

Coordinates, Coordinate Systems and LIDAR Data (Part 1)



Karrie-Sue Simmers

Darrick Wagg

November 6, 2014

Summary: Coordinates and the systems to which they reference can be either a very complex, or a very simple thing depending upon how you look at them. The fact that such possibly complex concepts can be simplified is a blessing and probably very welcomed by many. You'd be surprised by how many people we encounter working within the geospatial industry that have little understanding of coordinate systems. In some cases, this is quite understandable, as it can have a negligible effect on the task at hand, but in others it can be quite disastrous for all involved. With the GeoCue workflow management software, we have built in quite a robust system for assisting users with the projections, datum, epoch, and even local ground transformations that one may encounter while processing data. On the other hand, processing software, such as LP360 and the Terrasolid suite of products, generally try to keep things simplified as much as possible. For instance, TerraScan for the most part doesn't really concern itself with what coordinate system the coordinate for a laser point belongs. It simply assumes, unless you specify differently, that all the data you are working with is within the same coordinate space. In this article, we'll tackle the simpler side of the spectrum to get you started, and save some of the more complex concepts for a future article.

The Design Cube

Since the Terrasolid products simply revere the coordinates as the values themselves, with no need to know the reference system (unless performing specific functions), all that is necessary is to ensure that your design seed file is configured in a manner to be able to contain those values, and of course maintain the data to an adequate level of precision.

First, and foremost, the Terrasolid products work within the MicroStation 3D environment. When starting with a seed file, a user must ensure they are using a 3D design file, and not a 2D one. In MicroStation, the 3D design file has a limit for the size of the coordinate space. This is generally referred to as the design cube, and is the limits within which all work is performed. The design cube represents the total volume of the DGN File in which all points are defined with respect to X, Y and Z coordinates. Points can be placed anywhere within the 3D cube.¹

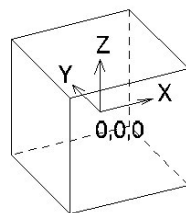


Figure 1 - MicroStation Design Cube

¹ Microstation V8i Select Series 3 Help Guide: Understanding 3D Models – Basic 3D Concepts

In the basic form, this works well with respect to LIDAR data which has Easting (X), Northing (Y), and Elevation (Z) values assigned to the point cloud. This data can be displayed within the design cube and rotated around the different axes. It also means that any georeferenced point data may be loaded into TerraScan whether it came from an airborne, mobile, static terrestrial or other system.

Resolution and Origin Offsets

The first problem that many users encounter is when the coordinate values become too large to fit within the design cube (Figure 2). To understand this better let's look at a little background. The Terrasolid applications, as do the LAS specifications, use signed 32-bit integer values when it comes to storing coordinate values of laser points and images. This is an important note to remember, as starting with MicroStation V8, Bentley modified the MicroStation environment so that coordinate values can be stored within the design cube as 64-bit integer values. This change was not coopted by Terrasolid, so there are really two design cubes: one for the design file vectors, and one for the points and rasters loaded in the Terrasolid packages. It is important to note that the design cubes do not need to be aligned in v8 and v8i as they once did in the SE version of MicroStation. The reason Terrasolid only uses 32-bit values is to take advantage of the fact the 32-bit integer values only take up 12 bytes of memory, which saves memory for other Terrasolid tasks. And memory is very important when limited to running on the 32-bit MicroStation platform.

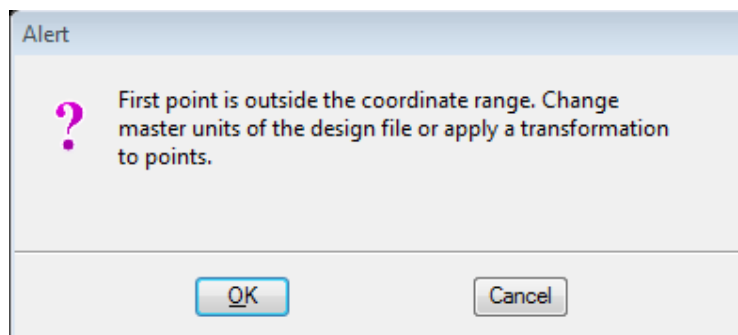


Figure 2 - Coordinate Range Warning

The setting that plays the biggest role in determining the span of the design cube in Terrasolid is the units of resolution. The user can control how coordinate values are stored within the program by specifying the resolution within the TerraScan Settings -> *Define Coordinate Setup*. Resolution is different from precision, which is different from accuracy. The *resolution* is the fineness to which an instrument can be read, while *precision* is the fineness to which an instrument can be read repeatedly and reliably. *Accuracy* is the degree of closeness of measurements of quantity to that quantity's actual value or correctness. Figure 3 helps to show the difference between *precision* and *accuracy*. The *resolution* is the width of the target rings. If you're interested, our CTO, Lewis Graham, wrote an article in *LiDAR News*² that covers these concepts in more detail.

