bim WORKSHOPS

THE REVIT THEORY OF RELATIVITY:
UNDERSTANDING SHARED COORDINATES

Instructor: Paul F. Aubin

Session Description

If you are new to Revit®, and particularly if you are coming to Revit® with an AutoCAD® background, the approach Revit® takes to coordinates, positioning and origin points can be a little baffling. On the surface, it appears that Revit® simply does not have a "zero" point, or any way to input precise coordinates. As with many things, appearances are not always what they seem. Revit® does indeed have an origin and the ability to input with precision. The trick is that in Revit®, coordinates, movements and measurements are always relative to something else. In this class, we will explore the "Revit® theory of relativity" (AKA "Shared Coordinates).You will learn how to set up Shared Coordinates, link files with Shared Coordinates, and maintain the relationship as the project progresses. If like me, you have let your AutoCAD experience ruin you, or have just not been able to get your head around Revit® coordinates, this session is here to help! (You should have familiarity with Revit® essentials).

LEARNING OBJECTIVES
At the end of this class, you will be able to:
• Set up Survey Points and Project Base Points
• Set up and maintain Shared Coordinates
• Work with Shared Sites and manage Locations
• Configure single building and multiple building sites.

About the Speaker:
Paul F. Aubin is the author of many CAD and BIM book titles including the widely acclaimed: The Aubin Academy Mastering Series. His latest book: Renaissance Revit takes a deep dive into the Revit Family Editor. Paul has also authored several video training courses for lynda.com (www.lynda.com/paulaubin). He is an independent architectural consultant who travels internationally providing implementation, training, and support services. Paul's involvement in the architectural profession spans 25 years, with experience that includes design, production, CAD management, mentoring, coaching and training. He is an active member of the Autodesk user community, and has been a top-rated speaker at AU for many years. Paul is also a frequent speaker at the Revit Technology Conference (RTC) in both the US and Australia, the BIM Workshops and Minnesota University. His diverse experience in architectural firms, as a CAD manager, and as an educator gives his writing and his classroom instruction a fresh and credible focus. Paul is an associate member of the American Institute of Architects. He lives in Chicago with his wife and three children.

Introduction

Before learning Revit, I was a long-time AutoCAD user. As a long-time AutoCAD user, I found Revit's "apparent lack" of coordinates quite troubling. *How were we ever supposed to place anything precisely when I can't type in 0,0 anywhere?* Perhaps you shared my experience and frustration? After much self-inflicted pain and anguish, I have since come to see things the "Revit way" and gotten over my "AutoCAD-centric" way of thinking... I am feeling much better now... The reality is that while "absolute" coordinates may seem comforting in their finality and well, "absoluteness" we do not experience the World this way. In "real life" we always have a relative view of the World around us. When you are sitting in your office on the tenth floor of the building, do you have the perception that you are floating high in the air, or rather that you are really just sitting in a chair a few feet from the floor? Our experiences in the World around us are relative. Shouldn't our design software be too? Well in Revit, as you have no doubt discovered, all coordinates, movements, dimensions and measurements are *always* relative to something else. In the topics that follow, we will explore the "Revit theory of relativity" (OK, it's not really called that). If you have let your AutoCAD experience ruin you and have just not been able to get your head around Shared Coordinates, this session is here to help!

Revit Origin and Base Points

Let's start right in with the question of origin. I am often asked about the origin (or **0,0**) by new users of Revit. So to answer the question: "does Revit have an origin?" the answer is **YES**. So the next logical question is, "where is it?" The simple answer is: "it's in the center of the screen." Satisfied? No? OK, here is a simple exercise to locate it for yourself:

1. Launch Revit and create a new project from the default template.

Note: For this session, for my examples and screen shots, I have used the Autodesk provided: Default.rte template file included with the US installation.

2. Type **VG** (or on the View tab, click Visibility/Graphics), scroll down to and expand Site and the check (to turn on) **Project Base Point** and then click OK.

3. The Project Base Point appears as a round symbol. Select the icon and the coordinates of this point will report as 0,0,0 onscreen.
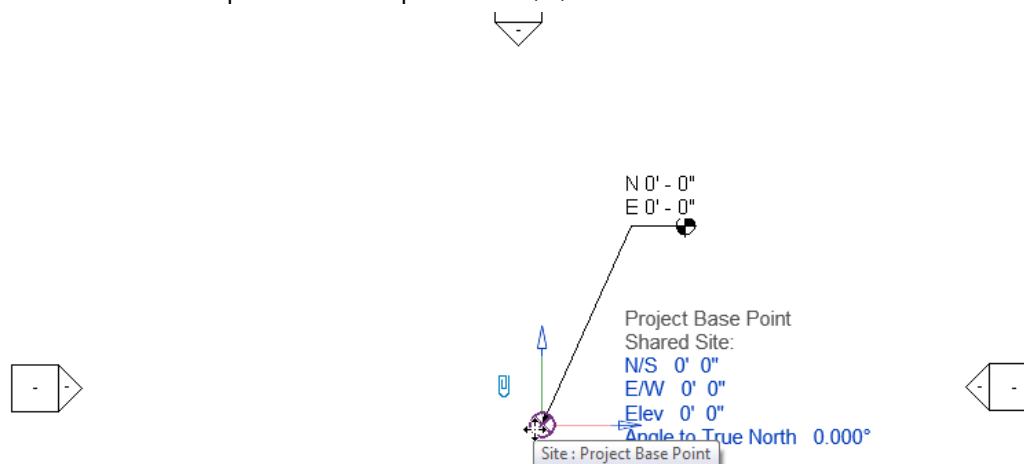

FIGURE 1—TURN ON THE PROJECT BASE POINT USING VISIBILITY/GRAPHICS (VG)

You will also notice that it is basically in the center of the screen (relative to the elevations). There are two alternative ways that you can report coordinate locations onscreen.

