LUCY KUHNS: Welcome to Tunnel Modeling for BIM. Like I told you, it's going to be half Civil 3D, half Revit, and a little bit of InfraWorks at the end. And I'm sorry for you sitting way off in the corner because the angle of the screen is really not the best.

Hello, my name is Lucy Kuhns, and I'm a premium support specialist with Autodesk. And presenting with me today is Safi Hage, and he's also a premium support specialist. I do civil engineering and he does structural engineering.

And we're very pleased to present to you today the mixture of two of our softwares for success for tunnel engineering. The examples that you're going to see today are very roughly based on the Grand Prairie express, which is the new outer belt tunnel metro system around Paris. It's not specifically this project, but we're going to see examples in the area. And it is a very interesting project.

The part one agenda-- I'm going to do part one, which is the civil engineering aspect. Safi is going to do the structural and Revit part. Where this class fits into your BIM process. Why you need both simple 3D and Revit. The key concepts for BIM for infrastructure. The tunnel progression, which is going to be the example we're going to use to demonstrate BIM for infrastructure. The importance of data management. Now, I'm not going to do Vault, but we are going to talk about how we manage our data so that we can be successful with dynamic modeling. Then we'll do data extraction, and then Safi is going to talk about Revit. And then we're going to come back and put the results into InfraWorks.

So where does this class fit into your BIM process? Well, in your BIM process, you have a lot of documentation and planning to do. So we have, in the execution phase, process mapping. I'm going to show you and give you examples of process maps at a general overview level. And then I'm going to show you a few more detailed process maps that would work into a workflow manual. Now, the reason I'm showing you this is these are process maps that are specific to Autodesk software, but we know that you are going to make your own process maps. So I'm giving you skeleton examples, and you can take those examples and use them as your own. Rip them out of the PowerPoint, of the documentation, and use them as your own. And I will even give the file, the raw files, so you can change that.

So process mapping. Here is a general process map. And things to notice on this map. Here is the topic of infrastructure design. And we're going from base map creation to preliminary design. And then the output at the far end is we're ready for detailed design, which is then going to go, as you know, in very many different directions.

Key things here. The yellow blocks represent documents. But we're all about data, so that's what you're seeing here, is all of the different data pieces that we're going to use to build these models. And important in the data structure is the green box. The green box is what? It is our single source of truth. So this process map will help you to organize and understand that, because we know in BIM that that single source of truth is a very important piece.

Now, here is a more detailed process map that would fit into more of your workflow manual, as we get more granular into your BIM documentation. And again, here we have the green blocks which represent the single source of truth.

So a key concept for the general practice of BIM. In BIM, we have parallel tasks. So, to bring it down to the level that Safi and I are doing today, I'm going to be working on the civil engineering aspects and Parallel. At the same time, Safi is going to be doing the detail aspects. Why can we do this? Because our models are dynamic, our models are progressive, and they can be upgraded, optimized at any time without having to go back and start at square one or start at the beginning.

Collaboration. We know that with a BIM system, that collaboration is key. And you of all people know that. So progressive design, we never have to go back to square one to start our design again. It's a continuum. So that's the overall concept for BIM.

And now, what are the benefits or differences between Civil 3D and Revit, and why do we need to have the both of them? So in Civil 3D, we're dealing with two types of projects. We're dealing with long, long corridors, linear projects-- and linear projects that go up and down and curve and are very non-linear. We also deal with what we call campus or site projects. Huge, huge areas such as airports or subdivisions or things like that. So those are the two big, big things that we're dealing with.

What does this mean? We're dealing with very large coordinate system values. Oftentimes when we're in UTM or state plane coordinates zones, we're not dealing with 5,000, 5,000. We're dealing with a half a million or 1 and 1/2 million, or in Finland, 25 billion. Well, there are some very interesting coordinate systems where we've seen huge, large numbers. This is double precision. Does Revit do double precision? No. Safi said no. So this is one of the things that we have to understand and work with when we're dealing with these large infrastructure projects. Of course, the non-planar elements, we're talking about the plan alignment, and the profile, the vertical.

OK, the other thing that Revit can't do that Civil 3D does is TINs with cut-aways. What is a TIN? Triangular, irregular network. So if this is a-- and they're used to represent surfaces, whether it's a top surface or maybe subsurface, geotechnical surfaces. We can have cut outs, we can have curved boundaries. In Revit, what happens? These things all get filled in. So, that is a difference between Civil 3D and Revit. Now let's look at Revit. We need to use Revit because Revit is the go-to tool for BIM. When do a BIM model and information modeling, Revit is the go-to tool in the universe. And it's fantastic, and that's why we see many, many people trying to do civil engineering projects in Revit. Why is this not a bad-- a good idea? Because Revit works on grid systems that are planar. We have levels that are planar. It's difficult to have things go like this in Revit. So, we're dealing with parametric families, and in Civil 3D we're dealing with objects. So that's close. Revit is great for document presentation, and it does fantastic making and cutting sections. Beautiful section work, beautiful details, beautiful documentation, and also beautiful rendering. So we're going to take the best of both worlds and show you how to benefit from this.

Here's a process map. This is the simplest one you're going to see today. So I'm going to do a horizontal alignment, a vertical alignment, and cross-sectional design. How do we get it? How do we get this curvilinear project into Revit? We're going to do it vis-a-vis the LandXML That's going to be our transfer tool. And then Safi is going to show you how you take the data in the LandXML and use Dynamo to get it into Revit.

