Solving the "Grid to Ground Problem" with Custom Coordinate Systems

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CV327-6   Grid projections such as the State Plane Coordinate System (SPCS) and Universal Transverse Mercator (UTM) Coordinate Systems can be very useful for many reasons. However, they can leave us with the grid-to-ground problem, where distances on the ground are not the same as the distances we get when we inverse coordinates. In this class, you will learn how to solve this problem using a low-distortion projection. This is essentially a custom coordinate system defined for just your project or local region, where the "grid" and "ground" distances are the same. Your grid-to-ground problem will melt away.

About the Speaker:
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Creating a Custom Coordinate System

Before adding or editing a coordinate system, type **UNITS** at the command line, and increase the Length Precision of the Drawing Units as shown in the image below:
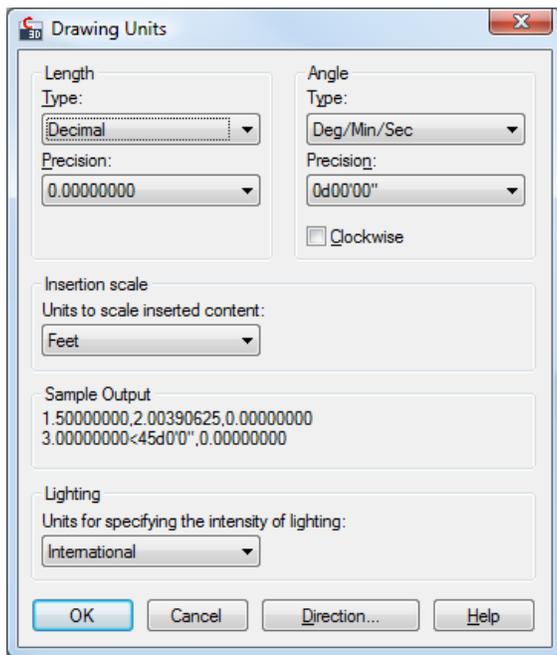
In particular, the setting for the Scale Factor in the Coordinate System Definition uses this precision setting. Failing to increase the setting may cause the stored value to be rounded to a lesser precision, which can have disastrous effects on your Coordinate System definition.

## The Global Coordinate System Manager

Once the Length Precision has been increased, start up the Global Coordinate System Manager by selecting the "Define Coordinate System" button in the Ribbon in the Task-Based Geospatial Workspace, as shown below:

Alternatively, you may type **ADEDEFCRDSYS** at the command line. *(Tip: When typing a long command at the command line, you can type a few characters and hit TAB to auto-complete the command. If the auto-completion gives you the wrong command, hit TAB again to jump to the next command, or SHIFT+TAB to go back to the previous command.)*

This will call up the Define Coordinate System dialog box seen below:
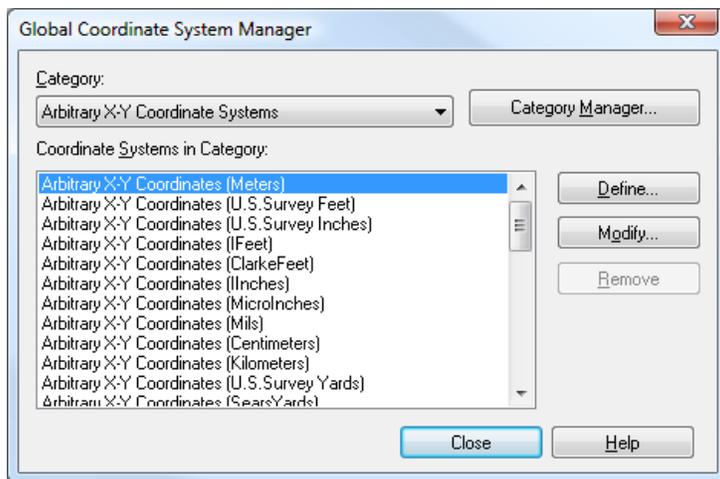
Select "Category Manager..." to create more Coordinate System categories, or select an existing Category using the combo box in the upper-left.

