Getting Control of the Project:

Improving model-based layout using survey control

Shannon Lightfoot – McCarthy Building Companies, Inc.
Zach Crumal - Autodesk®
Shayne Hamel - Autodesk®
William Palmgren – TOPCON Positioning Systems, Inc.

CR3095-L Establishing control on the jobsite is essential for doing layout with a total station. Without control points, the BIM data can't be referenced to the physical jobsite. Control can be established many different ways. The object is to establish the most accurate control that you can to ensure efficient multi-trade model-based layout. This hands-on lab highlights the new features of the Autodesk® Point Layout® plug-in for improving survey control workflows within Autodesk® AutoCAD®, Autodesk® Revit®, and Autodesk® Navisworks® Manage software.

Learning Objectives

At the end of this class, you will be able to:

- Distinguish between State Plane and Project coordinate systems
- Set up a project for aligning coordinate systems between multiple-trade BIM models
- Create and align to a shared coordinate system in AutoCAD and Revit-based software
- Establish survey control for an improved model-based layout workflow

About the Speakers

Shannon Lightfoot is responsible for management and implementation of McCarthy's VDC initiatives within the Central Division. This includes establishing VDC project strategy, training field personnel, monitoring BIM project execution, providing support for BIM process improvements, and performing research and development on new BIM technology. His main focus is to help project staff gain efficiency, improve quality, and increase productivity using BIM technology.

Zach Crumal currently works for Autodesk as a Product Support Specialist for Autodesk Point Layout. Formerly with Get The Point (GTP), Zach worked as Lead Sales/Support/Training for Construction and MEP firms across the country. He has worked as a BIM Specialist for Saunders Construction in Colorado and currently lives in Denver. He has his B.A in Architecture from the University of Colorado at Boulder.

Shayne Hamel currently works for Autodesk as a Principal Software engineer on the Autodesk Point Layout team. Formerly a founding member of Get The Point (GTP), Shayne designed and developed what is now known as Autodesk Point Layout into the construction layout management and analysis package used by many of the leading construction companies today. Prior to starting GTP, Shayne worked for over a decade in the HVAC and Mechanical estimating software industry. He received his B.S. from the University of Oregon and continues to reside in Eugene.

William Palmgren currently works as a BIM Professional Services Manager for TOPCON Positioning Systems, Inc. He works with new product research and development, workflows, equipment design, testing, training, and technical support. William has over 20 years of experience in the commercial and semiconductor construction industry starting with hand detailing and layout to 3D modeling, BIM Manager and Project Manager. He has always strived to leverage technology to improve BIM to Field through design, fabrication and installation practices. He has had success doing this through use of multiple Autodesk products and 3rd party applications, Total Stations and 3D Scanning equipment.

Establishing Control on the job site is essential for doing layout with a Total Station, without control points we can't reference the BIM/CAD Model information to the physical job site. Control can be established on a job site many different ways. The object is to establish the most accurate control that you can depending on the field or job site conditions.

The basic principle of control is finding at least two matching points in Building Information Model (BIM) that you can find in the field. Two points is the minimum the total station requires to function but having three or more control points gives us more control because you can check angles and distance.

Control can be set on the jobsite before we get there by a surveyor and the coordinates given to us in many different ways. We can receive the information on a PDF, CAD file, or a list of coordinates but they are generally some sort of offset from the structure or the survey monument locations for the site. That information needs to be placed in our BIM/CAD model so we can line up our points to layout with the control out on the jobsite. If the site has no control we can make our own by laying out offset points from structure and matching them to the CAD model. For example, 4'x4' offsets from Column A1, H1, A10 and H10 that we layout out in the field the old school way with string and tape then place the same offsets in the CAD Model. Matching points in CAD that we can find in the Field.

Getting Control or Gaining Control on a jobsite is the act of checking all the control points necessary to continue your work. Never trust that control points are accurate unless you checked them yourself. Anybody can make a mistake and not checking control before you use it is a huge mistake. When we

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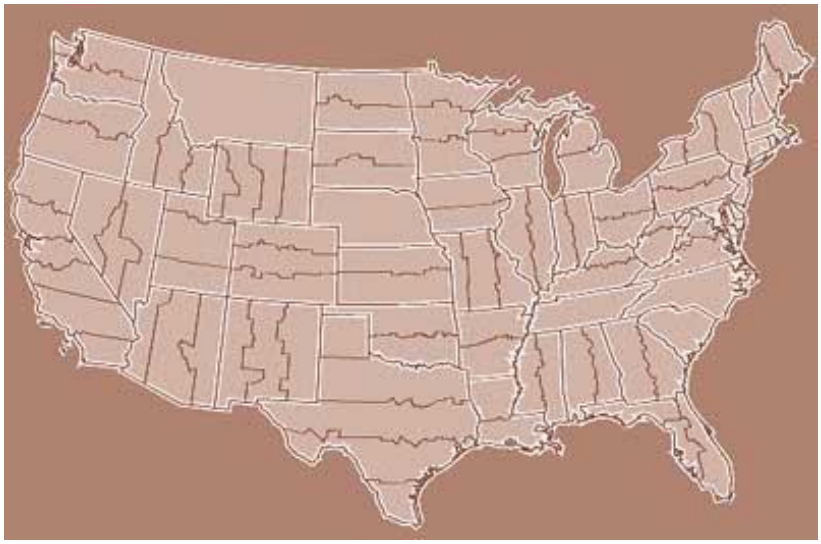
check control we are looking for a deviation or error from what the Cad file says and what the total station is actually measuring. These errors can come from the CAD file, the equipment or the actual points in the field not being placed properly. We need to verify all these possibilities before we blame anyone else or question the accuracy of the control. If it says control point at A1 is 200' from control point H10 then when we measure it with the total station we should get the same reading. We will normally see a deviation or a difference from the CAD dimension to the total station measurement. This deviation tells us how accurate the control is. A deviation of zero is optimal but normal real world conditions leave us with about a 3/16" deviation. Once we see up to a 1/4" and on to a 1/2" deviation or more, this is where we need to start looking for why these are not more accurate. The larger the deviation the less accurate the layout will be. Distance between two points is one check, we also need to check the angular accuracy between points. If the CAD file says that between control points A1, A10 and H1 is a 90deg angle we need to make sure that is the case in the field. Angles are more critical to accurate layout then just the distance measurement.

Coordinate Systems

First we will review a few different types of land survey control. It is important to understand how this concept works because most of the information regarding control on a new site will be from a surveyor. There are really only a few ways land survey is done these days the first is by using the State Plane Coordinate system another less used system would be the Universal Mercator coordinate system and then finally sometimes the survey coordinates are started from something like Northing 5000', Easting 5000' to avoid any negative numbers. For the purposes of this class we will only focus on the more widely used State Plane Coordinate System.

The **State Plane Coordinate System** (SPS or SPCS) is a set of 124 geographic zones or coordinate systems designed for specific regions of the United States. Each state contains one or more state plane zones, the boundaries of which usually follow county lines .There are 110 zones in the continental US, with 10 more in Alaska, 5 in Hawaii, and one for Puerto Rico and US Virgin Islands. The system is widely used for geographic data by state and local governments. Its popularity is due to at least two factors. First, it uses a simple Cartesian coordinate system to specify locations rather than a more complex spherical coordinate system (the geographic coordinate system of latitude and longitude). By thus ignoring the curvature of the Earth, "plane surveying"



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methods can be used, speeding up and simplifying calculations. Second, the system is highly accurate within each zone (error less than 1:10,000). Outside specific state plane zone accuracy rapidly declines, thus the system is not useful for regional or national mapping.

