

X-PAD Ultimate FAQ Series

Scaled State Plane Coordinates: Method #2

More FAQ's like this one are available here: [[X-PAD FAQ Series](#)]

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By: Mark Silver, ms@igage.com

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Note: X-PAD Version 4.6.015 or higher may be required to complete this procedure successfully and match the provided screen shots.

Thesis

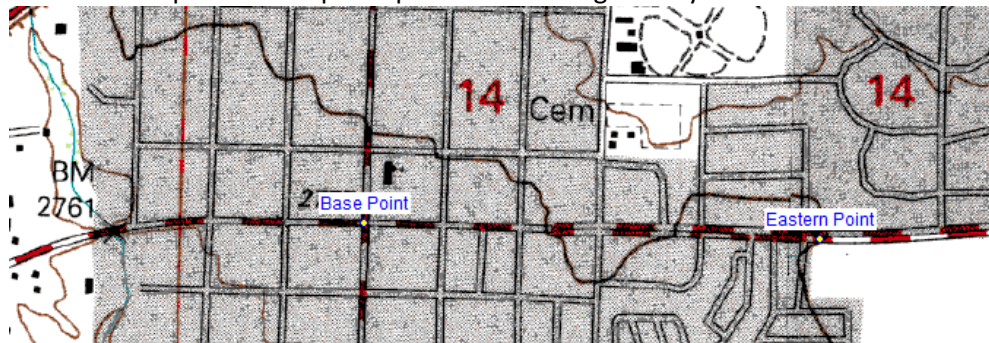
This FAQ shows how to replicate a State Plane Coordinate system brought to Ground, matching an SPC basis of bearings between two points. This is method #2 of a series of 3 methods.

This method is the preferred method as it balances distortion around the Base point by making the projected plane orthogonal to the plumb line at the Base point.

Method #2:

This method sets an Oblique Mercator projected surface at the center point and rotated to match State Plane Convergence. As you move from the center point, this method produces less distortion than scaling a SPC system from the SPC origin because the projected surface is orthogonal to the earth center vector at the Base point, instead of tilted back to the SPC zone center.

Let's work a full example for a couple of points in Washington City Utah:



Throughout this FAQ I will highlight coordinate values that we will need to complete the new projection.

Western Point, the Base Point:

Lat Lon Ellipsoid: 37 07 48.88043 N 113 30 35.44965 W NAD83 (1)
2786.820 Ft orthometric; 2706.895 (825.062 m) ellip (2)

UT South SPC (sFeet): 10,017,594.0413 Sft N 1,054,514.4670 Sft E UTS NAD83 (3)

We don't want to confuse future surveyors with coordinates that are nearly identical to SPC coordinates, lets choose coordinates that do not match the SPC coordinates by only using the 6 digits of the SPC coordinates:

Truncated Local Coord: 017,594.0413 Sft N 054,514.4670 Sft E (4)

However, because the leading digit is 0, our new coordinate system would have a negative Northing if we moved south more than 3.3 miles and a negative Easting if we move west more than 10.3 miles; so, let's just make the leading digits 5 and 3. This will also clearly distinguish the Northing values (which will start with 5) and Easting values (which will start with 3):

Adj Truncated Local Coord: 517,594.0413 Sft N 354,514.4670 Sft E (5)

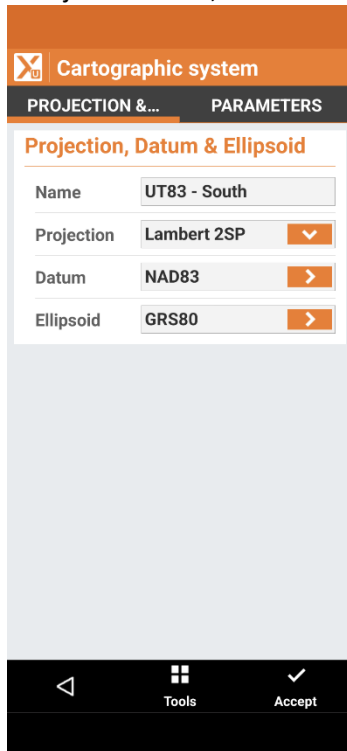
These will be the desired Northing and Easting coordinates for the Base Point in our new system. They are close enough 'looking' to the SPC coordinates to remind us and future surveyors where they were derived from.