On the Annotate tab, you can click the **Spot Coordinate** tool and add a spot coordinate symbol to the Project Base Point icon. There is also the **Report Shared Coordinates** tool on the Manage tab, on the Coordinates drop-down button. This command will allow you to click on an object onscreen and it will display the coordinates of the point you select on the Option Bar.
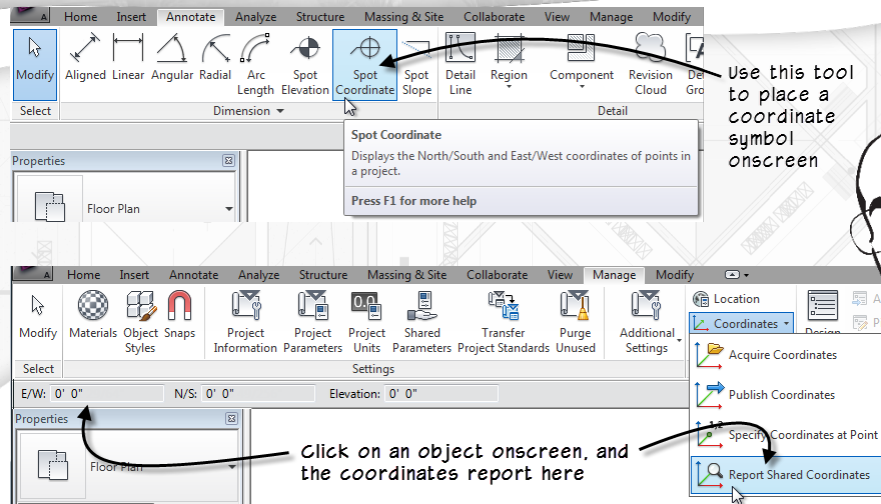

FIGURE 2—REPORTING SHARED COORDINATES

So now we can see that Revit does in fact have an origin and it is at the center of the screen. Feel better now? I thought you might. So if your goal was know where the origin is; congratulations. You are done. But, not so fast, there's more to the story. The real question is: "so what?" "What does this 0,0 do for us? Well, at the moment; nothing. Recall that, EVERYTHING in Revit is relative. So in order for this Project Base Point that we now have displayed to be meaningful, it has to be defined relative to something else. Only then does it become useful.

4. Click on the Project Base Point icon.
Notice that the numerical values are editable temporary dimensions.

5. Click on and the E/W value and type in a new value such as **100**.
You will actually see the Project Base Point and the surrounding Elevation markers appear to shift onscreen. Think of how such an edit would behave elsewhere in Revit… For example, imagine selecting a wall and then editing the temporary dimension. What would happen? The selected wall would move to a new location based on the value you input correct? In other words, the selected element moves in relation to the element associated with the temporary dimension. *If that's true, then in this case where was the movement measured from?* Look at the current value of the E/W temporary dimension on the Project Base Point. Notice it now reads 100. But it is still not really clear what the 100 references. Well, it turns out that a Revit project does not have one, but rather TWO origin points. The second point is called the **Survey Point**. You can turn it on with VG as well. It represents a "known point in the real world." For example, if you Civil Engineer gives you a survey with some established benchmark or known site point, the Revit Survey Point will represent this. This will help you establish the proper positioning of the project on its physical site. To see the Survey Point:

6. Type **VG** (or on the View tab, click Visibility/Graphics), scroll down to and expand Site and the check (to turn on) **Survey Point** and then click OK. The Survey Point is triangular in shape.

By default, both points are in the same location. However, if you are following along here and moved the Project Base Point above, you should now have a space of 100 separating your two points.
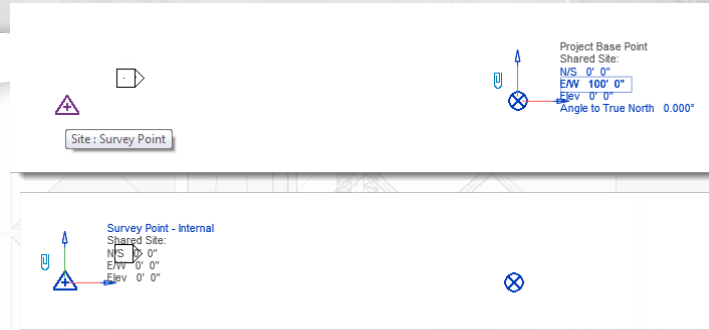

FIGURE 3—TURN ON THE SURVEY POINT USING VISIBILITY/GRAPHICS (VG)

You will notice also that the dimensions on the Survey Point are not currently editable. However, the Survey Point icon CAN be moved; doing so would actually shift the coordinate system. *This means the new location of the moved icon would now be 0,0!*

7. Try dragging the Survey Point onscreen. Then click first the Survey Point (and note its coordinates) then the Project Base Point (and note its).