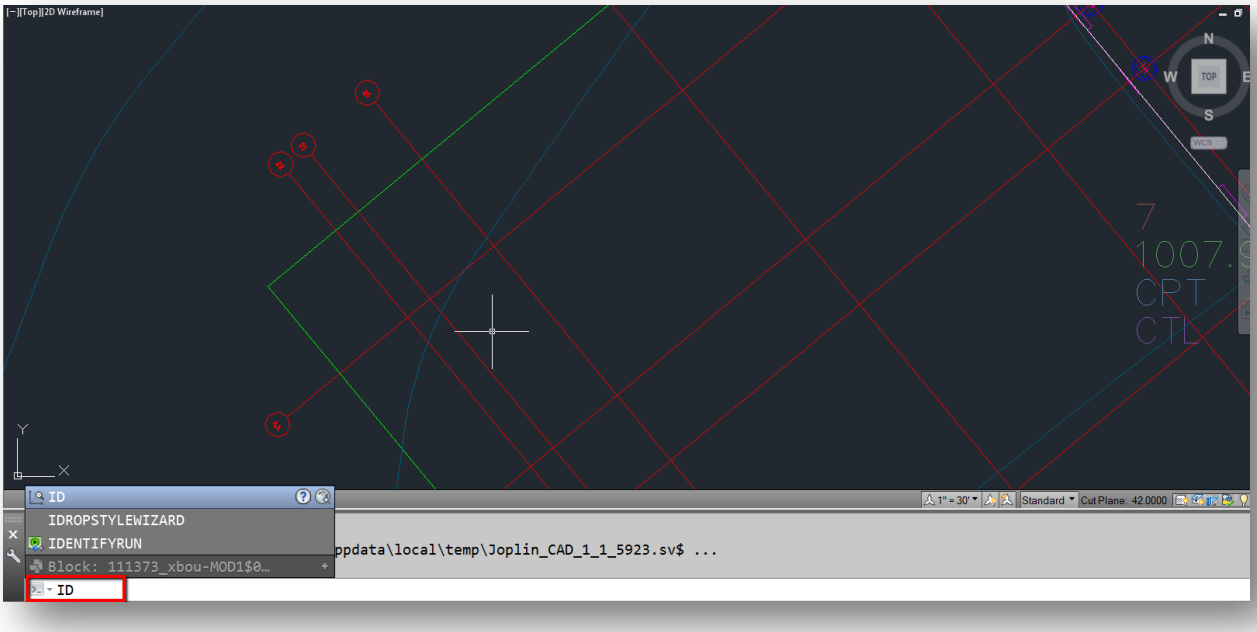
Originally, the state plane coordinate systems were based on the North American Datum of 1927 (NAD27). Later, the more accurate North American Datum of 1983 (NAD83) became the standard (a geodetic datum is the way a coordinate system is linked to the physical Earth). More recently there has been an effort to increase the accuracy of the NAD83 datum using technology that was not available in 1983. These efforts are known as "High Accuracy Reference Network" (HARN) or "High Precision GPS Network" (HPGN). In addition, the basic unit of distance used is sometimes feet and sometimes meters. Thus a fully described coordinate system often looks something like: "Washington State Plane North, NAD83 HARN, US Survey feet". This information is needed in order to accurately transform data from one coordinate system to another.

Section 1: Project Setup and Coordinate System Management

1. The first thing we will do is identify the Coordinate System within the model, whether you are working with an AutoCAD file, a Survey File (TXT/CSV), or a Revit file.

   In AutoCAD

   a. Enter “ID” in command line and hit Enter



   b. Select any location (Grid Intersection, etc.) in the project

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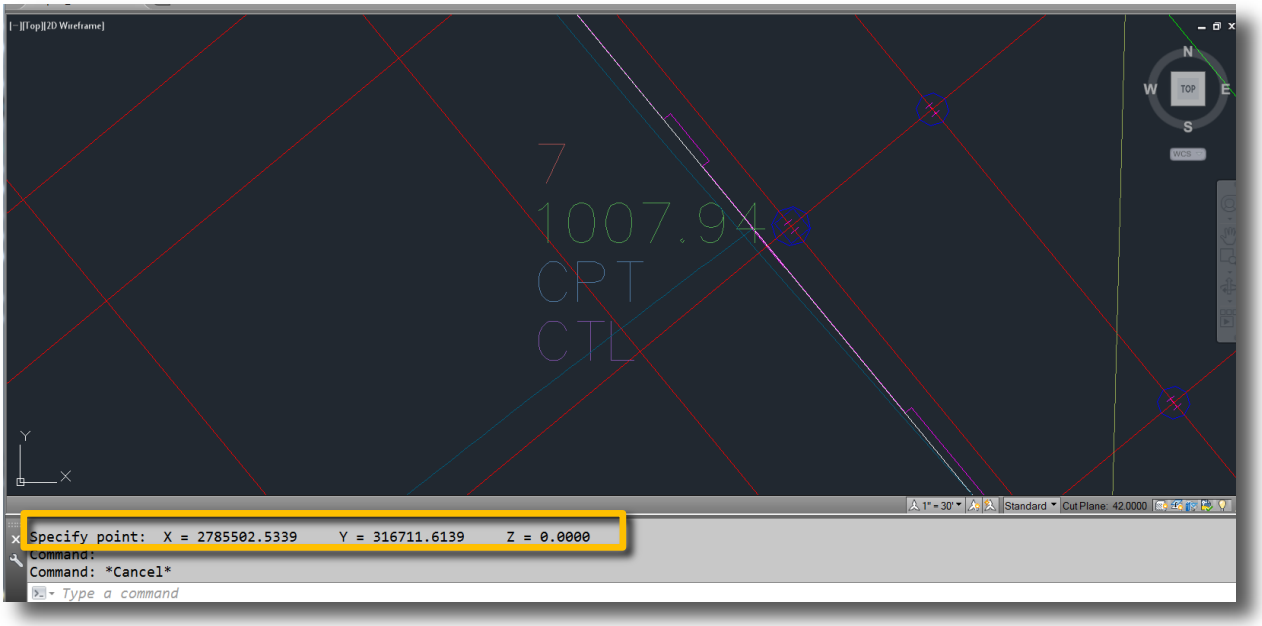
b. Identify the drawing coordinates (X=, Y=, Z=) of the project located in the bottom toolbar.