Key concepts for BIM for infrastructure. Now BIM for infrastructure is a little bit different than BIM for building. Here we have showing subsurface utilities with an invisible surface. Now when we have these utilities, the utilities we have to know what utilities are what, when they interfere. Here is a virtual construction project. We do it on the computer so that we can have this overpass built in the median without disturbing the traffic on either side. If we model this in the computer, then we're going to be successful when we model it or really do it in the real world.

Now, here's the ultimate in a BIM model. This is Seattle, and this is a simulation of an earthquake. Have you seen that before, Heidi? I've seen it. This is a wonderful model used for simulation. That's of the BIM tasks that we do in this case of safety simulation for earthquakes.

This is another simulation for a BIM model, and this is a timelining. Here is one that shows an animation to determine clash. This is a clash detection scheme. Now these are tasks that we do in regular BIM, but more specifically, BIM for infrastructure. When we have a clash, as noted here, we can, because we're in a dynamic model-- that's one of the criteria-- we're able to switch back easily to the authoring software. We're able to change that and then go right back into the federated BIM model to make that change instant and update. So these are things and tasks that we do with a BIM for infrastructure model. So it's a little bit different than running HVAC ductwork in a building.

So, a quick review. BIM for infrastructure. The model has to be 3D. The objects have to have intelligence with attribution, behaviors, and styles. They have to be dynamic. They have to have real world coordinates. We have to know where they are on earth. And then they have to live throughout the life cycle.

Now, just to review. Remember, overall BIM, parallel tasks, a continual progression, compliance with constraints, and optimization.

So now we're going to get into this tunnel progression we start at the beginning, creating a base map. I'm not going to go into detail here, but here's one of these example tear-away flowcharts that you can put into your bin process manual. This is one of the ones that would be more detailed to go into your workflow part of your manual, the instructions. And this is specifically for Civil 3D.

So how are we going to build the basemap? We're going to use Model Builder in InfraWorks, and we're going to be able to use the tool in InfraWorks that will enable us to get a great amount of data very, very quickly, so I can start my project in a matter of minutes. I'm zooming in to Paris. We're going to go to the southeast side of Paris, [SPEAKING FRENCH]. And this is where our project is going to be. So I don't have to buy data, I don't have to look at-- I don't have to go to an agency, beg, borrow, steal data. I'm just going to take what's available. Remember, this is open-source data. I'm not going to use this for survey grade stuff. But if you haven't used the Model Builder part of InfraWorks, this is a fascinating tool.

So now, what I've done is I have ordered this model. I've made a limit, I've ordered the model, and it's going to be processed. And then, literally, in 15 minutes, half an hour, I'm going to get an email and the email is going to tell me that my model is ready. And it's pretty amazing. Success, I like that. [SPEAKING FRENCH].

And we have success in getting our model, so now, I'm able to start. This gives me a very, very quick start. And the model builder results-- in InfraWorks, this is this is what we'll see. And that is a great, large area. I have road center lines, I have waterway information. I even have building representations. So if I zoom in to show you this-- and, of course, I have the aerial imagery. That's nice, I didn't have to look for that and line it all up and get it to work. And I also have a very rough terrain. So that is the Model Builder, if I zoom in.

One of the things that we must do when we get a model from InfraWorks, is we have to put it onto a coordinate system that we're going to use. We can't-- because these models are done in what? Lat and long, latitude and longitude. So we need to set up a coordinate system, and once I have the coordinate system set up, then I'm ready to start my design process. Because have you ever laid out a road in arc degrees and seconds? It doesn't work.

All right. When I get this information from InfraWorks, I import it into Civil 3D. From InfraWorks, we export out one of two file types. A SQLite or an IMX file. I also have to set up my project in Civil 3D to the same coordinate system, and that coordinate system again, so that I'm going to be able to work on a projection, a flat projection. And that's the information. How long did it take me to get this very, very robust basemap? It took less than a half an hour.

And if we zoom in-- I'm going to zoom into one of the neighborhoods, and we're going to go to Rue Albert. So first of all, we can see that when I brought that information in, that it has a name. And we have the buildings. And I can also, in my collection of objects over here-- that's the surface by the way. And when I go into the center lines, you can see, look at the alignments that I have in here. And we'll go down here to Rue Albert and we'll do a zoom to it, and we're going to go right to that neighborhood. So within just a short amount of time we have this very nice basemap fabric, or layer. A bunch of layers for information.

So, a good basemap has to include a lot of, very much-- a lot, a lot, a lot of data. And these are the typical pieces of data that we might have. We don't get them all from Model Builder, so we have to do what? Now we have to start working, and once we identify the area, now we can start getting more precise information and data. Maybe even surveying data, and more localized and more accurate information for the cadastral layout, the topography, even imagery, our transportation layer, utilities, environmental, political boundaries, all of that good stuff.

So here is a very short demonstration of dragging and dropping GIS files into Civil 3D. Who knew it could be so simple? You just drag and drop these shapefiles in. We don't have to worry about making connection string or connecting data. It just comes in. I'm also going to bring in the center line of our proposed tunnel. Again, very, very easy. The word GIS and GIS data used to scare people. Now we just drag and drop it in. As long as we have a known coordinate system, it's going to come in. And here I'm showing a buffer that was automatically created along that center line.

So now we identify our areas of interest. And in our areas of interest, we're going to add some true control, because now I've identified where I'm working, I have to start getting it more precise. So here is the GIS of the station locations along the route. And here is the station location that we're going to concentrate on for our section of tunnel. And we're going to bring in some survey control points. And once I had those survey control points, I need to put in a tie. So that means that I set up a benchmark for the area of interest. Why do I need to have a known benchmark? So that when I start to bring in Revit models, we know how to place them, and where they're going to be placed. So we're starting to increase the precision, as we say, of our model.