Now that we have both points displayed and having done this simple experiment, you can hopefully start to understand their relationship relative to one another. As noted, the intention of the Survey Point is to "anchor" us in the real World. It represents a real and known benchmark location on the building's site (usually provided on the survey). The Project Base point is simply a known point on the building itself (usually chosen by the project team). Think of the Survey Point as the coordinates in the *World* and the Project Base Point as *local building* coordinates. For example, The Survey Point might be located at the manhole in the middle of the street outside the building or on a utility pole, while the Project Base Point might be at the front door or column line intersection A1. You can choose the point that is most convenient to the project team. What is important is NOT specifically where the two points are, but rather their relationship RELATIVE to one another. This is what we mean by Shared Coordinates in Revit. Specifically, the Survey Point is a known point in the Shared Coordinate System. It is called the Shared Coordinate System because it represents the coordinate system of the World around us and is therefore "shared" by all buildings on the site. The Survey Point defaults to the origin (0,0,0) of the **Shared Coordinate System**, but you can move it to ANY convenient point for your project.
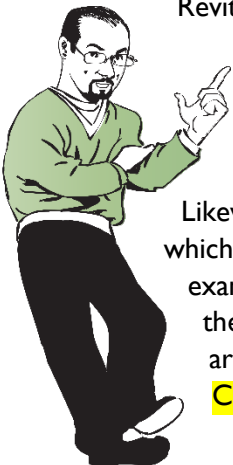
Likewise, the "Internal Coordinate System" of your building is the building's "local" coordinates which typically are oriented perpendicular and parallel to something meaningful in the building. For example, if the building has a 30° rotation on the site, it is much more convenient to work on the building horizontally and vertically with respect to your screen, the building's major architectural elements and the plotted sheets, rather than at 30°. This is the local Internal Coordinate System and "Project North."
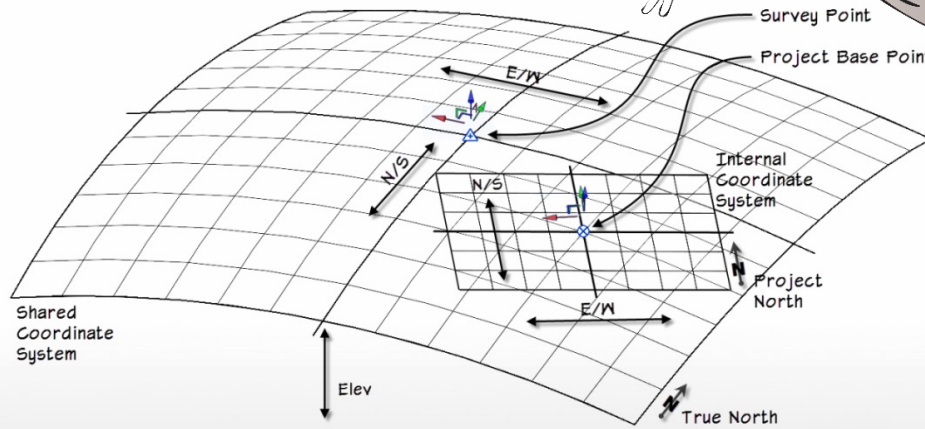
FIGURE 4—VISUALIZING THE RELATIONSHIP BETWEEN INTERNAL AND SHARED COORDINATES

The existence of both coordinate systems lends meaning to the other. If we did not have both, we would be forced to assign arbitrary meaning to coordinate system and its origin and force the building to match the survey or vice/versa. The Revit system allows us to keep both! And more importantly, it allows both to have real-world meaning.

Project Location Tools

As noted above, the Project Base Point and Survey Point can be moved. In other words, while they are located at the origin by default, they do *not* have stay there. There are a few ways to move them. You can move the point icons themselves directly onscreen using the Move tool or temporary dimensions (as we have already seen). There are also some commands on the Manage tab. Moving the points onscreen offers results similar to these commands depending if the icon is **clipped** or not. (Click the small paperclip icon to clip or unclip) Let's look at each option and command.

- **Position>Relocate Project**—This command moves your project relative to the Shared Coordinate System. You can use it in plan or elevation views and it works just like the Move command; you first click a start point, then a new point. The result will be a change in the numerical offsets reported by the Project Base Point and is basically identical to the result achieved above by editing the temporary dimension on the Project Base Point.

- **Position>Rotate True North**—This command changes the orientation of True North relative to the orientation of the building. (Revit understands both True North; North with respect to the actual site and Project North; "up" relative to the screen (or plotted sheet) and usually set parallel or perpendicular to major building geometry). To use this command, you must be in a plan view and the plan view must have its Orientation parameter (on the Properties palette) set to **True North**. It behaves just like the normal Rotate command
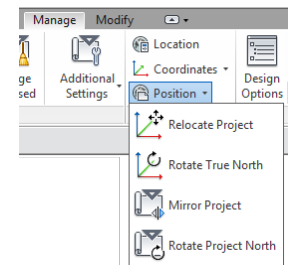
but the result impacts the orientation of the entire building relative to the site. After rotating True North, you can see the results on the Project Base Point and Survey Point icons.
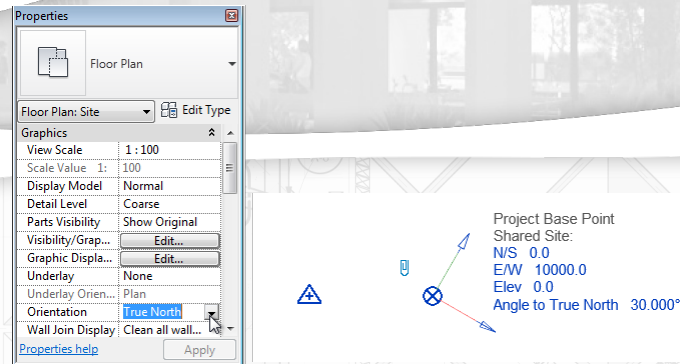

FIGURE 5—ROTATE TRUE NORTH IN A PLAN WHOSE PROPERTIES ARE SET TO TRUE NORTH

Note: You can also rotate True North by using the temporary dimension on the Project Base Point icon. This method does not require that you first change the orientation of the plan view.

- **Position>Mirror Project**—This command mirrors (flips) the project with respect to the Shared Coordinate System. Please note that all aspects of the project "flip". So if you flip left to right and you started with an elevation on the right named East, the elevation that ends up on the right following this command will be named West! *(I recommend avoiding this command if at all possible).*

- **Position>Rotate Project North**—After adjusting coordinate systems, sometimes the plans and other views don't fit as nicely on the sheets. For example, if your building is much taller than it is wide, you might wish to rotate Project North. This offers several pre-sets like rotate 90° or 180°. You can also rotate arbitrarily if necessary. You can easily avoid this command by planning your building orientation to match the proportions of your monitor and/or plotted sheets. Project North and Project Base Points are meant to be convenient. Don't make you work harder by assigning unnecessarily complex meaning to these items. Keep it simple. With a little pre-planning, you will rarely need this command.