In your Survey File (TXT/CSV)

a. Observe the column headings to identify the coordinate format (i.e. NEH / YXZ vs. ENH/XYZ – Point Order)

	A	B	C	D	E	F
1	POINT NU	Y	X	Z	DESCRIPTION	
2	1	-1462.98	461.4858	1013.16	CP	
3	2	-1109.15	-529.791	962.92	CP	
4	3	166.9079	-808.875	998.11	CP	
5	4	1039.877	244.6252	993.17	CP	
6	5	-515.916	1181.687	1008.38	CP	
7	6	-230.412	-271.096	1007.54	CP	
8	7	-308.057	-240.251	1007.94	CP	
9	8	-225.494	236.3619	1022.9	CP	
10	9	107.8808	-193.201	1008.53	CP	

Note: NEH refers to (Northing, Easting, Height)

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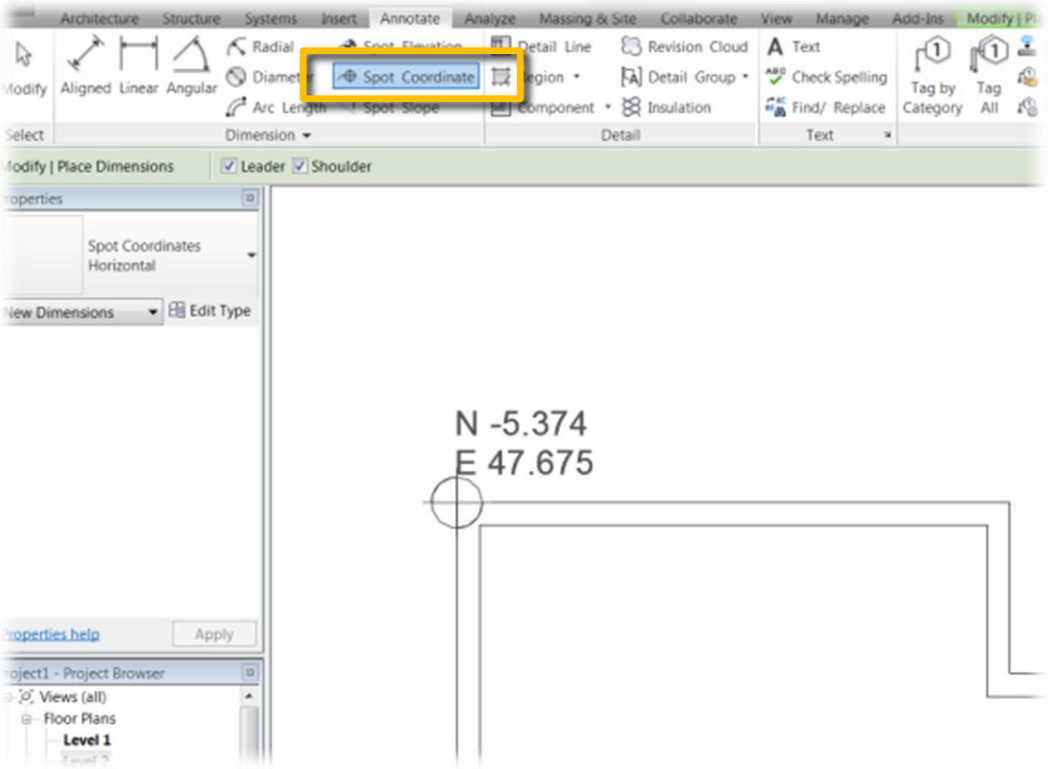
In Revit

a. Click on the “Spot Coordinate” tool.
b. Hover your cursor over an element to get identify what coordinate system is in use. (State Plane vs. Project - Coordinate System)



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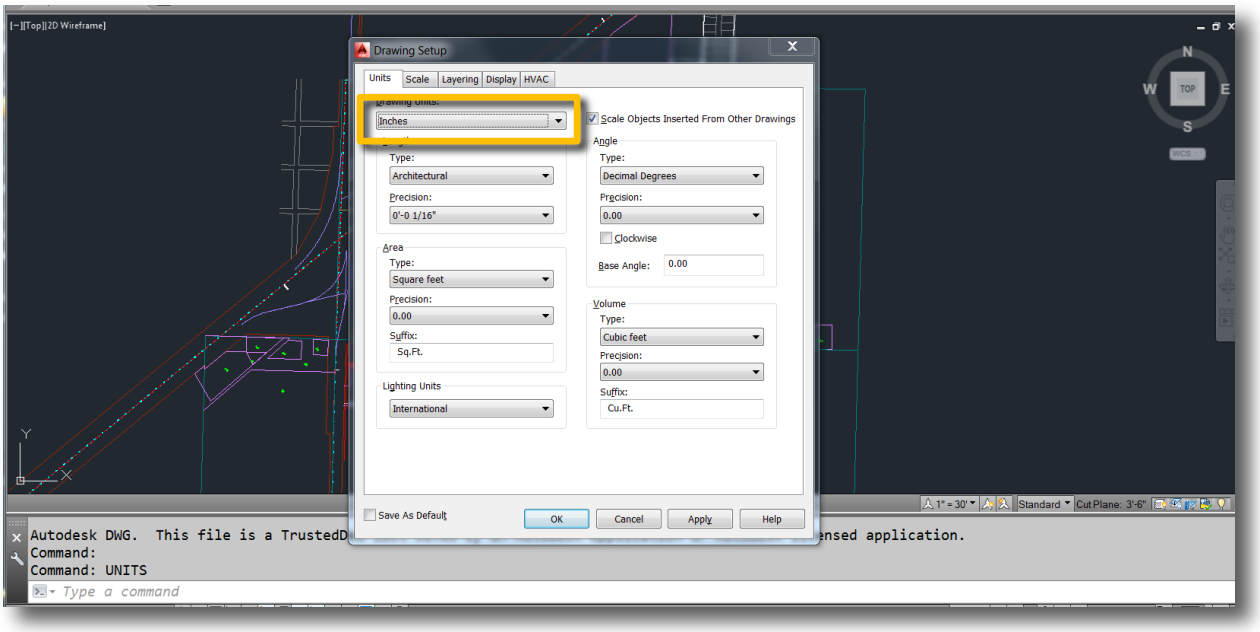
2. The next steps will go through managing the coordinate system.

   a. Access the project units by entering “Units” in the command line.

   b. Notice that the Drawing Units are in Inches, click the drop-down arrow and select Decimal Feet.

   Note: Drawing Units will need to match the actual survey file units. For the purposes of this demonstration we will use Decimal Feet.



   c. Change Drawing Units to Decimal Feet.

   d. Select “OK”.

   e. Once you have changed the drawing units, a dialog both will appear, select “Don’t rescale any existing objects”

   Note: **Caution - Precision can be lost by rescaling objects. This is not recommended.**