Modify Coordinate System - "General" tab

Once you have selected the proper category, select "Define..." to create a new coordinate system from scratch, or select an existing coordinate system, and select "Modify..." You'll then see a dialog box similar to that shown below:
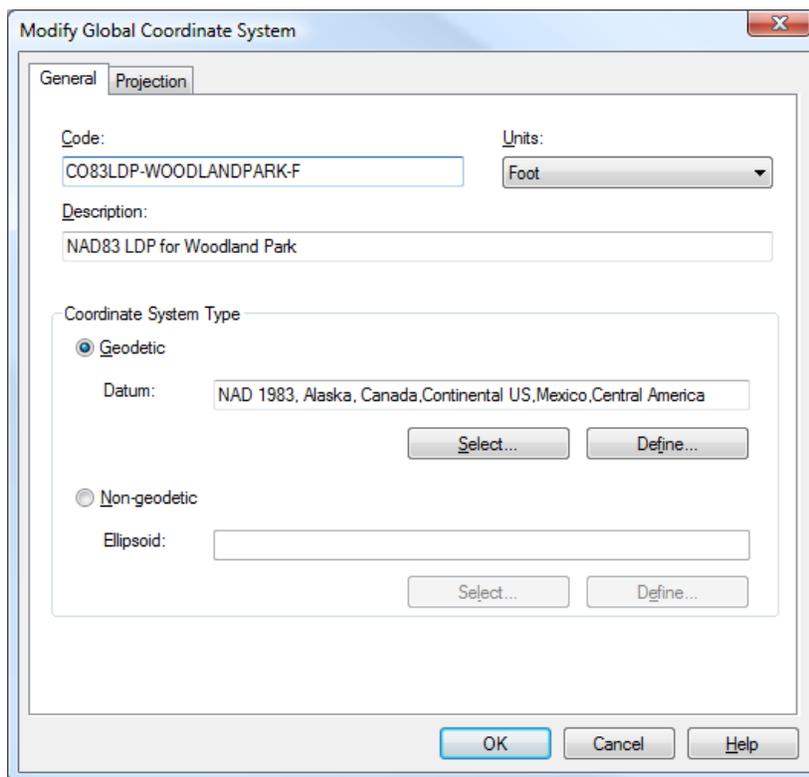
Code

When you create a new Custom Coordinate System, you must specify a unique Code for that system. Autodesk has not provided clear guidance on how these codes should be created. In general, the best option is to look at some similar coordinate systems, and create a code that is similar to those, yet unique in a key way.

In the United States, most 1983 State Plane Coordinate zones use the following format:

$$SS\text{83-}ZU$$

In the above string, **SS** is a two-letter code indicating the State. **83** indicates the basis is NAD83. **Z** indicates the zone, and is usually one of "N" for "North", "C" for "Central", or "S" for "South". **U** is a string indicating the units, and is usually "F" for "US Survey Foot" or "IF" for "International Foot", or left blank for "Meters".

For our example, we're in an area where we would normally use Colorado State Plane, Central Zone, US Survey Foot. This Coordinate System has a code of:

CO83-CF

This code indicates the State of Colorado ("CO"), NAD83 ("83"), Central Zone ("C"), US Survey Feet ("F").

For our new code, we're going to create something similar. We'll keep the "CO83" part to indicate that our new coordinate system is in Colorado, and is using NAD83 as its basis. However, we'll also add "LDP" to indicate that it's a low distortion projection. We'll also add a string to indicate the target area of our projection, which is centered on Woodland Park, and we'll keep the "F" to indicate the zone is in US Survey Feet. So, the Code for our new Projection is as follows:

CO83LDP-WOODLANDPARK-F

Units
This is where we specify the units for our Coordinate System. There are a lot of options to choose from, but most of the time, we'll use either "Foot" (aka "US Survey Foot"), "International Foot", or "Meter".

Coordinate System Type
In this section, we specify the datum for our Custom Coordinate System.

In most cases, we'll want to use a defined datum such as NAD83. However, we have the ability to also define our own custom Ellipsoid, should we desire.