- **Coordinates>Specify Coordinates at a Point**—This command allows you to click on an object at a point, an edge or a surface. You can also click on your Survey Point with this command. A dialog will display with editable fields where you can input known values for the selection you made. You would acquire appropriate values to input from your survey file or Civil Engineer. Using this command, you can achieve the same results as most of the other commands listed here but in a single step. In most cases, this is the most reliable way to establish your "real-world" coordinates.
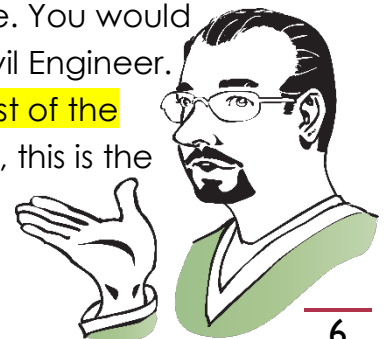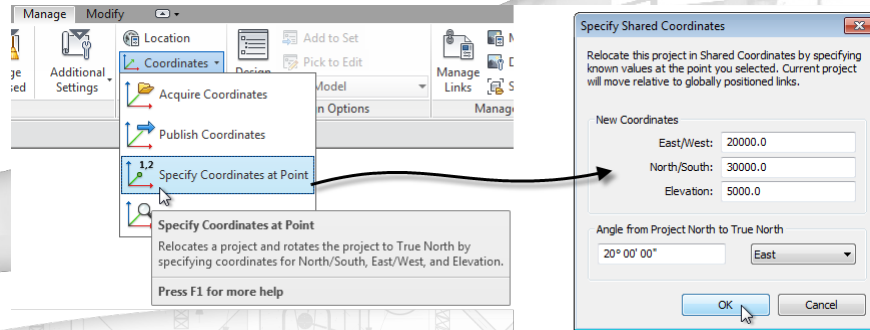
FIGURE 6—USE SPECIFY COORDINATES AT A POINT TO INPUT EXACT WORLD COORDINATES

- **Coordinates>Report Shared Coordinates**—This command was mentioned above. Use it to get a read out (on the Options Bar) of any point on a selected element onscreen. The read out will display the Shared Coordinate values for the selection.

Understanding Location

So far we have limited our discussion to just a single file. What happens with coordinates when you begin linking other files (CAD or Revit) into the current file? This is where Shared Coordinates really gains its fullest value. Since Revit understands the notion of a global (or World) coordinate system, it is pretty easy for us to "share" this coordinate system with more than one project. All of the projects will "share" the same basis for their positioning in the World—thus the name "Shared Coordinates." To fully understand the concept, let's introduce another new concept called: **Location** and **Shared Sites**.
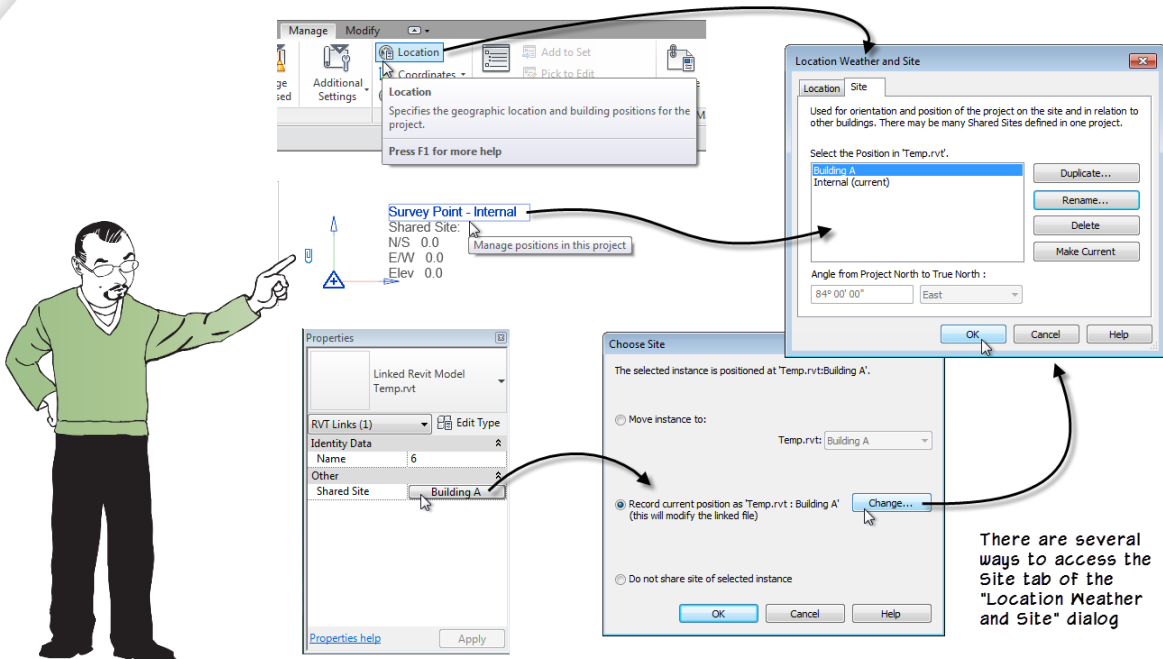

FIGURE 7—ACCESS THE "LOCATION WEATHER AND SITE" DIALOG IN SEVERAL WAYS

To fully describe where an object sits in 3D space (its location), we need three dimensions East/West position (X coordinate), North/South position (Y coordinate) and elevation (Z coordinate). We also

need the rotation angle East or West of True North. These four bits of information uniquely position our building on the site and with respect to other buildings. Further, we can assign a unique name to the collection of these four bits of data. This named collection of coordinates is referred to in Revit as a: **Shared Site**. To manage our Shared Sites, we use the Site tab of the "Location Weather and Site" dialog. To get here, you can use the Location tool on the Manage tab, and then click the Site tab. Alternatively, you can access the Site tab directly from the Survey Point icon or from the Shared Site item on the Properties palette when a linked file is selected.

A Shared Site is how we describe **where** our building sits and **how** it is oriented on the property. A project CAN have more than one Shared Site saved in the "Location Weather and Site" dialog. By default, each project has only one Shared Site which is named: "Internal" by default. This name simply describes the fact that the default for any project is its "internal" local coordinate system. As you begin to save Shared Sites, it is highly recommended that you name them more descriptively.