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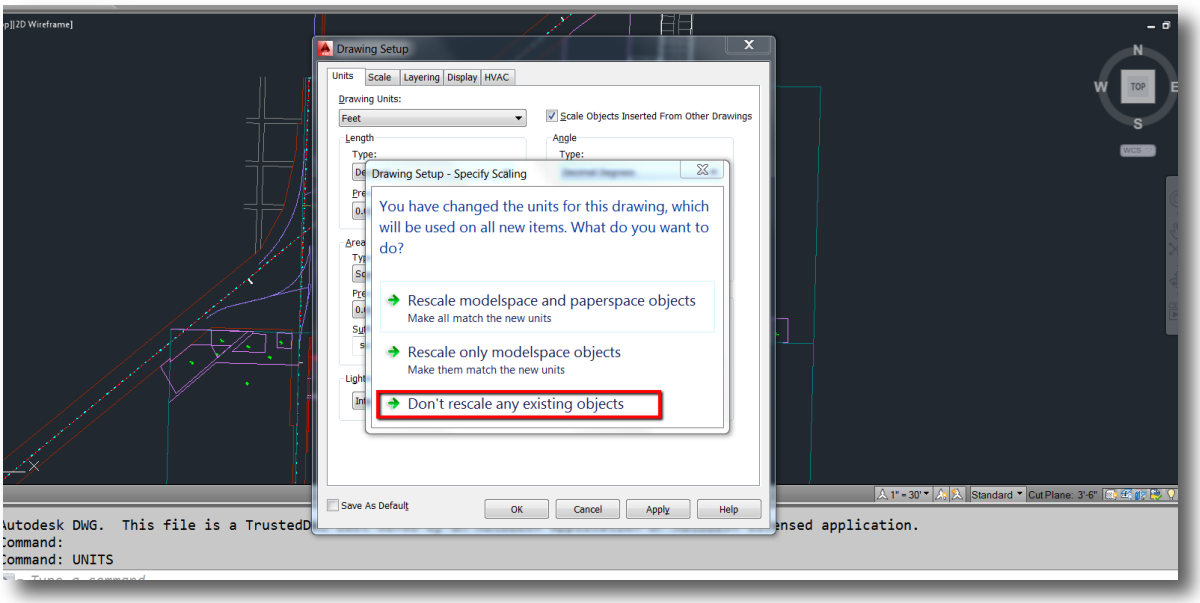
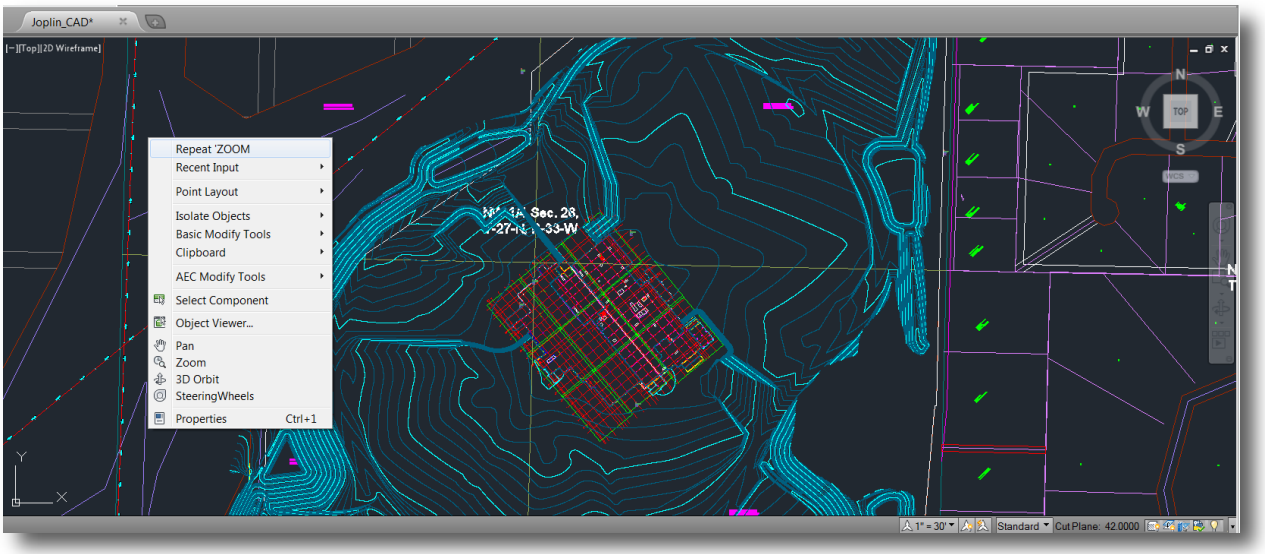


3. The next steps will take you through how to use the Autodesk Point Layout tools.

   To access the Autodesk® Point Layout tools in AutoCAD/Civil 3D simply Right-click (Context click) in model space



   a. There are a couple ways to import points with Autodesk® Point Layout

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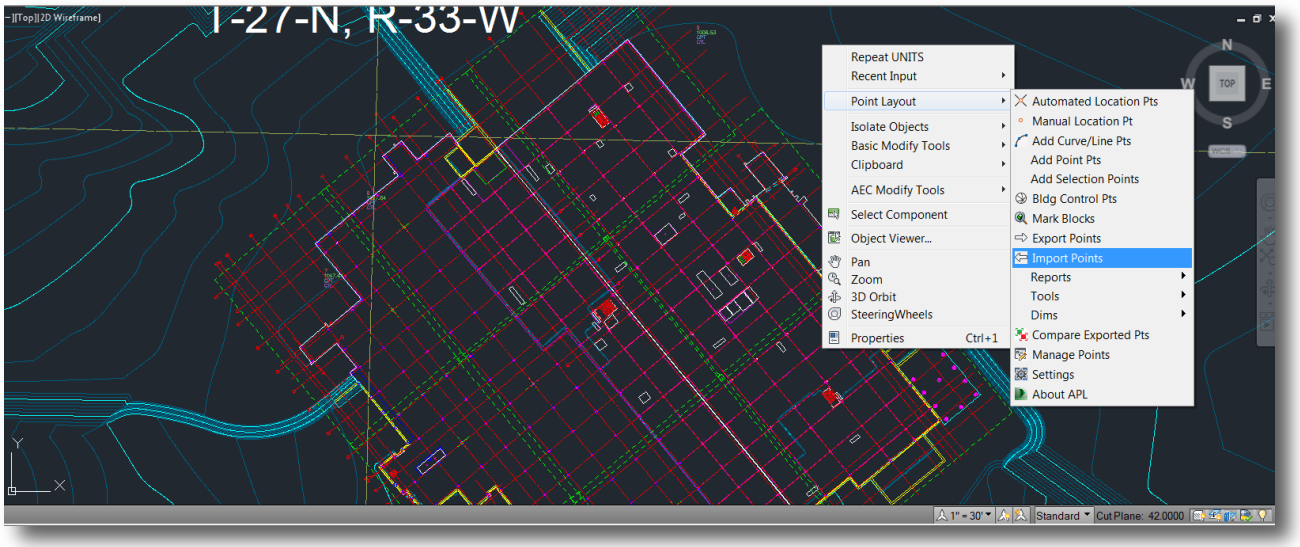
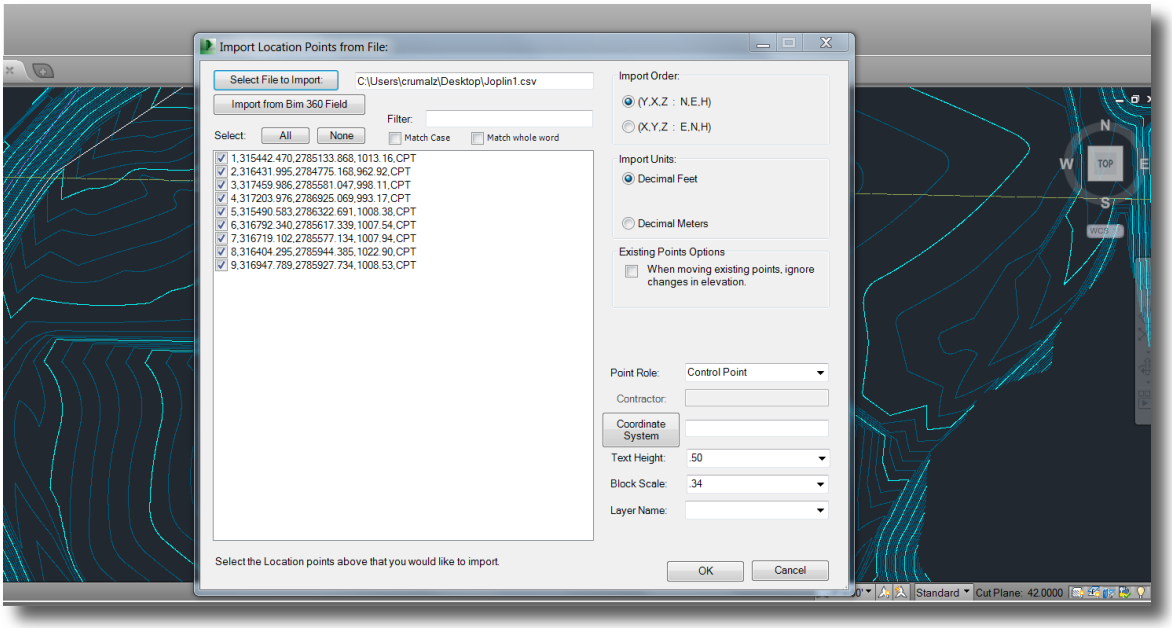


Option 1: Import from Survey File

- Select “Import Points” from the context menu
- In the dialog box, click the “Select File to Import” button
- Select the Survey File to import points from.