Now, just a word about geolocation. When we build something in infrastructure, we have to locate it on earth. So that means it has to be truly on earth, and you'll be able to tell me where this is. I've already told you, it's in Paris, but let's make sure it's in Paris. And we're going to zoom out. That's the outskirts of Paris. And there is the southeastern side of England. So you know we're in the right spot.

So this is because we're in a georeferenced project, we can turn on the Bing mapping service, and we can instantly see that aerial imagery and give us that contextual-- the real world context of our project. And also, if I put in control points, there we have them in latitude and longitude. Why? Because I need to do this in my surveying utilities. I need to be able to go to that spot, use it on my mobile devices, and end up at that point and not somewhere at 5,000, 5,000.

Let's talk about you geotechnical information. When we're doing subterranean work, geotechnical is going to be a big part of this. Civil 3D does have the ability to put in geotechnical data. So I dragged and dropped the borehole information in. Again, GIS, just dragged and dropped it in. And I'm looking, I'm verifying with my Bing maps, just to verify where those borehole sites were, in case I need to go in inspect or anything. It gives me the visual cue of that. Now I'm using the geotechnical add-in. And I'm connecting to the whole SI database, which gives me the information, --that really gives me the location of each borehole, and then also the strata. The geologic strata for each of those.

Now here, I'm going to show you a traditional 2D representation. It's called a strip plan, and there is the 2D strip at each one of the points for the different sub surface information. And now because it's Civil 3D, we put those as a pool in Civil 3D. And again, here it is with the color coding that matches the 2D strip data. Once I have that 3D, it's very easy to make separate TIN surfaces for the tops and bottoms of each of those strata. And we can see what they look like.

So when we're doing tunnel work, we have specialists-- serious specialists-- that do very intense geologic work. This is a start on that. This is a quick way that I can start to proceed with my design, and then after the specialists have done their work, then we can update the design with their work. But this gives me a good start and a good knowledge of what's happening.

And I can take this information out because these are TIN surfaces that we're seeing here. And just to show you that they're TIN surfaces, I'm going to do a cutaway, I'm going to make a profile of these. And when we make a profile, you're going to be able to see the boreholes that I cut through, and you're also going to be able to see that this is dynamic. So there is the cut through those surfaces. And then as I move that cut line, it's going to instantly update. Now some of the very serious geotechnical software does not do dynamic cutaways like this. So again, this gives us a good idea to get a quick and early start. And now I'm going to take those layers-- excuse me, those surfaces-- export them out to Civil 3D in case I want to reference those. So the geotechnical part of Civil 3D does do the traditional strip and 3D bore. It gives us the strata and it also allows us to do dynamic profiling.

Now, once we have this, let's put it in Civil 3D and look how we can generate some excavation quantities. This is an interesting one. I've got the green layer, the orange layer, and the blue layer. And I've got my tunnel. This is this section. Here's the top of the tunnel, that red line there. This is-- excuse me, the blue line it represents the top. The red line represents the bottom. Here's the cross section. Can you see that there's a lot of green up here? And then we have a little bit of orange, and then we have a very tiny little piece of blue. And because

Civil 3D does average into area volume analysis, if I look at those tables, it's going to give me an update.

So I'm showing you two different sections right there. Let's zoom in on this. I'm looking at the green material. And I just want to look at the cross-sectional area there. We can see that area is roughly 94. Remember that, 94. And if I look at the blue value, it's roughly five. And it makes sense. That's almost 100, that's five. So the middle value is going to be what? Somewhere in between. And voila, there it is, 57. So now I'm convinced that this is a good, accurate cross section.

Now what's the magic about this? If I move the tunnel, what's going to happen to the cross section? It better change because that's one of the principal fundamentals of a good BIM model. It has to be dynamic. So let's see if this actually worked. I have hit rebuild the corridor, and you'll see it snap. See it snap? Now, if I look at that, I raised it up high enough so I don't have any blue. I'm out of that strata zone. And we can see I have a whole lot of green and I am even in the top filll at the top. And I have 30 units there. And I already told you the answer. How much blue do I have? Nothing. So did our model work? Yes. I always like to ballpark when I'm doing things, and so that's a perfect example of how we can do dynamic work, and why we need to have dynamic BIM models.

About the excavation quantities, the way that we can do this-- because I know excavation for sub surface work is extremely important. So we have several ways to determine those quantities. The way I just showed you is what? Average and area. I can also do 3D solids. I can extract these as 3D solid chunks, and that's going to also give me a good mask property to get me the volume. And then, of course, you saw the automatic updates. And also, this works if, like I said, when the serious geotechnical engineers supply me with more data, guess what's going to happen to my model? It's going to update. Guess what's going to happen to my volumes? They're going to update. I would have to generate another solid to get that.

Let's look at the cross sectional design progression. And I talked about one of the fundamentals of BIM for infrastructure is the ability to take a model and keep working it forward, never having to go back to the beginning, back to square one. So here we're going to look at dynamic and static cross sections. This first one I'm going to show you is a cross section that is static. And the reason I know it's static, I made it from a polyline. So I took the true design of the cross section, and I just did CAD. I did really good CAD work, and I made a static tunnel. Because in this particular case, we know that this tunnel is not going to warp. It's going to be very continuous.