In many situations, you will only require a single Shared Site for each project file, however there may be situations where multiple Shared Sites are appropriate and desirable. For example, in a condominium development, the same building design may be sited multiple times in a subdivision. You could use a single Revit file and copy it multiple times. Each copy would be given its own Shared Site thereby allowing each instance to have its own unique location in Shared Coordinates.
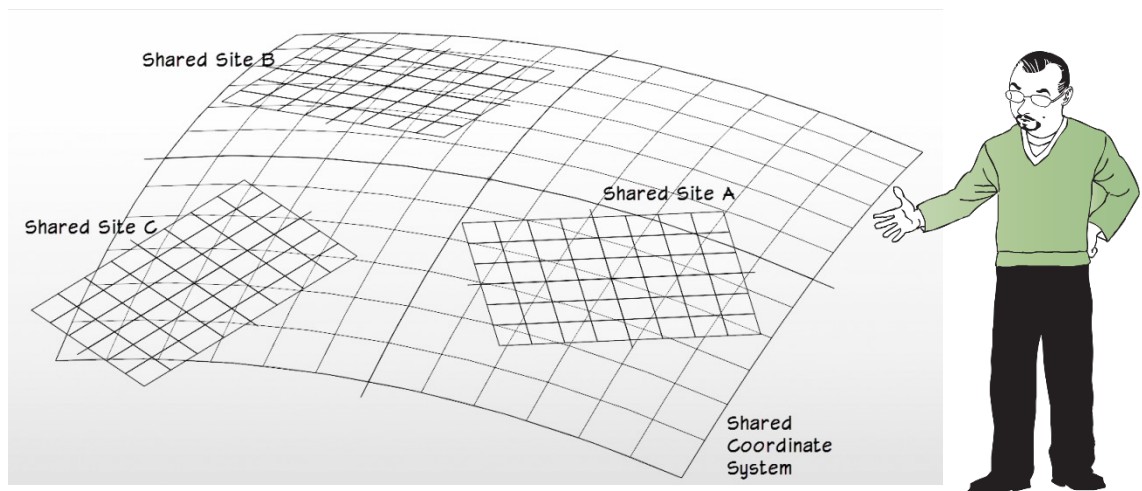

FIGURE 8—VISUALIZING MULTIPLE SHARED SITES IN A SHARED COORDINATE SYSTEM

Scenarios

There are potentially many ways that you can set up any given project. There are also several tools and a few approaches available to approach the setting up of Shared Coordinate systems. We have discussed many tools, but for a little more hands-on look, I have chosen two simple scenarios.

- Scenario 1—a single pair of files. (For example a building on its property)
- Scenario 2—a multi-file setup. (For example a single property with many buildings)

Scenario 1—A Single pair of files

In this scenario, we assume two project files that need to be linked together. (However this process would work nearly the same with linking CAD files, but for simplicity here, I will only be discussing Revit linking). The essential process is simple. Create each project file with an orientation and location that is convenient and logical for THAT file. Do not choose a location, origin or orientation based on the site

file or any other building in the campus. Remember, everything in Revit is relative. So determine the best orientation and location for the project file you are in and then use that orientation and location to build your model. In other words, try to make it perpendicular and parallel to the screen and sheets.

When you are ready, from the Insert tab choose **Link Revit** and locate the other file. For each pair of files that you link, you have to perform the basic setup. That means that the first time, you can choose any option you like for Positioning. I recommend just using **Auto – Center to Center**. We will be repositioning in the next step.

Tip: Again, this is the place where it is best to forget about the AutoCAD past and just focus on the "Revit way" to do this. In other words, though you are tempted to use Origin to Origin, it is often not the best option when linking a building to its site. Origin to Origin is best when linking between disciplines. For example, linking the MEP or Structural files to the Architectural.

Next you will move and/or rotate the linked file into the correct relative position. Finally you will **save the Shared positioning and assign it to a Shared Site.** That's it. Once you have established the relationship, Revit will maintain it for you. You can open the other file and link in reverse, this time choose the **Auto – By Shared Coordinates** option and the file will know exactly where to go!

Let's assume that you are positioning a building relative to its site. If you want to try this out, create a simple building in one Revit file (call it: *Building*) and then create a simple site plan in another file (call it: *Site*). You don't need to get too fancy, just a few objects in each file is suitable.

1. Open the *Building* project file. (Use VG and make note of where the Project Base and Survey Points are). Close the file without saving.
2. Open the *Site* project file and then Link in the *Building* project using: **Auto – Center to Center**.
3. Move and/or Rotate the *Building* linked file to make the building sit properly on the site. For this test, be sure to both **move** and **rotate** the building. This way we will have a different Project North and True North and different base points when we are finished.
4. Select the linked file and on the Properties palette, next to Shared Site, click the **<Not Shared>** button.
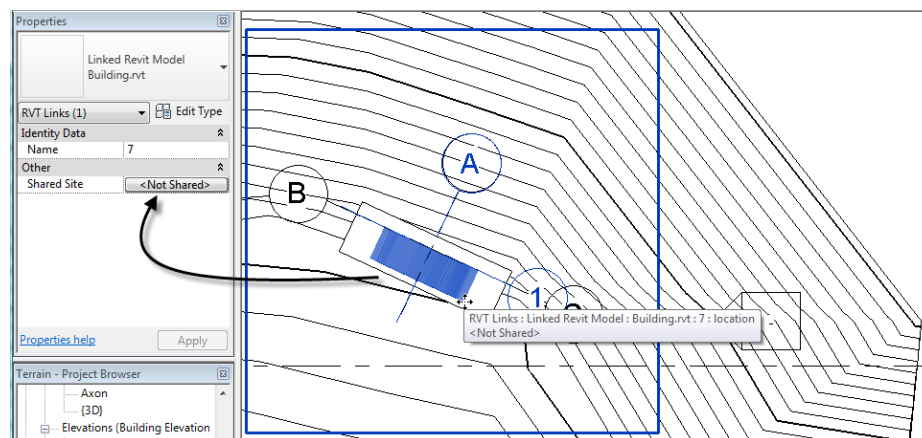