Modify Global Coordinate System - "Projection" Tab

On this tab, we specify the Projection Type for our Custom Coordinate System, along with all the requisite projection parameters. These parameters will vary, depending on the type of projection we select. In the image below, our Projection Type is the Lambert Conformal Conic, single standard parallel.
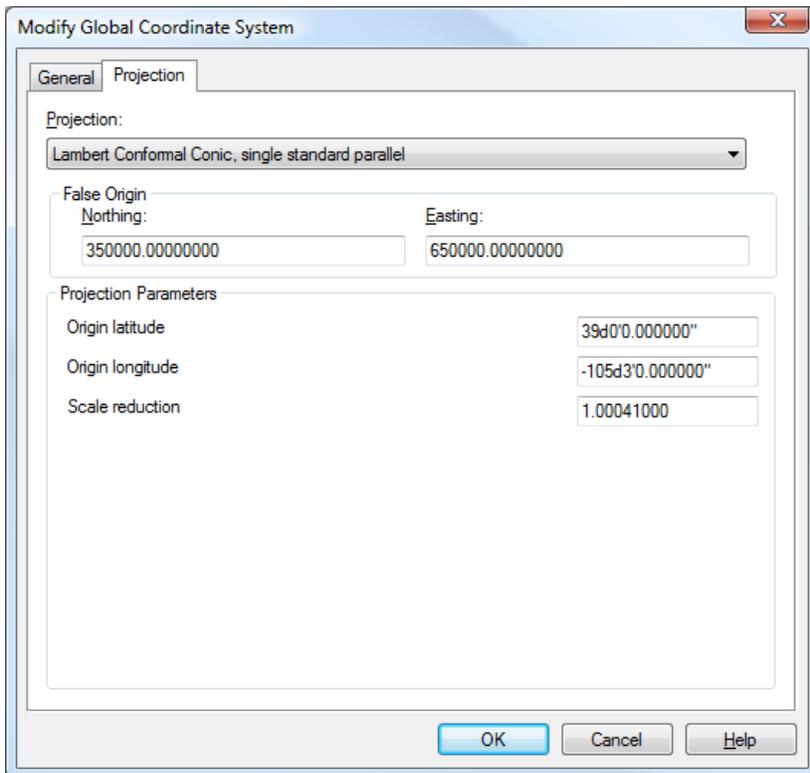
Projection

This is where we select our Projection Type. If our target area is roughly square, it doesn't matter much which projection we use. However, if our Project extends longer in one direction than another, we may wish to use the following guidelines:

Direction of longest extents	Projection Type
East-West	Lambert Conformal Conic, Single-Parallel
North-South	Transverse Mercator
Other directions	Oblique Mercator

False Origin

These are the coordinates at the Origin Latitude and Longitude. It is best to chose values that are distinctly different from each other, so that Northings and Eastings cannot be confused. It is also best to choose values that result in coordinates that cannot be confused with other standard coordinate systems in the region, such as the State Plane and UTM coordinates.

Origin Latitude and Longitude

The geodetic coordinates of the point used as the basis for our coordinate grid. The Origin Longitude is called the Central Meridian for some projection types.

Scale Reduction

This is where we enter our datum scale factor.

Transforming Coordinates in Civil 3D

To transform Coordinates in Civil 3D, we need to create a custom Point File Format, and use that Point File Format when importing or exporting Points. As the Points are imported or exported, they will be transformed between our drawing's Coordinate System and the Coordinate System specified in the Point File Format.
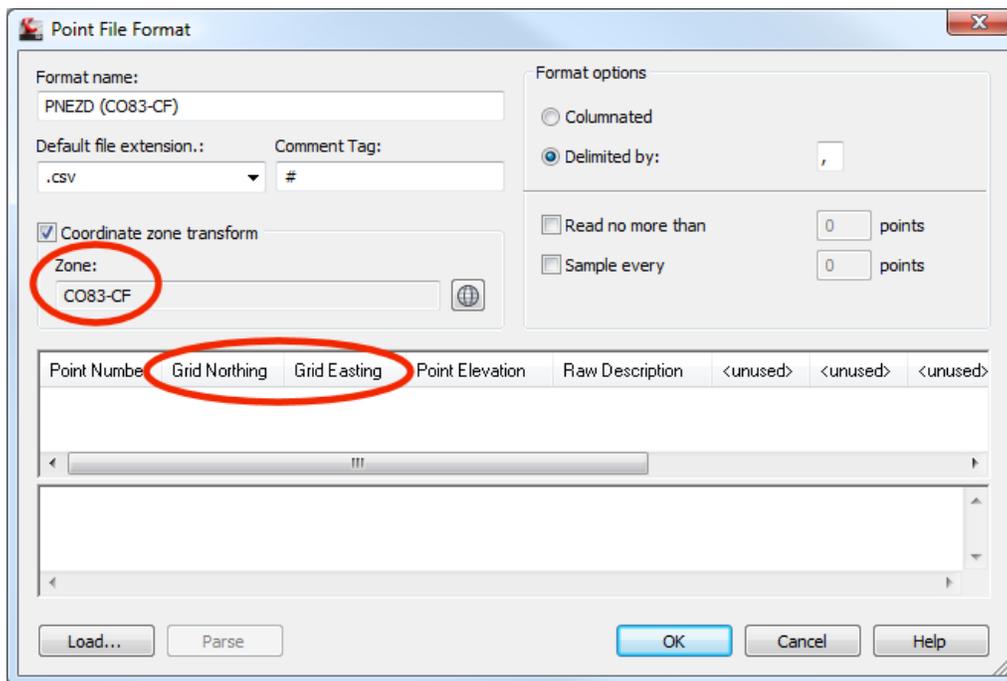
Note that in order to transform coordinates, we must also select "Grid Northing" and "Grid Easting" columns instead of "Northing" and "Easting". We also need to make sure the option to "Do coordinate transformation if possible" is selected.

