from satellites above the local horizon. Given that GPS receivers around the world are collecting data simultaneously and that global data sets can be aggregated for processing, the hypothesis is that vertical (radial) may turn out to be the strongest component if simultaneous data from both sides of the world are used for interpolation within the birdcage of GPS satellite orbits (Burkholder 2003).

4. Given that orthoimagery is the focus of the subject report, the GSDM provides for efficient plotting and production of orthophoto maps based upon imagery from various sources. Given a database of geocentric X/Y/Z defined points, an orthophoto map is generated by plotting the Δe and Δn components of each point with respect to the Master P.O.B. as selected by the user (Burkholder 2003). I am not familiar with the details of "draping" but such practice appears moot if the imagery is already in the same 3-D database. I've sat before a computer and flown through a virtual housing development where all points were relative to each other but not connected to the real world. Orthoimagery adds the "real" connection and if done in the X/Y/Z frame, eliminates the "shadow" problem.

5. For me, the challenge would be to resolve the readings from each sensor into rectangular spatial data components (Burkholder 2001) but I've been assured the details are well understood for normal based measurements as well as for vertical based measurements (El-Sheimy/Valo/Habib 2005).

Comments on Points Made in Report

One could say I'm really suggesting that a raster file be converted to a vector file by coming up with the geocentric X/Y/Z coordinates and covariances for each and every pixel in a file. That may be considered impractical, but innovative users and tinkers have a way of meeting the challenges and overcoming such obstacles. Interoperability will take on a new meaning if/when everyone uses the GSDM as a common model and database. The individual steps and processes are quite well proven and documented. A credible leader needs to step forward, organize/facilitate the discussion, evaluate the feedback, and orchestrate consensus among users to build on an integrated 3-D database. It will be an exciting process.

Having suggested that, the following comments are directed to various parts of the report:

1. Page 2, item 1: Is there a specific concise definition of "surface model?" As I understand it, a surface model is a collection of points purporting to describe the relative position of points within a given area. I'd like to see surface model defined as a collection of geocentric X/Y/Z points in specified area that describe a given feature or features. That includes the luxury of both relative and absolute position.

2. Page 4 Introduction, first paragraph: Orthoimagery is suggested as the base layer of the NSDI. That will happen if each pixel in the image has an ECEF X/Y/Z value along with reliable covariance information. Is that a practical goal and how long will it take for that to become "standard"?

3. Page 4, last paragraph: New technology really should be evaluated in terms of the 3-D environment. For example, LIDAR does not measure elevation does it? Rather LIDAR records the distance to an object in 3-D space. Or is it the **difference** in distances to adjacent features in the same point cloud? Whether the measurement is distance or differences in distance, elevations are inferred from those data. But, what is the precise definition of elevation? The ambiguity of definition and whether it is absolute or relative gives rise to uncertainty. If elevation (Burkholder 2002) is taken to be ellipsoid height, then the reference is precisely defined as is the quantity being measured.

4. Page 5, Imaging Sensors: The "all digital production workflows" need to be very carefully defined. The difference may be obvious to those building measurement systems but isn't there a huge difference between processing the distance data obtained from LIDAR data and the pixel location of a feature obtained from a digital

camera – even though both are digital instruments? And, isn't it true in the case of digital camera that the co-linearity equations are still the backbone of the processing required to intersect the rays that define each pixel location with geocentric ECEF X/Y/Z?

5. Page 5 and 6: If the elevation concept and production process are identified more clearly, it will eliminate a lot of ambiguity about "good" elevation data. Once the X/Y/Z's and covariances of each pixel (or sub-set of pixels) everything is known about the location of the point and the standard deviation of that location in terms of absolute accuracy with respect to the datum or network and, if correlations are stored as well, local accuracy. It might take awhile for this feature to find its way into standard practice, but I believe the benefits can be enormous.

   A side note is that an X/Y/Z database of points provides accurate data for digital "fly-throughs" and the problem of building shadows does not exist.

6. Page 6, accuracy: The GSDM supports a definite and specific (proven) method for establishing and tracking the accuracy of spatial data according to the assumptions and quality control guidelines imposed by the user. Issues related to various technologies used to obtain the spatial data are handled by professional in the various disciplines. Said another way, each instrument or sensor and related observations are processed to obtain standard spatial data elements – either absolute X/Y/Z positions or relative $\Delta X/\Delta Y/\Delta Z$ or $\Delta e/n\Delta/\Delta u$ components (corrected as needed for deflection-of-the-vertical) – that are compatible with the GSDM. Then interoperability is enhanced and "consistency between independent data sets" is not longer a difficult issue. And, given appropriate standard deviations are input as part of the data, disparate data sets can be merged each with its own accuracy. The stochastic model portion of the GSDM will accommodate various levels of accuracy. Of course, each user needs to understand that data on different datums should not be combined in the GSDM. The HTDP (NGS web site) software available from the National Geodetic Survey (NGS) can be used to move data from one 3-D datum to another and from one epoch to another.

7. The remainder of the report deals with policy and user interactions – no comments.

The recommendations are all good – given traditional model assumptions. At some point, later if not now, existing technical procedures and associated policy decisions need to be evaluated in terms of the GSDM having a single origin for 3-D data. It is a sea-change and one that will have an enormous impact among spatial data users worldwide. Is that the challenge for which the USGS will develop expertise and leadership?

References

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