FIGURE 9— ON THE PROPERTIES PALETTE CLICK THE SHARED SITE BUTTON

In the "Shared Coordinates" dialog that appears, you will be given the option to either Publish or Acquire the coordinates. There is a description of each option in the dialog that appears. What it essentially boils down to is that you are synchronizing the Shared Coordinate System between the two files. In other words, before this command, the two files know nothing of each other's coordinates. After the command, they will SHARE the same coordinates. So, which file's current coordinate system do you want to use for both files? Do you want the current host file to share its system with the linked file? Or would you prefer the linked file to share its system with the host? Typically I like to let the site file's coordinates to become the overall Shared Coordinates. So in this case, since I am in the Site project and it is hosting the Building project, I would want to "Publish" the coordinates to the Building project (replacing its Shared Coordinate system and making it match the site host file). Please note that regardless of which option you choose, NO changes are made to either file's local internal coordinates. What we are doing right now is simply recording how we want the two files to coexist physically in 3D space. You could simply click Reconcile here to complete your choice, but as noted above, I highly recommend that you take the additional step of renaming or copying the named Shared Site Position.

5. In the "Share Coordinates" dialog, next to *Building.rvt: Internal*, click the Change button. (This opens the "Location Weather and Site" dialog to the Site tab). You can **Duplicate** or **Rename** the default Shared Site named Internal. If you only require one Shared Site, simply rename it. Otherwise, choose Duplicate. Choose a good descriptive name. You are describing the building's location on the site here. "Preferred Site," "Alternate A" or "North Quadrant" are good examples.
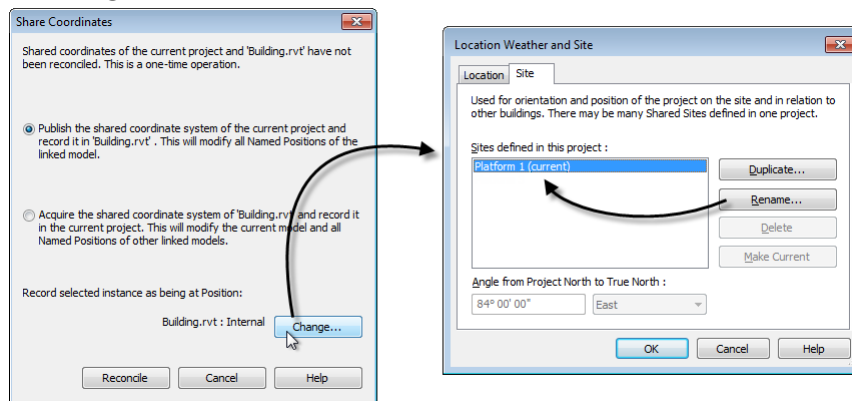

FIGURE 10—CHANGE THE SAVED POSITION AND RENAME IT MORE DESCRIPTIVELY

6. Click OK in the "Location Weather and Site" dialog, and then click the **Reconcile** button in the "Share Coordinates" dialog. Finally to make all the changes "stick" we must save both files. Click the Save icon on the QAT and in the "Location Position Changed" dialog, click the Save option at the top.
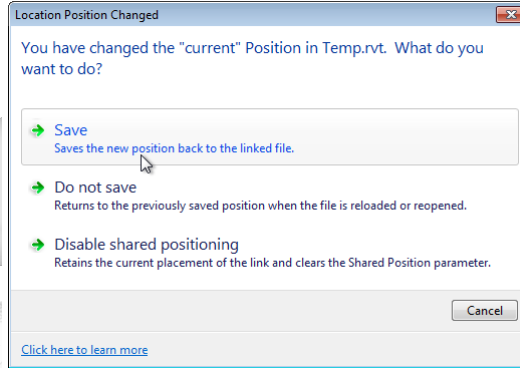
FIGURE 11—SAVING ALSO PROMPTS YOU TO SAVE THE LINKED FILE AND ITS SITE(S)

The first option: Save is the *only* good choice. If you choose either of the other two options it negates the changes you have made. So neither is a good choice. <mark>The final step is to test what you have done.</mark> You do this by opening the other file and linking again. (You cannot have both projects opened at the same time, so close the current project first).

7. Close the *Site* project and open the *Building* project.

8. If necessary, using VG, turn on the Project Base Point and Survey Point icons. Notice that the building file remains oriented horizontally and vertically relative to the screen. Notice that the Project Base Point and the Survey Point are offset from one another. Notice also if you click on them or query their coordinates that the values reflect the changes made in the other file.
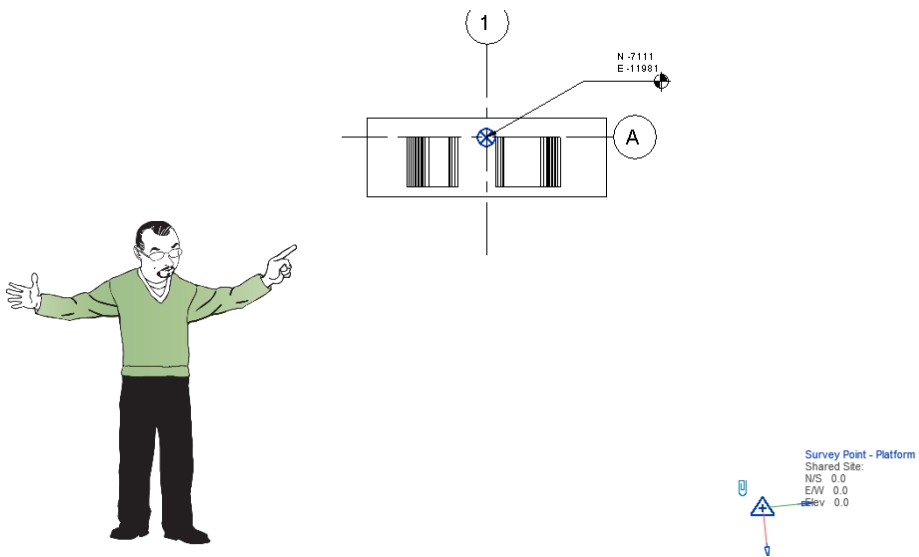

FIGURE 12—OPEN THE LINKED FILE TO SEE THE RESULTS

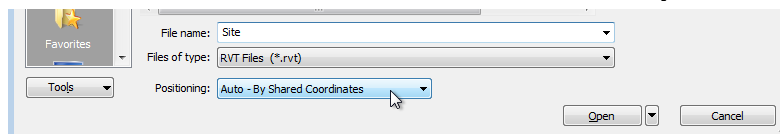9. Link in the Site file to this file. This time, choose **Auto – By Shared Coordinates**.