Eastern Point:

Lat Lon Ellipsoid: 37 7 48.57847 N 113 30 0.41208 W NAD83 (6)
2804.71 Ft orthometric 2724.847 ellipsoid (7)

UT South SPC (sFeet): 10,017,502.6769 Sft N 1,057,350.6039 Sft E UTS NAD83

Make a new job in X-PAD, select the matching SPC coordinate system as the **Cartographic system**:



Then go to **JOB: Points** and enter the Base point as point #1 and the East point as point #2 by moving the WGS84 slider to ON and entering the Lat and Lon values:

Edit point [1]		Edit point [2]	
COORDIN...	PROPERTI...	COORDIN...	PROPERTI...
Point	1	Point	2
N	10017594.0416ft	N	10017502.6773ft
E	1054514.4670ft	E	1057350.6039ft
Z	2786.820ft	Z	2804.710ft
WGS84	<input checked="" type="checkbox"/>	WGS84	<input checked="" type="checkbox"/>
Geodetic coords	Latitude-Longitude	Geodetic coords	Latitude-Longitude
Latitude	N 37°07'48.880430"	Latitude	N 37°07'48.578470"
Longitude	W 113°30'35.449650"	Longitude	W 113°30'00.412080"
Height	2706.895ft	Height	2724.847ft

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Go to **COGO: Quick distance** and inverse from point 1 to point 2:

Quick distance	
Point 1	1
Point 2	2
From first point	Extended
Distance unit: Feet (US)	
1 - 2	
Distance (Grid) 2D	2837.608ft
3D	2837.664ft
Height diff.	17.890ft
Bearing	S 88°09'17.607960" E
Slope	0.63%
ΔN	-91.3643ft
ΔE	2836.1369ft

Make a note of the **2D Grid distance** and the **Grid bearing**:

2837.608 sft (GRID)

S 88 09 17.6037 E

(8)

Projection Goal

After we build our new projected system, we will be successful if the projected coordinates for the Base Point Lat/Lon match (5) and the inverse from the West Base point to the East point is the Ground Distance (slightly longer than the Grid distance) at the bearing shown in (8).

Compute an elevation scale factor (ellipsoidal reduction) for the Base Point

You could use an approximation, but it will be best to compute the elevation scale factor using this equation for the earth radius at a latitude:

$$r = \frac{a\sqrt{1-e^2}}{1-e^2 \sin^2 \phi} \quad \text{where, for GRS 1980 (and NAD83);}$$

a = semi-major axis (radius of equator) = 6,378,137.000 m

e² = eccentricity squared = 0.00669438002290.

φ = geodetic latitude.

(9)

The easiest way is to use my 'Ellipsoid Reduction' tool which you can obtain here:

<https://iggps.com/out/utilities/EllipsoidalReduction/index.htm>

Enter the Latitude and Ellipsoid Elevation of the Base point:

Radius at 37 6 48.88046 N = 6,372,283.754,6 meters

(10)

The tool also computes the elevation scale factor at 825.062 m (ellipsoid height), which is what we really want:

Elevation Grid to Ground SF: 1.000,129,476,657

(11)

This will be the scale for our new custom projection.

Note: this is NOT a Combined Scale Factor for the State Plane projection. It is the ellipsoid reduction factor and would need to be combined with the grid scale factor at the Base point to get the CSF.

A new Cartographic system in X-PAD

Return to the Cartographic system and change the Name to 'WashingtonCity' and the Projection to 'Hotine Oblique Mercator':

Cartographic system		Cartographic system	
PROJECTION &...	PARAMETERS	PROJECTION &...	PARAMETERS
Projection, Datum & Ellipsoid		Projection parameters	
Name	WashingtonCity	Origin Lat	N 37°07'48.880043"
Projection	Hotine Oblique Me	Origin Lon.	W 113°30'35.449650"
Datum	NAD83	False East	0.0000ft
Ellipsoid	GRS80	False North	0.0000ft
		Scale	1.000129477
		Azimuth	S 0°00'00.000000"
		Rect.grid angle	S 0°00'00.000000"
			

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On the **PARAMETERS** tab, set the **Origin Lat** to the Latitude of our Base point, set the **Origin Lon** to the Longitude of our Base point and set the **Scale** to the ellipsoid elevation scale factor. For now, set the **False Easting** and **False Northing** to 0 and both the **Azimuths** to 0.0 degrees.

Click on **Accept** to save the new projection. X-PAD will recompute the projected coordinates for point 1 and point 2 based on this new, temporary projection.

You could look at them if you want to verify that 'something' happened:

Edit point [1]		Edit point [2]	
COORDIN...	PROPERTI...	COORDIN...	PROPERTI...
Point	1	Point	2
N	13528567.7069ft	N	13528537.3079ft
E	0.0000ft	E	2837.7674ft
Z	2786.820ft	Z	2804.710ft
WGS84 <input type="checkbox"/>		WGS84 <input type="checkbox"/>	
Geodetic coords: Latitude-Longitude		Geodetic coords: Latitude-Longitude	
Latitude	N 37°07'48.880430"	Latitude	N 37°07'48.578470"
Longitude	W 113°30'35.449650"	Longitude	W 113°30'00.412080"
Height	2706.895ft	Height	2724.847ft

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However, we need to configure the projection azimuth before we make use of the coordinates. Go to the COGO: Quick Distance screen and compute the inverse from point 1 to point 2:

Quick distance	
Point 1	1
Point 2	2
From first point	Extended
Distance unit: Feet (US)	
1 - 2	
Distance (Grid) 2D	2837.930ft
3D	2837.987ft
Height diff.	17.890ft
Bearing	S 89°23'1 0.517634" E
Slope	0.63%
ΔN	-30.3990ft
ΔE	2837.7674ft

Note: the 2D distance is a valid Ground distance now.