Note: Make sure the point information is correct (order, units, coordinate system)



Option 2: Import from BIM 360 Field

- Select “Import Points” from the context menu
- In the dialog box, click the “Import from BIM 360 Field” button
- Enter your username/password

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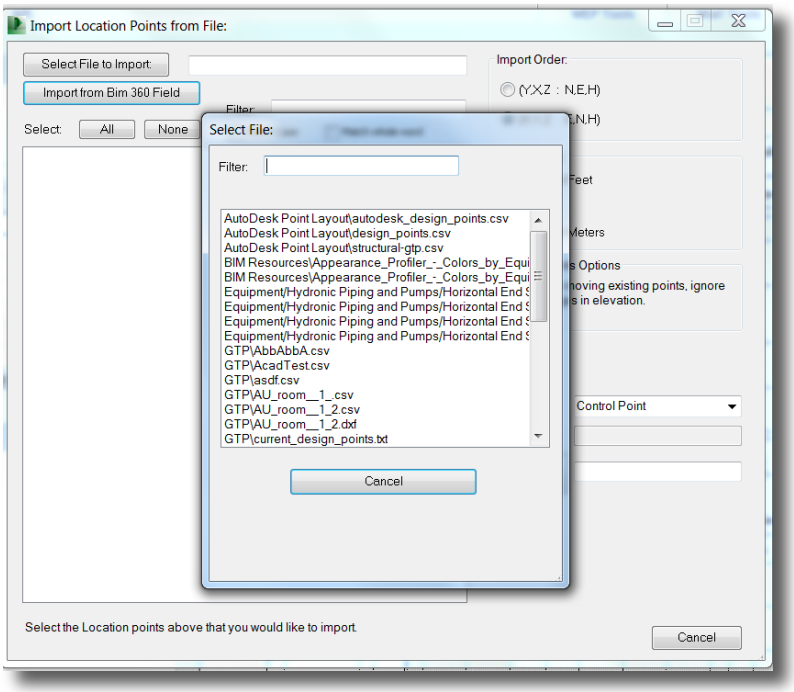
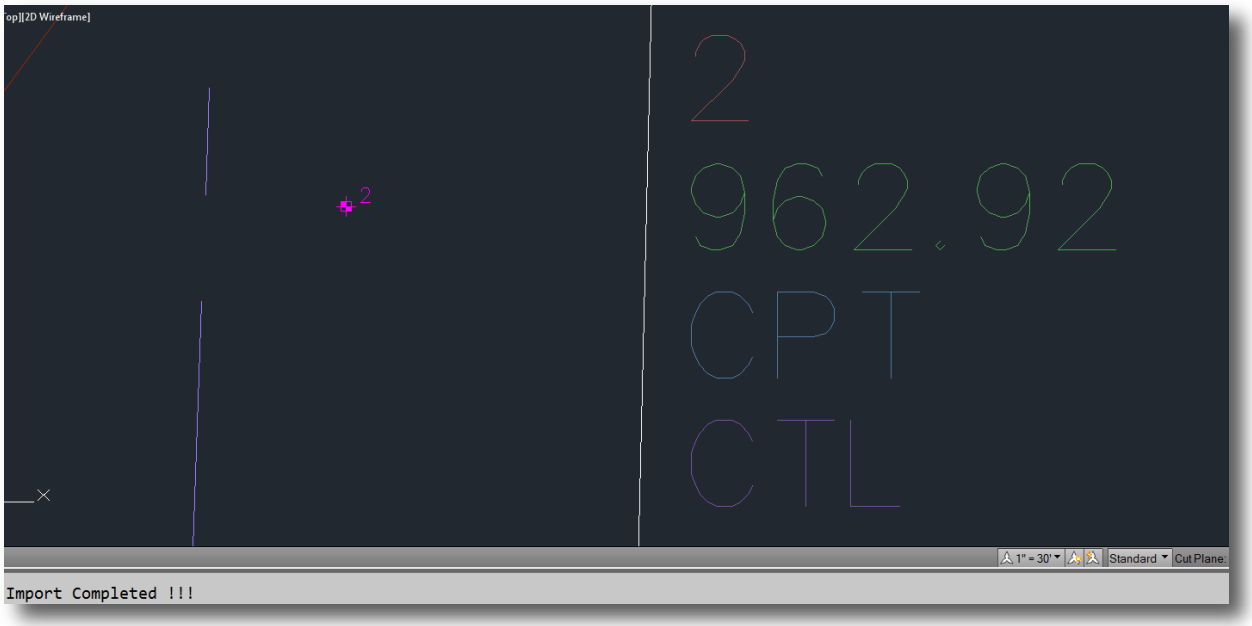
- Select Project and the appropriate Library, Task or Issue



Note: Upon import, you will have the option to select different point import types as shown below.

b. Once you've selected your point type, your import is complete!