FIGURE 13—AFTER ESTABLISHING SHARED COORDINATES, YOU CAN LINK WITH THEM

Notice that the site file comes in exactly in the correct location and orientation. ==Part of the beauty of Shared Coordinates is that you only need to set them up once==. From then on, both files will "know about" each other. Feel free to experiment further using any of the tools or techniques covered so far.

Scenario 2—A Multi-File Project

A multi-building project typically has a single site file with many buildings on it. Each building might be a separate Revit project, or you may also find the need to use the same Revit model in more than one location on the site (this was mentioned briefly above).

A multi-file project includes the same considerations as a single building project but has the extra added complexity of coordinating multiple building models with respect to one another. Each pair of files is set up the same way as above. ==The difference is that, the Shared Coordinate System is now shared amongst ALL the files, not just the pair==. Therefore, you should consider carefully which file you wish to execute the process from. In most cases, the Site file will be the obvious choice. But this is not required.

Managing Shared Sites

Establishing multiple Shared Site locations can be very useful. There are two basic scenarios: the first (mentioned above) involves using more than one copy of the same project on the site. The other scenario is the establishment and saving of alternate site locations for a single building. The set up for either scenario is similar.

1. Set up the initial links and save the shared coordinates as before.
2. Select the linked file, copy it to a new location. Adjust the positioning of the file (Move, Rotate or Align) as required.
3. Select the copied linked file. On the Properties palette, note that the Shared Site is reset back to <Not Shared>. Click this button.
4. In the "Select Site" dialog, choose the second radio button and the click the Change button. In the "Location Weather and Site" dialog, click Duplicate and give the new Shared Site a name.
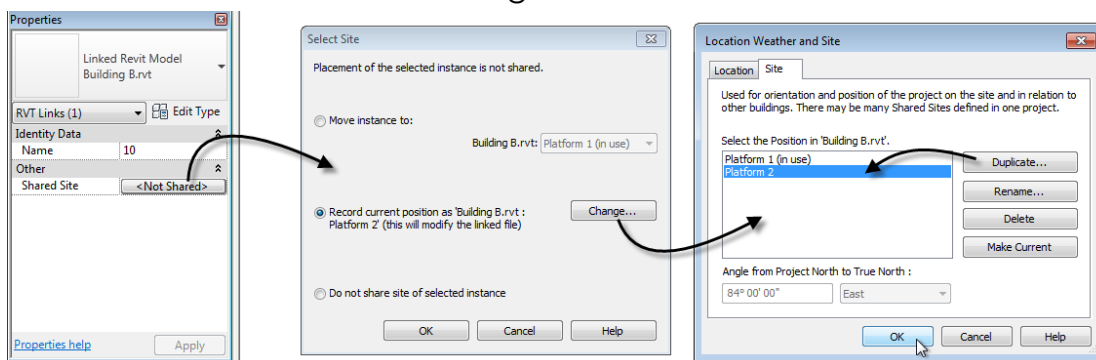5. Click OK twice to dismiss the dialogs and save the file.

FIGURE 14—COPY A LINKED FILE AND THEN DUPLICATE THE SHARED SITE TO MAKE IT UNIQUE

You may have noticed that this time we were not asked to publish or acquire. This is because the relationship between the host and link is already established. You can only use each saved Shared Site location one time. So if you make three copies of the file, you will need at least three named sites. You can have as many named sites as you like. This allows you to try the building in different locations just by

returning to the "Select Site" dialog. If you need multiple copies of the building on the site (like the condominium example) you are finished. If you only need one, simply delete the extra copy (or copies). <mark>Doing this you can try the building on various alternate site locations.</mark>

6. Delete the copied linked file and then select the original linked file. On the Properties palette, click on the button next to Shared Site (it will be named whatever you named your Shared Site above).

7. In the "Choose Site" dialog, click the Move instance to radio button and choose the other site. Click OK to see the results.

Notice how the building moves to the other location and orientation. Let's do one last exercise. We will close the current file and reopen the linked file. Then we can change which named location is active.

8. Close the current project and then open the building file where you just added multiple saved Sites. If necessary, type VG and turn on the Survey Point.

9. On the Manage tab, on the Project Location panel, click the Location button. Click the Site tab.

Notice the two Sites with the names you assigned. One will have the label (Current) next to it. This is the currently active Site location.