Now, on the other hand, I have another cross-section which is dynamic. And Mr. [INAUDIBLE] there is an expert at making things dynamic. Right? Right. And so here we can see that I have targeting and I have parameters that allow me to move this in and out, and have a dynamic situation. So those parameters, I can take the width, I can take any one of my targets, and I can make one of these sections do what? Do a lot of things. It's very interesting. I see people that have 50, 60 cross sections. And if they would have known that they could have a target and they can do this, they would only need how many? One.

So how are we going to use these targets? If I don't have any information on the cross section, what am I going to do? I'm going to use my-- uh-oh, did we forget the-- We're going to go directly into the exotic one. I'm going to show you targeting. The targets are just going to follow CAD lines. This is just good ol' AutoCAD. And I'm going to do a widening on this tunnel. And so I need to identify which CAD line, And I'm just going to do the width. And there is our model. So with one simple cross section, we can see I have a transition zone and a widening. And I did that just with the one cross section. And you can see it go wide in the cross section. It goes wider, wider, wider. And now it goes narrower, And it goes deeper and deeper as I drop down with the profile. So we had the plan, the profile, and the cross section view. That's a nice thing about Civil. If you're not into civil engineering, these are very valuable layouts that show you the plan view, what's happening as it goes up and down, and then this as the cross section. Those are the three components that are the theme of this class that we're going to transfer from Civil 3D to Revit.

So the dynamic corridor modeling. Now, this is the LOD, the level of detail components. And now we get to my favorite. I love generic subassembly pieces because I can do a lot with just super simple things very, very quick. And I call this rough. I'm just going to rough out the bottom of my tunnel. And I can do this very quickly. And you can see I also use a very rough frequency rate. Why? Because I don't want to make a heavy corridor until I really know what the design is. I keep this fast and lightweight like a Ferrari.

And now, we can see that I'm going to take that very same generic subassembly. I'm going to set it to the targets because I want to make sure that my targeting is correct. I'm going to make the but the floor of that tunnel widen out and come back in. And there it is, it's widening out so my targets work. Now the thing I'm going to do, is I'm going to make this fine. I'm going to smooth this out as if this is going to be a rough cut that I'm going to make in there. So what am I going to do? First I'm going to show you that the widening works using this familiar layout of a planned view, a profile view, and the section. And you can see how each end, how that tunnel gets wider, the floor gets wider, and then comes back in. And it also gets deeper as we go down, in reference to the red line, which is the surface line.

And when that is done, when we see it come back up towards the surface, now we're going to take that model and we're going to smooth it out. So I'm going to take the frequency and I'm going to make it, chop it up into more finite elements. So finite element analysis, we know the more elements you have, the more accurate it's going to be. So look how we smoothed it out. Did you see how the curves smoothed out?

Now we're going to go to the next level of detail where we know what the cross sectional shape is, and we know that we have some tracks in there. We have some rail bed in there. And I'm going to assign that subassembly to our corridor. It's the same one. It's the same with the generic, but now I'm making it with more detail. So I'm jumping from a level 100 to a level 300. And we can see that's what it looks like. OK, in the 3D view that's all right, but let's look at it in the good old section viewer. And here, I'm going to look at this specifically coming into a curve because as we step through this, I'm going to zoom in on the tunnel area itself. So you're not going to see it go up and down because we're going to constantly change the elevation. Look what happens when we go into a curve. Is that right?

AUDIENCE: The cant.

LUCY KUHN: The cant. Thank you very much. So here we have canting applied in the curve. And as you watch, when I move through that curve, it's just like super elevation. It's going to go up and then settle back down. So what does that mean? That means that my model has intelligence, it has criteria. So the criteria means that based on the speed, based on the radius of that curve, I need to-- you've all been in a rail car and when you go fast around the curve it tilts up. Just like super elevation on a highway.

So the criteria based design is what enables this to happen. And again, I'm going to show this to you again, because it's important. That we have to, in order to make this work, have to give a speed to our system. And we have to apply criteria to a system. This is the criteria. This is an ASCII type of file. What does that mean? If it's an ASCII file, this is XML, it means I can edit it and I can make my own criteria. Is this good news? This is great news, because I'm going to take what is delivered with a box of Civil 3D and I can apply my own standards. I can also make some interesting, very simple geometric standards as well.

So here we're going to apply the cant. And the cant is applied, believe it or not, to the alignment, to the horizontal alignment. That's what holds the data. Here's the tabular data for that entire alignment. So it's very easy to see. I can do it with a wizard, or I can do it in tabular form. Now let's watch. As we come into the curve, you can see the magenta line as I'm moving, and you can see that the canting is applied and then it's going to flatten back out, which makes total sense. So this is the automatic application of this information, and of course, I'm going to put a style on there that labels it. And the label can look-- in this case, it looks literally like the cross section showing, the tilt showing the flat bottom and the tilt of the upper line.

Here's another demonstration of very, very simple criteria, and how we can change it tabularly. If I have a constraint on the minimum radius of a curve or the minimum length of a tangent line, I can go in-- and you saw the yellow alert boxes-- I can go in and manually change that or I can graphically change that to get rid of those heads-up information about a violation in a criteria that I have applied. So very important to save design time.

Here is another one of these process maps that you're welcome to use. This is what we just did, corridor development. The interesting thing on this one is look at the output. The yellow dots on the right hand side are the output. And this is the output that I need to transfer and use across different applications, whether they be Autodesk applications or other types of applications. This information that comes out on the right hand side is agnostic.