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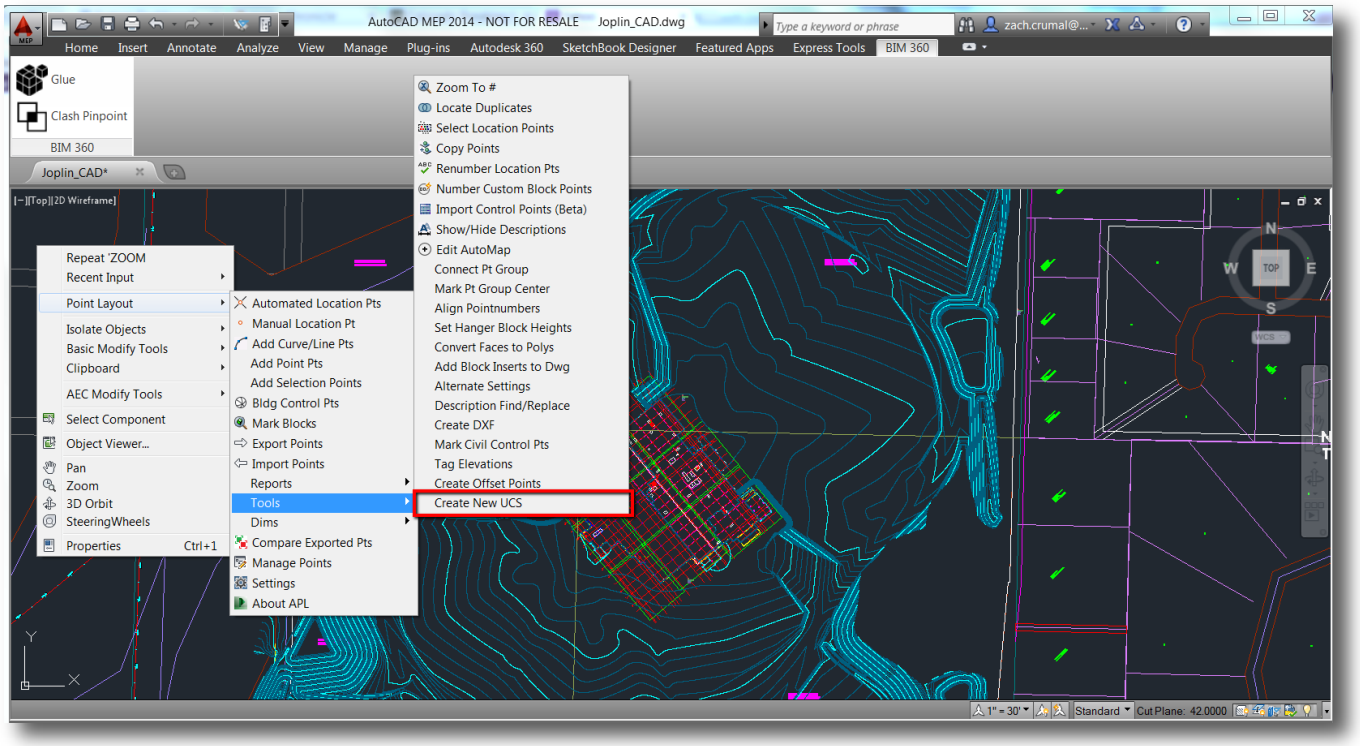
Section 2: Creating a shared coordinate system

This next section will explain how to create a shared coordinate system in AutoCAD and Revit, that all team members can use to maintain alignment between the model and real world field coordinates.

AutoCAD

1. Right-click to access Autodesk® Point Layout
2. Select “Tools” > “Create New UCS”



3. Select two (2) location points (Control point or grid offset). Prefer Building Control - Grid Intersection or Offset from grid. When establishing site control establish building control!

4. Enter the XYZ value for those two point locations (New Coordinates - ex. 5000, 5000, 0, State Plane)

5. Save off new UCS Coordinate System for future use.

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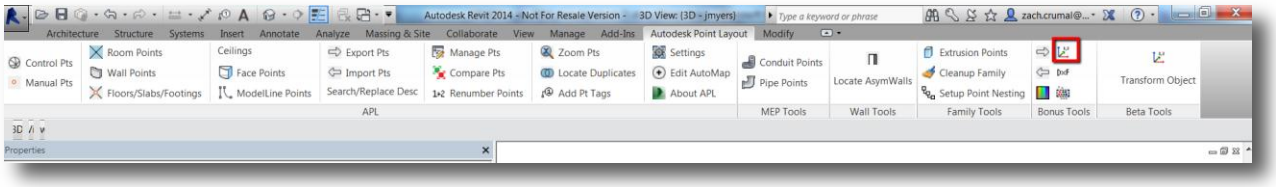
Revit

1. In the toolbar select the Autodesk® Point Layout tab.

2. In the “Bonus Tools” section, select the “Create Coordinate System” icon. This will allow you to create a Coordinate System to match from known control points.



3. Enter two (2) point locations matching the AutoCAD locations (the respective XYZ/NEH coordinates)

Note: If your points don’t match (Difference in lengths), then there is a units discrepancy or incorrect locations were matched.

A dialog box will appear prompting you to select Workplane or Element

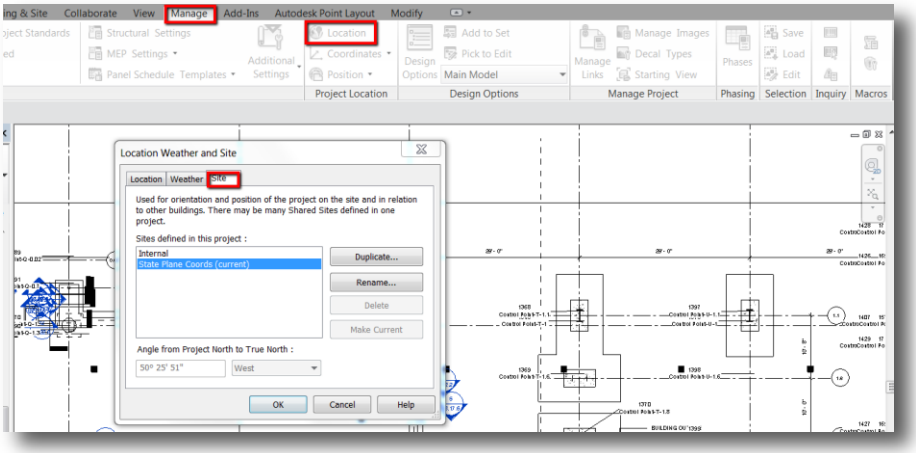
4. Select “Workplane”
   This will snap your points to the current Workplane.

5. Save off New Coordinate System for future use during import/export

To make sure your new coordinate system is now in the project:

1. Click on the Manage tab
2. In the Project Location section, select Location.
3. In the dialog box, click the Site tab: This shows all coordinate systems in the project

Note: *Internal* is the Default Shared Coordinate System. Select the new coordinate system and click the “Make Current” button to change it to the default coordinate system.



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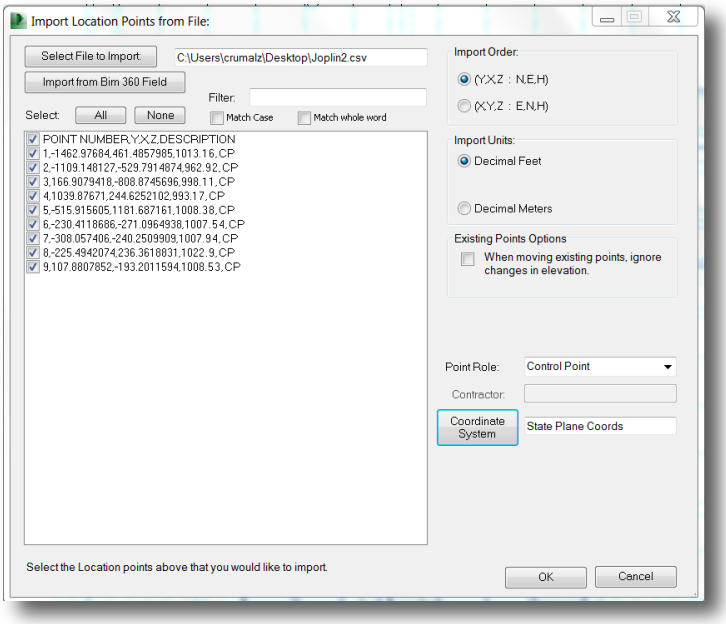

Import 'CAD' control with New Coordinate System in Revit using Autodesk® Point Layout

Section 3: Creating Building Control Points

Now that you have your site control established, this section will explain how to create/add points to your model.