² Graham, L. (2012, October 03). Accuracy, Precision and all That Jazz. *LiDAR News*, 2(5), pp. 46-49. Retrieved 30 Oct 2014, from http://www.lidarnews.com/PDF/LiDARMagazine_Graham-AccuracyPrecision1_Vol2No5.pdf

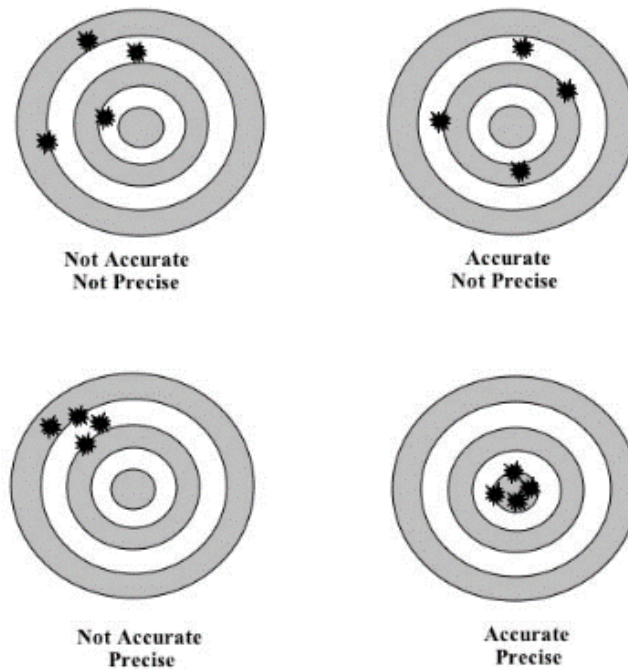


Figure 3 - Accuracy and Precision

Define Coordinate Setup is defining the *resolution* of the dataset. A good way to think about resolution is to pick up a ruler and take a look at it. The spacing of the tick marks on the ruler is the resolution, hence, affecting the precision by which measurements may be made. With metric coordinates a resolution of 1000 will cause all coordinate values to be rounded to the nearest millimeter. Modifying the resolution of our seed file as such will then produce a coordinate cube which has a size of 2^{32} millimeters or 4294967.296 meters. If the design cube has a coordinate system that is centered at [0.0, 0.0, 0.0] this means that all of the coordinate values of the data would need to fit between -2,147,483 and +2,147,483. If the data does not fit within that coordinate range then an origin offset would need to be added. The origin offset would modify the center of the design cube from the default [0.0, 0.0, 0.0] to the newly defined center as shown in Figure 4. Thus, allowing a different set of coordinates to be loaded into the software. When the offset is not properly applied, then TerraScan will warn users (Figure 2) that there are coordinates outside of the range. A good check is to always review the first point shown on the Read Points dialog (Figure 5) to ensure it fits within the design cube.