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Linear Distortion

Maximum Projection Zone Width	Maximum Linear Horizontal Distortion		
	Parts per Million	Linear Distortion	Ratio
16 miles 26 km	1 ppm	0.005 ft/mi 1 mm/km	1 : 1,000,000
50 miles 80 km	10 ppm	0.05 ft/mi 10 mm/km	1 : 100,000
71 miles 114 km	20 ppm	0.1 ft/mi 20 mm/km	1 : 50,000
112 miles 180 km	50 ppm	0.3 ft/mi 50 mm/km	1 : 20,000
158 miles 254 km	100 ppm	0. 5 ft/mi 100 mm/km	1 : 10,000

Height Above and Below Projection Surface	Maximum Linear Horizontal Distortion		
	Parts per Million	Linear Distortion	Ratio
20 feet 6 meters	1 ppm	0.005 ft/mi 1 mm/km	1 : 1,000,000
210 feet 63 meters	10 ppm	0.05 ft/mi 10 mm/km	1 : 100,000
420 feet 127 meters	20 ppm	0.1 ft/mi 20 mm/km	1 : 50,000
1050 feet 319 meters	50 ppm	0.3 ft/mi 50 mm/km	1 : 20,000
2100 feet 637 meters	100 ppm	0. 5 ft/mi 100 mm/km	1 : 10,000
4200 feet 1.3 km	200 ppm	1.1 ft/mi 100 mm/km	1 : 5,000
7000 feet 2.1 km	300 ppm	1.8 ft/mi 100 mm/km	1 : 3,000

Additional Scale Reduction

Scale Factor k_r	Distortion	Approximate separation of standard parallels (Lambert)	Zone Width
0.999999	1 ppm	0° 10'	16 miles 26 km
0.999998	2 ppm	0° 14'	22 miles 36 km
0.99999	10 ppm	0° 31'	50 miles 80 km
0.9999	100 ppm	1° 37'	158 miles 254 km

Common Ellipsoids

Ellipsoid Name	Equatorial Axis	Polar Axis	Inverse Flattening
Clarke 1866	6,398,206.4 m	6,376,516.0 m	294.9786982
GRS 1980	6,378,137.0000 m	6,356,752.3141 m	298.257222101
WGS 1984	6,378,137.0000 m	6,356,752.3142 m	298.257223563

Average Ellipsoidal Radius in the US: 20,906,00 feet
6,372,000 meters

Formulae

R = Ellipsoidal Radius
h = Ellipsoidal Height
H = Orthometric Elevation
N = Geoidal Separation

k_t = Scale Factor for Tangent Projection
k_r = Additional Scale Reduction Factor
k_s = Scale Factor for Secant Projection
δ = Distortion

$$h = H + N$$
$$k_t = 1 + \frac{h}{R}$$
$$k_s = k_t \cdot k_r$$
$$\delta = k \cdot \frac{R}{R + h} - 1$$

Sample Metadata Statement

All distances and bearings shown hereon are grid values based on the following projection definition:

<u>Linear Unit</u>:	US Survey Foot
<u>Geodetic Datum</u>:	NAD83
<u>Vertical Datum</u>:	NAVD88
<u>Projection</u>:	Lambert Conic Conformal, single parallel
<u>Origin Latitude</u>:	N 39°00′
<u>Central Meridian Longitude</u>:	W 105°03′
<u>Scale Factor</u>:	1.000410 (exact)
<u>False Northing</u>:	350,000
<u>False Easting</u>:	650,000

This projection was defined such that grid distances are equivalent to "ground" distances over the project area.

The Basis of Bearings is geodetic north. Note that grid bearings shown hereon (or implied by grid coordinates) do not equal geodetic bearings due to meridian convergence.