Now the importance of data management. If I need to make changes, I'm going to have to think about data management and I'm going to talk about my source information, and I'm going to talk about consumer information. So my source objects, which would be something like a surface in alignment, and then my consumer object is the actual corridor itself. And the different types of the deliverables that come from the combination of a source and a consumer drawing, it kind of works up, I'll show you the pyramid. And eventually, we get to a deliverable, whether it's a document deliverable. In this case, we're talking about a model deliverable.

And we have Object Management methods. XREFs, that's with AutoCAD, that's just the most simple type of data management that we can use. We also have data references, data shortcuts. And then we can also get into a vault project if we want to do this.

So let's look at what happens if we change some of the source data. So here I am creating a source drawing. And in this case, I'm creating the source horizontal alignment and the profile. And we're looking at this information and I'm going to create that-- first, we put in an XREF. And I'm going to put in an XREF just so we can see what's going on behind the scenes, and that's the little house. Now what I'm doing is from that XREF, I'm actually putting not a house, it's the station. And I've pulled out of that XREF. I pulled the 3D model out of the XREF. Did you know you can do that? That you could put CAD right out of an XREF? And then I put it in the profile view because it's a 3D model. And now, just to put it in there, what I'm doing is I'm making a reference to the horizontal and the vertical information, and then I'm going to be able to use this reference as I start to progress with my design. As I start to build the corridor, as I start to build other pieces that are part of this.

But now, what happens when we come back and we see-- I have the geologic information, and I see how deep that building is going to be. And we know that the tunnel has got to go through the station. So I go back to my source information and I take that vertical alignment and I make it and go through the building. And then I see that I need to fix it so it doesn't go through all of the geologic strata. That might be difficult to bore through granite and base rock. And so now what I've done, is I have that original source information, that source of truth, I've saved it.

Now, when a consumer opens the drawing, look what happens. This is a design drawing. The consumer says, uh-oh, I see that the original information has been changed. Pop. It changes. And I get a little warning in the event viewer that says, OK, your data has changed so you better check things. And look, there it is. So it's instantly updating because I'm using a data management system. I'm not having to go to original drawings and recopy that information. It's all because they're linked together. So this is the data and the document management that we just saw. And remember, I said in the beginning, most of this is data, data, data. And then the documents are the yellow blocks that are the-- for example, the instructional manual or the references.

This is the pyramid of the hierarchy. It goes from level 1, which is down here. This is the source. These are your typical Civil 3D objects. So I would have a surface, an alignment, a profile. These would be the very basics. I used combinations of those objects to do what? To make a level two drawing. These drawings are what? Usually protected like survey points. I don't want anyone going in there and changing the alignment. Can you imagine, on the Grand Prairie, if they change the alignment just to go through my neighborhood? And then of course, then we get to the level 3, which would be the deliverable drawings, which are combinations of all of these. So a consumer drawing would be something like grading, you're site grading, things like that.

So now that we have our model progressed, let's talk about how we get our tunnel model out. And I said that the export on the right hand side of that process map , has to be something that is ubiquitous, that can be used in multiple different types of software. And then let's look at extracting a corridor solid.

So here I have a small area that I'm going to extract. And so I select on the corridor, hit the proper icon, pick the polyline that is showing me that corridor. And here-- this is very interesting-- I have the ability to apply logical naming and layering to that solid. Logical naming is extremely important in a BIM model. You have to know what is what. I have to know what a railhead is versus a ballast versus a concrete embankment. And we can do that in that dialog, because I want things like the layer name to hold that information.

And so I'm going to make this as an AutoCAD 3D solid. I'm pulling out that information and now we're going to open up the drawing that was made from just that small tunnel section. And that's what it looks like. It looks like our cross section. And I. Only brought out the ballast base So, there is our solid. If I look at in the side view, I see that it does have a tilt to it, it has a slope to it. If I look at the top, it has a curve. This is what Revit doesn't like. Revit doesn't like things with slopes. And if I do a mass properties of the concrete, that is giving me the volume of the concrete. So there is a good quantification, and it's done from the tessellation of that 3D solid.

I can also do the major geometry command. This is a great one. What if I had to paint the outside and the inside surface of that tunnel? Did you know that the MEASUREGEOM command, MEASUREGEOM, will give you the surface area of those solids. How cool is that? So now I know how much paint I have to buy to paint that tunnel inside and out.

So the extraction, like I said, with the 3D models, is you have to understand the settings primarily so I can put extended property data. I want to know that that's concrete on the outside of that tube, and that that surface with a ballast surface. And when we export from a corridor, things export differently. If I have a closed area which we call a shape in a cross section, it's going to come across as a 3D solid, that chunk that you saw, which was the tunnel. If I only have a link which represents the surface, like the surface that the rails sit on, like the ballast base, it's going to be called a body. Now bodies are difficult to work with in a BIM environment. I can't-- it's very difficult to do clash detection with a body because it's like taking a slice of a piece of paper through something. And I need something that has a little more meat to it, a little more thickness to it, to get it to function well in a BIM model. So I'm going to show you how you can quickly turn a body into a solid.

Heidi, do you know the command? She knows the command but told her not to spoil this. So that's a body. When I have a body, we need to convert to surface. So, write this down because this is something that's not very well documented. And once I convert this to a surface, you're going to see what it looks like. I'll put it in a conceptual view. So now this is just a mesh surface. Once I have the mesh surface thickened-- now you probably knew the thicken command. The thicken command is going to make that thin, thin nothing of a plane into something that has some mass to it. Because we have to have something with mass in order for it to perform in a BIM model. So that your CAD 101 for the day. AutoCAD 101.