The displayed Bearing:

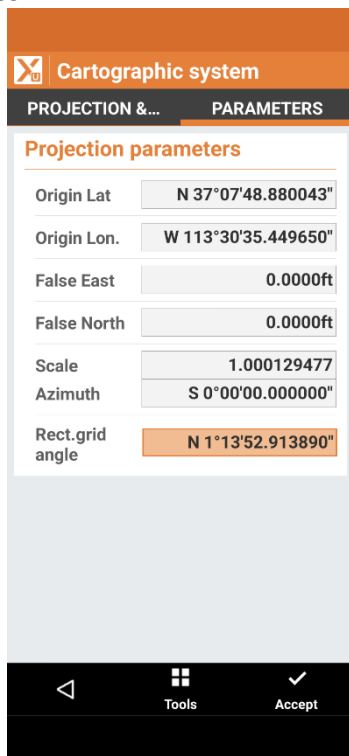
Bearing **S 89 23 10.517634 E** (12)

Is the Geodetic North bearing from Point 1 to Point 2. We need to compute the rotation required to match the state plane bearing:

TN	S 89 23 10.517634 E	89.38625489 SE (D.d Bearing)	(13)
Want	S 88 09 17.603700 E	88.15488992 SE (D.d Bearing)	(14)
Delta		1.231364970 (D.d)	(15)
		01 13 52.91389 (D M S.s)	(16)

*Note: it is a **positive** rotation angle from S 89.4 E to S 88.2 E. Also note that this TN to Projected bearing is not the SPC convergence at the Base point.*

Return to the **Coordinate System: Cartographic system** and set the **Rectangular grid angle** to 01 13 52.91389:



Return to the Points list and note the Northing and Easting of Point 1:

The screenshot shows the 'Edit point [1]' screen with the following data:

COORDIN...	PROPERTI...	SKET
Point	1	
N	13525443.5457ft	
E	290725.1137ft	
Z	2786.820ft	
WGS84	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Geodetic coords	Latitude-Longitude	
Latitude	N 37°07'48.880430"	
Longitude	W 113°30'35.449650"	
Height	2706.895ft	

Navigation buttons at the bottom: Prev, Next, Accept.

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Current 13,525,443.5457 N 290,725.1137 E (17)

Subtract the current coordinates (17) from the desired coordinates (5) to compute the False Northing and Easting (18):

Want	517,594.0413 N	354,514.4670 E	(5)
- Current	13,525,443.5457 N	290,725.1137 E	(17)
= False	-13,007,849.5044 N	+63,789.3533 E	(18)

Return to the 'Cartographic system: PARAMETERS' screen and enter the False Northing and Easting (18):

Cartographic system

PROJECTION &... PARAMETERS

Projection parameters

Origin Lat	N 37°07'48.880043"
Origin Lon.	W 113°30'35.449650"
False East	63789.3533ft
False North	-13007849.5044ft
Scale	1.000129477
Azimuth	S 0°00'00.000000"
Rect.grid angle	N 1°13'52.913890"

Tools Accept



Return to the Point list and verify that Point 1 has the correct Northing and Easting:

Edit point [1]

COORDIN... PROPERTI... SKET...

Point	1
N	517594.0413ft
E	354514.4670ft
Z	2786.820ft

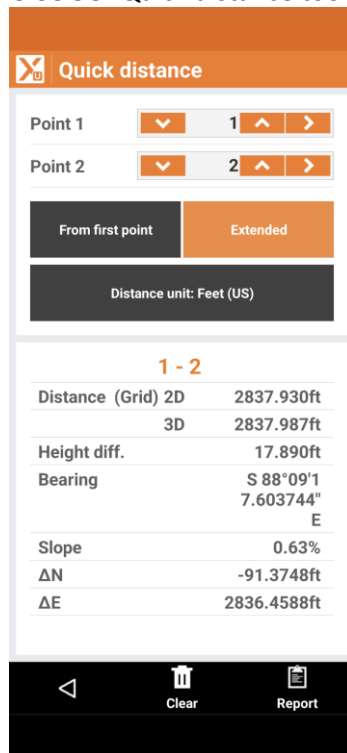
WGS84

Geodetic coords: Latitude-Longitude

Latitude	N 37°07'48.880430"
Longitude	W 113°30'35.449650"
Height	2706.895ft

Prev Next Accept

Go to the COGO: Quick distance tool and compute an inverse between point 1 and point 2:



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If the system is correct, the distance will be the Ground distance (scaled for the Base point) and the bearing will match the SPC grid bearing:

S 88 09 17.6037 E (8)

Success!

Save your work!

Immediately after verifying that the system is correct, return to 'Coordinate System' menu, click on **Tools**, then click on **Save as predefined** to add this coordinate system the 'predefined coordinate system' list.