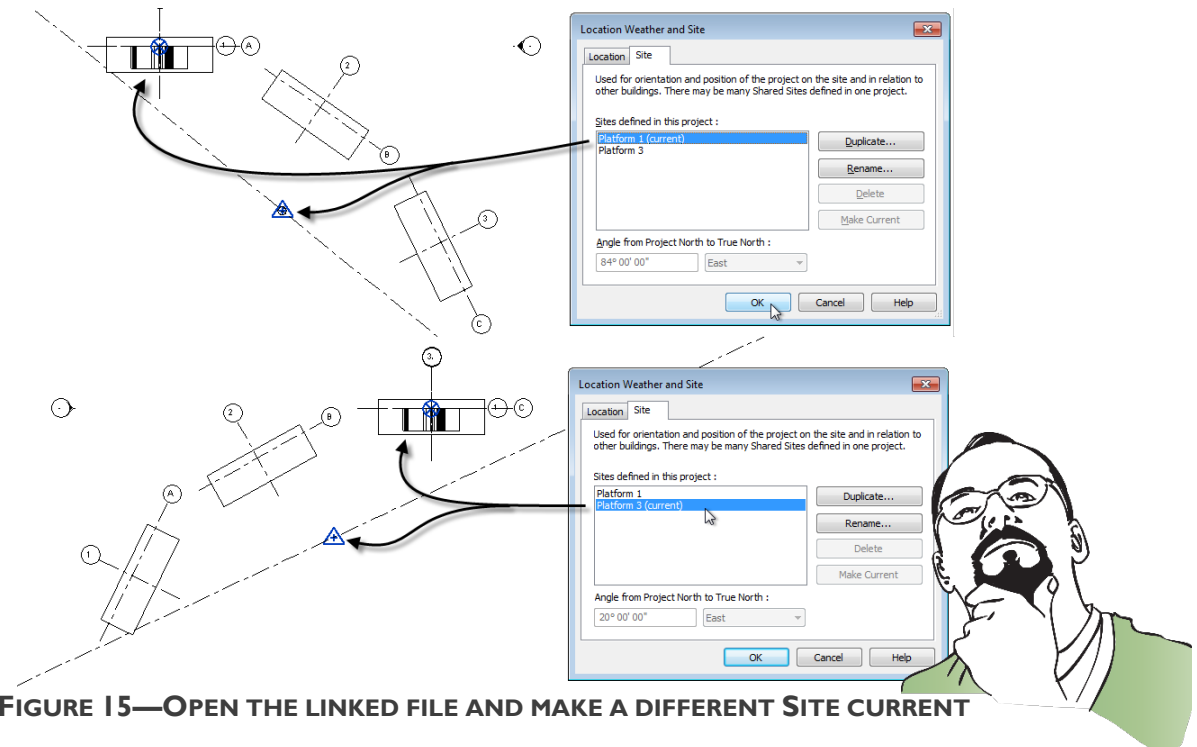10. Select the non-current Site and then click the Make Current button. Click OK to see the result.

FIGURE 15—OPEN THE LINKED FILE AND MAKE A DIFFERENT SITE CURRENT

Notice that the Survey Point has moved and reoriented. <mark>You have just instructed Revit to make the onscreen project behave as if it were sited at the other location.</mark> Very cool!

Multiple Buildings

Now let's add a few more buildings.

11. Close the *Building* file and reopen the *Site*.

12. In Windows Explorer, make a copy of the Building file and give it a different name. If you want you can open it and change the geometry a little.

Now let's link the new file. Since you copied it from the original, it will already have the same shared coordinates and the two saved sites.

13. Link the copied file into the *Site* project. Use: **Auto – By Shared Coordinates**.

The "Location Weather and Site" dialog will appear displaying the two saved sites. Notice that one of them will be labeled as (Current). This is the site that you chose as current when you last had this file open. It does not matter which is current, you can choose either one when linking.
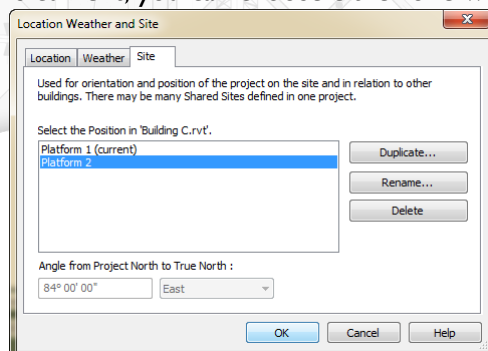

FIGURE 16—WHEN LINKING BY SHARED COORDINATES, YOU ARE PROMPTED TO SELECT A SITE

14. Choose the site that does not currently have a building on it and click OK.

You can repeat this process as many times as you need to. Copying and renaming the file in Windows Explorer is convenient early in the project before any building geometry is established. However, if this is not practical, simply link an existing file instead (not a copy). You will then have to repeat the steps above to establish the shared coordinates the first time. Remember, each pair of files must have the initial setup performed one time. From then on, you can use By Shared Coordinates in linking either file.

Cross Linking

At this point you have a *Site*, and *Building A* and *Building B*. One of the biggest benefits of this whole process is that all three of these files all share the same coordinates. So you can link Building A to B and vice versa without doing any further setup!

15. Close the *Site* project and open *Building B*.

16. Link in *Building A* By Shared Coordinates. When prompted choose your preferred site.

Very cool!

You can take it a step further by adding multiple sites to each file. Then you can select any one of the links, click the Shared Site button on the Properties palette and move it to a different site. In this way you can try different siting options for each building on the site.

Please feel free to experiment further. Thank you for attending.

bim WORKSHOPS

Further Study

You can find more information and tutorials in *The Aubin Academy Master Series: Revit Architecture*. Chapter 6 includes a tutorial on configuring linked files with Shared Coordinates.

I also have Revit video training available at: **www.lynda.com/paulaubin**. I have several courses at lynda.com including: *Revit Essentials*, *Revit Family Editor* and *Revit Architecture Rendering, Advanced Modeling in Revit Architecture, Formulas and Curves and many more*.

If you have any questions about this session or Revit in general, you can use the contact form at **www.paulaubin.com** to send me an email.

Follow me on titter: **@paulfaubin**

In addition to my books and videos, there are many other resources available online, in blogs, books etc. My good friend Steve Stafford (also a speaker here) has a very popular Revit blog at:
http://revitoped.blogspot.com

He has also taught on the subject of Shared Coordinates and his paper on the subject is well worth a read. You can find it posted here:

http://revitoped.blogspot.com/2013/06/coordinating-projects-using-shared.html?m=1

Another useful resource is recorded classes at Autodesk University. This one by David Baldacchino is quite good:

http://au.autodesk.com/au-online/classes-on-demand/class-catalog/2013/revit-for-architects/ab1412

Thank you for attending. Please fill out your evaluation.