The export of solids and points. Why do I need to export point data? Because that's my accurate control. I need to know where I am on earth. And the solids would be something like that the solid that I just made. Or, for example, the massing study of that station. And so I'm going to use IFCEXPORT. That's the command in Civil 3D that will give 3D solids for use in other applications. The IFC, what does IFC stand for, anyone know? Industry foundation class. Excellent. That's for, it has to be a 3D solid for that to work. It won't work on lines and things.

Now, MAPEXPORT, this is a killer tool. MAPEXPORT is incredibly important because this makes shape files. Why do we love shape files in BIM? Because we have geometry and we have tons and tons of attributes, and that's the best when you have BIM. Geometry with lots of data. And MAPEXPORT does that. One little trick, if you have serious COGO points-- COGO means coordinate geometry-- you have to turn those into point blocks before you can use the map export command. That's just the tip.

Now, we're going to get this over to Safi to work with Revit, but this is what we're going to work with. We have the horizontal alignment, we have the vertical profile, and the information that we need to take to Revit. Here is the starting station, so it starts at 2,000. It ends at 6,000. How long is this alignment? 4,000 meters. But it is a 3D alignment, so is it really 4,000 meters? It's going to be longer because look-- that's the alignment we're going to send out to Revit. You can see it beneath the surface because it's a tunnel. So that's the information, that 3D line is how we need to get to Revit. And just for kicks, if we list it we can see that it's a little bit longer than 4,000 meters. I would totally expect it to be that.

So, with that we have the 3D line. And the easiest way to get it out to Revit is by LandXML. So in Civil 3D I export to land LandXML. I only want to take the center line and the profile. I don't need any of the extra extraneous data. I use the most recent schema of LandXML-- well, the most recent schema that Autodesk recognizes, which is 1.2. And that's the output, the ASCII output. And with that I'm going to switch computers, or Safi's going to switch computers, and he's going to talk about Revit.

SAFI: So I'm going to present the second part of this class, so it's about preparing the Revit model. So here is the agenda. The challenge is to create a tunnel Revit model. The second part will be how to build it in Revit. And the last one will be some BIM uses, like drawing production, construction sequencing and quantity take off, because we have Revit model so it will be easy to use it to produce drawing and so on.

So, what are the challenges? There are two kinds of challenges. The first one is 3D geometry. So we need to get the 3D axis, which is not very easy to do in Revit because we don't have the features we have in the Civil [INAUDIBLE] tools, like profile horizontal. We don't have these notions in Revit. We have to position the section at the right place along this 3D axis. And we have to deal with larger model. So in Revit, it's a little bit complicated to deal with a 4 kilometers model, so that's why we will break it down in separate tunnels at the area of interest. For instance, near [INAUDIBLE] station, or near the shaft opening of the tunnel.

So we need also flow-- when you've got also Revit geometry, we also need to input some civil information to enrich the model. So we have to be georeferenced and we have to set up some alignment properties into it. So here you get a screenshot of the properties of the Revit model. These properties can be defined by yourself. So, that's mine. I do this one. So alignment name, profit and profit [INAUDIBLE] station and station and so on.

We got the main question is how to convey the information from the Civil altering tools to the Revit tools. So one answer could be Dynamo. So we will use Dynamo. I will use the LandXML coming from Lucy, and I will use it, read it into Dynamo because the LandXML is the kind of standard. I have the profile information, the horizontal informations. But I need to create the 3D axis into Revit. And also I've got the cross section. So Dynamo will process it, will read the LandXML, convert it, and then create the geometry into Revit.

So for that, I will use Dynamo Player, which is the most user friendly interface on Dynamo. Its a brand new one. Its has been released maybe one month ago, or something like that. So I will show you Dynamo Player. So it just runs scripts by pushing a button. So it's more easy for the users. They don't have to go into Dynamo and see all those flows of nodes and connection. It can be a mess sometimes, so this is more easy for the end user.

So, why LandXML? As I said, LandXML conveys a lot of information. The alignment properties, the curves of the profile, of the horizontal alignment, the cross section, and also the TIN Surface. But we are not going to get the chance of into Revit in this class, but it's possible as well. It's not an object oriented source files, LandXML, but its a structured data. So I can pick the horizontal alignment I need, I can pick the profile I need, and I can extract all the curve contained in these alignments. So that's why we are going to use the LandXML because-- and furthermore it's a kind of standard in the civil industry. So every civil [INAUDIBLE] tools can deliver such information.

So what's the big picture? So we got all the data in the LandXML. So for instance, an arc is defined by the start, the end and in the center and we will convert into Dynamo elements. So, once we got the profile and the horizontal alignment into Dynamo, its easy then to add the points. Then it's very easy, we've got already the node created by Autodesk for you. It's a reference point by point. So it's easy to convert to points in Dynamo to Rivet points. Then I'm in Revit so I can connect points, I can put that active component where I want. So this is my cross section, and then with the cross section I can do a loft. It will create a solid. So it will be a Revit native element, which is very important. It's not a [INAUDIBLE], it's not a [INAUDIBLE], it's not an IFC. It's a native Revit element. So I can control it, I've got full control of it. So this is the key point.

So, the first step is to create the 3D axis, so here is the process. I read the LandXML, I've got the horizontal alignment, line, arc, spiral. I convert it into Dynamo elements. So I got the PolyCurve. So I've got the xy coordinate of each point. I do the same for the profile, so I got the z coordinate for at each chainage, so then I can create some points into Dynamo. And then create the reference points and the 3D curve. So I will create all these things directly into Revit.