AutoCAD

1. Right-click for Autodesk® Point Layout (APL)
3. Select the "Building Control Points" tool
4. Add points to existing grid Intersections or offsets

Note: Isolate all grids lines and explode if necessary (may be necessary if grid lines are in an xref'd file)

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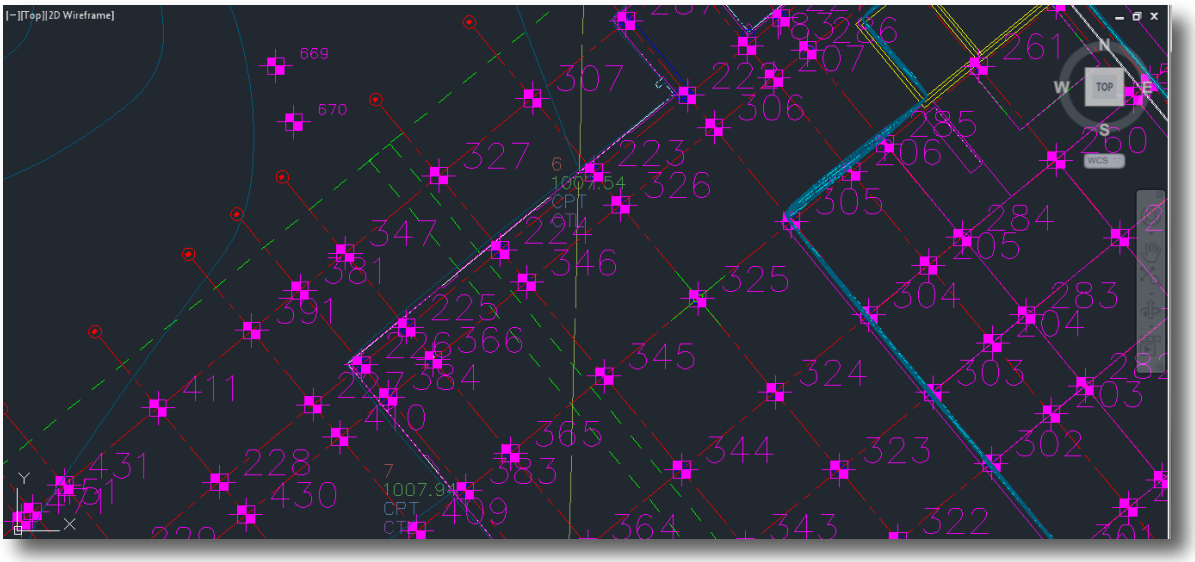
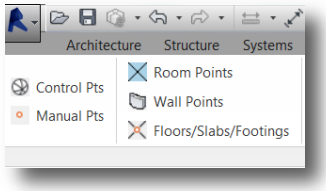
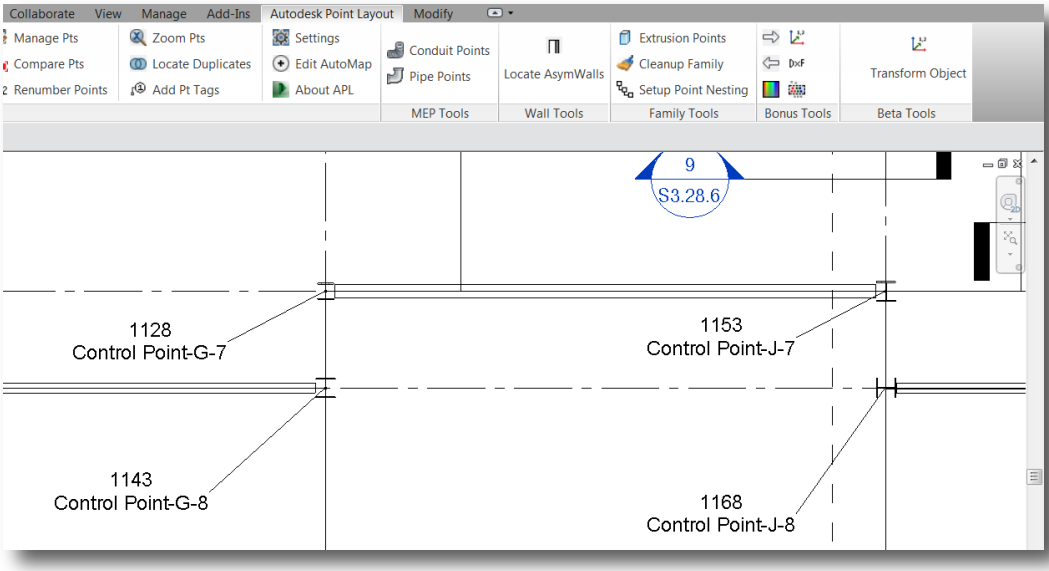


Revit

1. Click the APL tab.
2. Select the “Control Points” Tool



3. Select all grids lines intersections or offsets you want to place points on.
4. Click “Finish”



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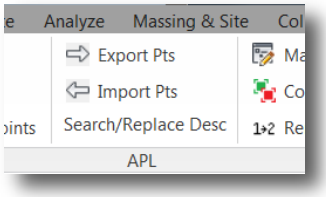
Section 3: BIM 360 Field Integration

In this section you will learn, how BIM 360 Field integrates with Autodesk Point Layout, and how to import and compare points taken from the Total Station in the field to your model.

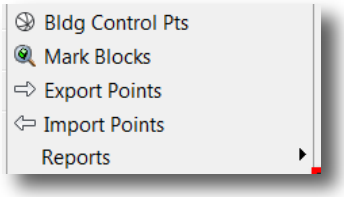
One of the most valuable features about APL is the ability to compare as-built point to points in the model and add them to BIM 360 Field as issues for QA/QC.

The workflow in both AutoCAD and Revit are very similar:

1. Select the APL tool
2. Select “Import Points”



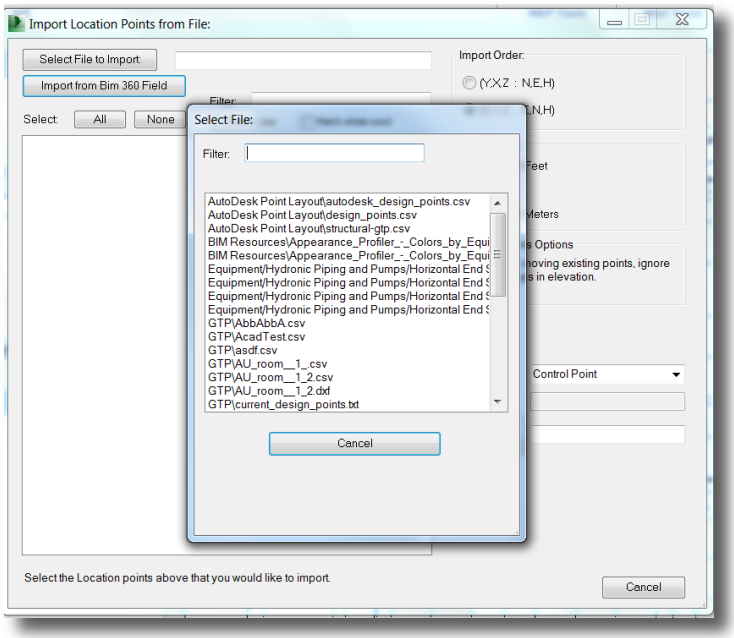
Revit



AutoCAD

Note: Import / Export control point files (.csv) to BIM 360 Field as Tasks

3. Enter username/password when prompted.
4. Select Project and the appropriate Library, Task or Issue



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Savings for GC's & Subcontractors

As previously discussed, establishing control on the jobsite is essential for performing model-based layout functions with a total station. Without accurate control points, the BIM/CAD data cannot be referenced to the physical jobsite. It is in the General Contractors best interest to Control the job site control. The entire point of using total stations for Layout is to improve accuracy and schedule by increasing productivity. With today's technology there is more risk and liability when you do not supply the project with accurate control and all of the contractors are making up their own or using different control.