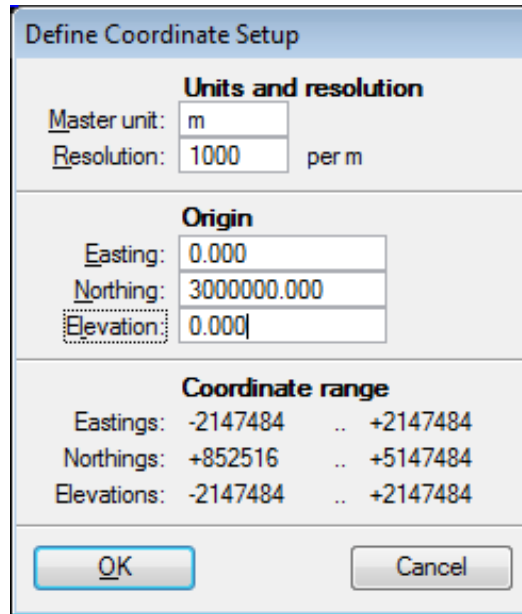


Figure 4 - TerraScan Define Coordinate Setup

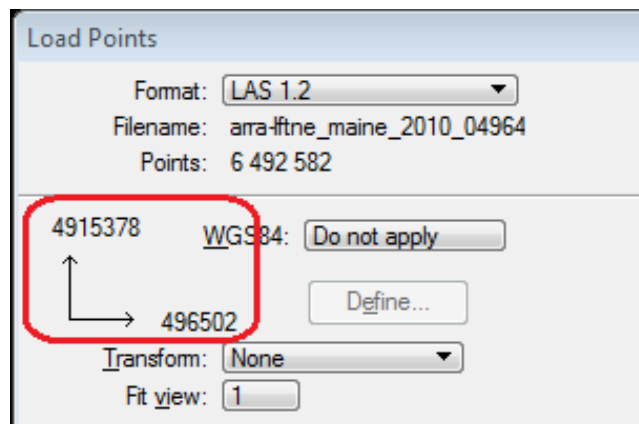


Figure 5 - Read Points: First Coordinate Range

Similarly, a resolution of 100 will cause all coordinate values to be rounded to the nearest centimeter. This will produce a coordinate range that goes from -21,474,836 to +21,474,836. If you have worked with the US State Plane zones you may recognize that several of them start with northing values that wouldn't fit within this range.

In addition, for datasets that are using imperial units, as opposed to metric units, it is important to define the master units of the design cube to represent the imperial units. The most common unit used is US Survey Feet, which is different than the unit of Feet. A value of 1.0 US Survey Feet is actually equal to 1.0000019685039 Feet and can result in a large data offset when working with large numbers, such as the northing values for a lot of coordinate systems. The units for the design cube are set in the MicroStation Design settings (MicroStation -> Settings -> Design File -> Working Units). It is good

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practice to set the resolution of the design file in the same units as the linear units. Warning: Be sure to set this information before loading any LIDAR data or creating vectors, as modifying the design file resolution after the fact will not transform existing data. The linear units are the only coordinate setup information that directly transfers from the design file to the Terrasolid products. Once the Define Coordinate Setup is used in a design file, then that information will be saved to the design file in a location for all of the Terrasolid products to access in the future. In GeoCue, the resolution of an LAS file is controlled on a project basis by the LIDAR 1 CuePac option (GeoCue Client -> Setup -> Options -> LIDAR 1 CuePac -> LAS). One may set the default to be used for all new projects, and it is usually recommended to set it to the highest resolution one may need as one can always reduce the resolution after the fact. Changes to the resolution setting in GeoCue only affect new LAS files that are generated.

The most important part of setting up the 3D design file for use with LIDAR data is to understand the units of the data that will be processed in the design file, and to understand the accuracy of the dataset. A common warning (Figure 6) that users will see is when the LAS file has been produced with a resolution of 1000, yet TerraScan is configured with the default resolution of only 100. This leads to a loss of data since the third decimal is dropped once the data is loaded into TerraScan. However, if the data is typical airborne LIDAR data, then that third decimal place value is really just noise, as it is well within the typical 3-4cm accuracy of some of the tightest data. This is not the case with mobile or terrestrial static scanner data, where that millimeter resolution is required so as not to lose any data precision.

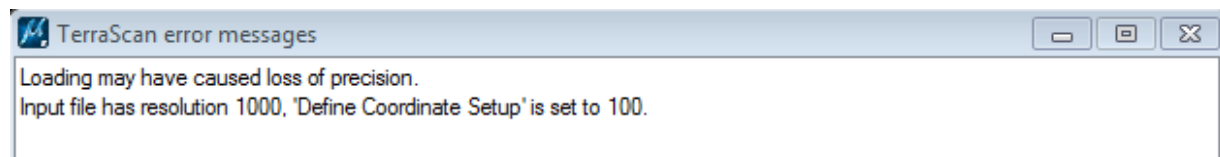


Figure 6 - Loss of Precision Warning

In the most basic sense, all of the coordinates in the same project must fit within the design cube that is configured, so it is best to review and properly configure this information before processing any data. As long as the data is then all in the same coordinate system, whether that is known or not, one does not need to worry about transformations and projections, and will be able to process LIDAR data with little understanding of them. In a future article we will look some of the basics behind coordinate systems and the typical transformations, projections and datums required to do more with your data.