Here's a video. So, as I said, I create-- it's a family. So a generic [INAUDIBLE]. I create some LandXML data properties. So it will be fulfilled by the Dynamo script. And in the input here, I create some properties. And the first one, for instance, if this is the interface with the user, in fact. So the user just have to set the field path of the LandXML. Here, you can see it. Just hit

OK, then run the script, LandXML alignment, so it will read all the alignments contained into the LandXML file. And create some types into Revit. So then the user just have to choose which profile and which horizontal alignment you need. Then just say, OK, what is the start station? For instance, 3,600 to 200 meters. What is a step in the horizontal alignment? So every 5 meters Just hit another script and it will create 3D axis directly in Revit. So every point at 5 meters spacement we can also input at what chainage it is for this point. And we have a point here in the middle, which is the point of vertical intersection. So we get also those kind of points.

If I project the 3D axis into a reference point, I will just double check the length. So remember, it's 200 meters. So the 3D axis is two hundred and something, and if I look at the length of the projection, it's perfect. It's 200, zero, zero meters.

So now, I will do exactly the same concept for the cross section. So I will read the LandXML. I've got all the cross section, got all the points, convert them into Dynamo, create some Revit lines, and then I will use those lines to create my own Revit family.

So all those properties can be a template for your family here. So I've got only the LandXML field path. I just interscript cross sections. It reads the LandXML. In this case, we've got three kinds of cross sections, dot dash 0102. I choose the dot dash 01, sorry. And then, I read another script. Remember to create the point in the line into Revit. So I will get the short and line created by the model-- it's in Civil 3D when you create the section, I will get back everything. It's not curvy, it's not a curve, it's just short and point. But I can use it to create my own stuff in Revit. So that's exactly what I'm going to do. So I will have my own section. And this section will help me to create my Revit model.

So next step is to place this adaptive component at the right place. This is the main challenge as well. So I need it to be tangent to the horizontal profile, and for the tunnel in the profile view I need it vertical. For bridges, it's a different story. I need it tangent to the 3D axis as well. So that's why I created three points, three adaptive points. Always at the same place. One meter, one meter. And those three points define a plane, a unique plane. Three points define a plane and also the rotation because my section needs to remain horizontal all in a section, OK?

So I can handle tunnel bridges with this method. So that's the demonstration here. So I got my 3D axis, I just create a family before. You see just three points here. This is the intersection of my tunnel and the outersection. So we've got three points to define the correct plane.

So the section out, it's exactly the same. I put them into my Revit family which contains 3D axis. Then I choose which section I need. OK, this is section of [INAUDIBLE]. I hit OK, render script, so it will place all the profile along the 3D path and create a loft. So I got directly a solid in Revit. And I create solid, I can set up some materials. It's a Revit model now. I will do exactly the same with the intersection. I've got also the chainage for all those profiles. I will change the section here in [INAUDIBLE]. It runs the same script. And it will create another solid. But I just have to say to Revit, it's not a solid, it's a void. And really Revit will do the job, it will just subtract there, the area. So I've got the Revit tunnel-- it's curvy and so on-- directly in Revit.

Then I have the geometry. So it's a combination of a 3D axis, of profile, solid. I've got some information. Remember, Dynamo fills some information, I created it. Some properties. I created it, so I've got the alignment names, the start and end station. Here it's full length. You remember the 4 kilometers long tunnel we saw. And I've got also information concerning the georeferencing here. This is the start of my Revit element. So with this information, I can georeference it into my project. So it's embedded into the Revit model indirectly.

AUDIENCE: So what happens if the alignments change?

SAFI: But we start the design of Revit when it's mature enough.

LUCY: It's not dynamic to Civil 3D.

SAFI: No, it's not dynamic.

LUCY: We've cut the chord.

AUDIENCE: I couldn't tell. You're pretty sure that--

LUCY: Or we just step it through Dynamo again.

SAFI: Yeah, it's very fast. So fast.

AUDIENCE: What about the cantilever inside? Does that get held in Revit?

LUCY: Yeah, we're just doing our tunnels. That's why you need Civil 3Ds.

SAFI: Yeah, it does the best--

AUDIENCE: That's the question. Does the cants not make an exact experience with Revit.

AUDIENCE: Excuse me, what happened between the points. Is it a straight line?

LUCY: Yes, it's a chord. Yes.

AUDIENCE: So do you really need to export, or couldn't you have just taken the points out of Civil 3D?

LUCY: You could have. But the reason we want to do it in Revit is because he showed you that block where we can put all the extra attribution in. And so now it's a real BIM tool with all of the information. And then also for the documentation, the cutaways.

SAFI: Yes, you will see.

AUDIENCE: But the geometry is not as precise as in Civil 3D.

LUCY: It's the same.

AUDIENCE: No, because you just-- between the two points is a straight line. So if there is a curve--

LUCY: The solid that I generate in Civil 3D is the same. It's tessellated. The tessellation. It's the very same. That's why he said-- I don't know if you picked it up-- the link--

AUDIENCE: --the alignment. The vertical and horizontal alignment. You put the points, and it gives me two points is a straight line.

LUCY: In Revit.

SAFI: In Revit. No I convert exactly the same. If it's knot, it will be a knot in Dynamo. If it's a spiral, it will be a [INAUDIBLE] curve. It will be interpolated. But you can say OK, I need 1,000 points if you want to. It's possible. But it's not straight. No, no.

AUDIENCE: You don't make the--

SAFI: No, I convert exactly. If it's a line in the [INAUDIBLE] it will be a line in Dynamo. If it's a circle, it will-- if it's a knot, it will be a knot. We don't have a spiral in Dynamo so it will be an [INAUDIBLE]. And parabola is the same, it will be an [INAUDIBLE]. [INAUDIBLE]. OK?