There should always be a project kick off meeting with all the subcontractors to discuss control and the proper use of the control and operation of the total stations on the project. Getting Control in the field is the act of checking all the control points necessary to perform your work accurately. The act of checking control points oneself to verify accuracy, is a recommended practice. Mistakes can happen and not checking control before you use it can cost the project a lot of money in schedule loss and rework. If everyone is using the same control everyone will end up in the same place.

Survey/Building Control Best Practices and Hints:

- Try to set up your total station on solid ground like concrete. When setting up in dirt or on pavement, the ground will expand and contract with sun and temperature moving your total station out of level throughout the day.
    - Use a tri-pod stabilizer and weigh down your tri-pod; it takes a lot less wind then you would think to blow over a total station.
- Check your set up and level of your total station every 40 shots or so.
- Try to use the same control points each day this will minimize the propagation of error.
- Try to measure your control points in the same order each day.
- After completing a setup routine (Occupy Point or Ref Points), always try to stake out another known point to verify your set up is correct.
- Shoot long on control and work close to your total station. If you have the choice to use two control points that are 50' apart and two control points that are 200' apart use the longest set.
    - Do not shoot past your control set up. If your control points used are only 200' apart you should not layout or store points past 200' from the total station.
- When using the Reference Point routine to set up, try and use at least three points and 90 to 120 degrees of angle.
- Calibrate your total station per manufactures recommendations to avoid instrument error.
- Calibrate the level bubble on your survey poles to avoid error.
- Check your optical plummet on the Total Station once a day and calibrate if necessary.

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- Check the prism pole level for plumb once a day and calibrate if necessary.
- Make sure you are exporting to Navisworks from CAD/Revit as 'Shared Coordinates'.

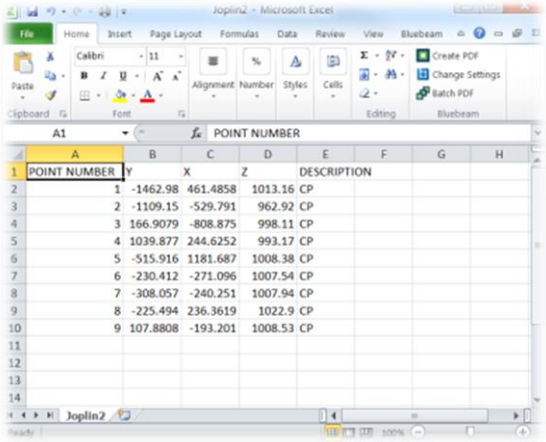
Glossary of Terms

What is control? Control is a set of Datum points on the jobsite that everything is measured from. Control is matching points in CAD that you can find on the jobsite.

What is a coordinate? This is how the total station and CAD software communicate dimensions or locations. To understand this process and remove some confusion we need to define the types of coordinates. A coordinate is a set of two to three numbers or letters that define a specific location. There are different ways these are communicated. Latitude, Longitude and elevation are more common with a GPS. For CAD and Total stations we use X,Y,Z and Northing, Easting and Elevations. This is where we get a little confusion, CAD software use coordinates in an X,Y,Z format and survey equipment refer to Northing, Easting and Elevation. These are the same just out of order from each other. Where X=Easting, Y=Northing and Z=Elevation. You will see that the first two coordinates are opposite but the elevation is in the same format for both. If we don't understand this coordinate order we will end up with information not matching. If you import points into a total station data collector in an X,Y,Z format and it is expecting the coordinate format to be Northing, Easting and elevation, the points will look rotated 90 deg and mirrored from what they looked like on the CAD file. We can set the total station data collector software to use either an X,Y,Z format or N,E,E format we just need to makes sure it matches the file we are trying to import into it.

Now that we have the coordinate system explained we need to review the different scaling between CAD files and survey equipment. CAD files are using a scale of inches. Survey equipment uses a scale of feet. So there is a 12x scale factor when moving information from CAD to a total station. This affects the coordinates in the .CSV file and the DXF file.

What is a .CSV? A .CSV file is the export file from CAD that gives the total station all the coordinate and dimensional data required to layout. This file includes the Point Number, X coordinate, Y coordinate, Elevation coordinate and the description of what this point is. A few things to remember: **1.** You cannot have two of the same point numbers in a .CSV file. **2.** You have to make sure your coordinate order (X,Y,Z) is the same order your data collector software is expecting.



	A	B	C	D	E
1	POINT NUMBER	Y	X	Z	DESCRIPTION
2	1	-1462.98	461.4858	1013.16	CP
3	2	-1109.15	-529.791	962.92	CP
4	3	166.9079	-808.875	998.11	CP
5	4	1039.877	244.6252	993.17	CP
6	5	-515.916	1181.687	1008.38	CP
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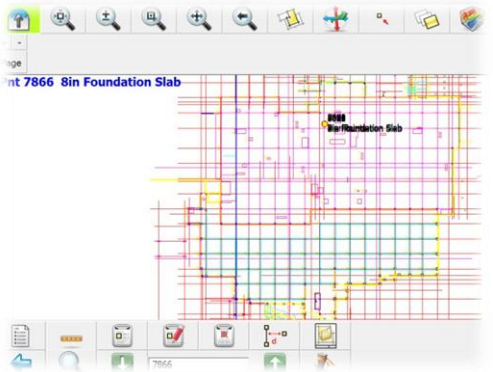

What is a DXF file? A DXF file is a graphical representation of the CAD file for the data collector. This would show items like the column grid, walls and other architectural background items that might assist with layout. A few things to remember about a DXF file. The file size has to be below 5mbs, remove everything from the DXF file like hatching, text, custom blocks, basically anything but lines and circles and it must be scaled to decimal feet.

Total Station – A total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read distances from the instrument to a particular point. The distance, horizontal angle and vertical angle information is received from and stored to an external data collector.

Point – Coordinate located with the total station that could represent the location of a hanger, sleeve, wall, housekeeping pad or equipment.

Control Point – A point used for a datum derived from the original surveyors or the general contractor. This is an extremely accurate point used to set the total station or a back sight over to establish orientation on the job site and relate to the CAD file.

Back sight – A back sight is set up over a control point to be used as a reference to establish orientation with the total station.

Data Collector – Handheld device used to transfer data to and from the total station.


Data Collector

Survey Layout Software – The software that runs on the data collector allowing it to communicate coordinate data to and from the total station.

Prism – a transparent optical element with flat, polished surfaces that refract light.

Prism 360^{0} – A prism that can be viewed from 360^{0}.

Prism Pole – An adjustable pole that the 360^{0} prism unit attaches to.

Bipod – A 2-legged support used to hold and assist with leveling a prism pole.

Tripod – A 3-legged support used for the Total Station instrument or a back sight setup.

Prism -30/0 – A larger diameter directional prism that can be set at a -30mm or a 0mm offset.

Prism Peanut -30/0 – A small diameter directional prism can be set at a -30mm or a 0mm offset.

Notes