So, now we have to georeference the model. So as I said, we are not going to create the wall model into Rivets. So we are picking the area of interest. So the gas station, the shaft and so on. And to georeference all of these product because we can imagine if it has two projects for 2901 and 2902, we need only one source of the coordinate system. This is a site file. And then the site file as the true coordinate system. And then the other project will acquire those coordinate system.

So we show you. So this is a site file. This is all alignments in 3D. It's well-georeferenced. So it's 2000 to 6,000. It comes from the same LandXML file. So now I will open a new project, completely new project. And then I will import the Revit family into this project. But first of all, I have to georeference this project, so I put it in meters. And then I will link the site file here. Whatever [INAUDIBLE]. And then I will just acquire the coordinate of this site file. It's a Revit file. So we have-- I retrieve the information. Then I will import my family into this project. It's an empty project at this moment. So we load it. And then I will just put it at the center of the project base point, and then I just have to get it, go to the properties. I've got all the information I need, so I can make it automatic. It's possible with Dynamo to read the data of this tunnel and set up into the project base point. I do it manually here, but it's very easy to do it. You can create your own script to do it automatically. It's possible as well.

So I will just change the [INAUDIBLE] now. So it's just copy and paste. And you can see that when I change the [INAUDIBLE], the tunnel will fit exactly at the right place in the project, according to the site file, so according to the main 3D axis. So now we just have to change the z so it's not the same. Just change the coordinate here. OK, and done. So you have your tunnel exactly at the right place in this project.

So now we got a Revit model geometry, some information, and it's georeferenced. And I said that this 3D model is composed of the 3D axis of side of a profile, so I made some subcategories for visualization. If you just want to visualize the profile, it's possible. If you just want to visualize the 3D axis, it's possible as well. So it's the same object with different view of the same object. And the profile controls the 3D solid, so if I change the profile, it will change this way. The profile will remain at the same place.

Now if we have two projects, it's easy. Now I'm in the site file and I will just import a model. So it's by shared coordinate this time because it's the same coordinate system. And you see the Revit linked file fits exactly at the correct place. And I can also import another one, which I made. It's 100 meters long this time. So imagine this one is for the gas station and the other one is the shaft. So I just link it by shared coordinates. And you can see here it's inside the right place.

So now we've got our Revit model. We've got the good geometry, the good georeferencing.

So now we can do some drawing production. So it can get a little bit tricky in Revit because we have some curvy to annotate, some reference so it can be difficult with a curvy spot. , Also the construction sequencing, and the quantity take off.

We also create some Dynamo script to help you to do that. So create some section per station with a step, let's say to every 20 meters at a specific chainage. And also another script to dimension the tunnel.

If I go back to my project, I have my tunnel here. I just put-- OK. And then I will launch-- I have some properties on it, you see section view step. 3,600 to get the correct chainage. And just create a step of the view. I just hit the command, and it will create the section directly in my Revit project. So because it's a tunnel, it's fine because it's vertical. And it's exactly the same steps. You cannot dimension directly because Revit dimension reference and the reference at the beginning of the end of the tunnel. But because it's profile, we can turn off the solid and dimension of profile. This is possible. It's exactly what I'm doing in the video, so I'm dimensioning the profile. So I'm dimensioning the Revit object. So if I change the profile, it will update the dimension because the section is at a specific profile chainage. Otherwise, it will not work. But--

AUDIENCE: [INAUDIBLE]

SAFI: But it's not dynamic. It's not dynamic. A lot of people want to choice. OK, so then I can add some [INAUDIBLE] point here. And if I change the profile here, I will change the dimension. And then you will see that the dimension will update directly. So I just move, increase the thickness of the tunnel, reloaded everything, and you can see the dimensions are moving.

So then, if I have another section. So if not a specific step, let's say every 20. I need a section that's specific chainage. Let's say 367. I hid this script. I clicked the tunnel and it creates the section exactly at the chainage I need. So it's 3,667. It's whatever you want. But in this case, I cannot dimension. So what I am going to do is to create some data. Behind the scene, I expose the Revit object into Dynamo. I put it with a plan in Dynamo. I got the intersection lines in Dynamo and convert them into data lines in Revit. So that the lines are related to this view. And it's possible now to dimension whatever the section is. Look, I'm creating just a section like that from 10 centimeters. Go to the view, so it's a little bit different. I hit the same function and just create some detailed curve here because it has been created in fact in Dynamo and I can add some dimension here as well.

So now, we go to the construction sequencing BIM uses. So following exactly the same concept, I can put adaptive components, like rock bolt, shotcrete, lateral girders. Can do some segmented rings for tunneling. And I can do-- because I am in Revit, I've got a nice feature like phases so I can assign for each element different phases.

So this is typical phasing process for tunnel. It has been done in Revit Let's go to the video. This is a straight one. It's faster. So I created some section. I use the same tool from [INAUDIBLE]. So it creates invert. I will do another piece of concrete here, then a shotcrete layer one for the excavation construction, the shotcrete layer too. And also the lining, the final lining. So I created each solid per phases. You will know why just right after. And then I can add some material for each solid because it's shotcrete. It's cast in place, or depending on the concrete, you can add the material you want for every solid. So then I load it into my project, put it somewhere, and then I have to put some lateral girders and rag bolts because for the excavation.

So here I selected this element. The same story, I just input the information in my element, so the shift of the lateral girder would be 1.5-- 0.5 meters, and the spacing is every one meter. I just hit this function. It will create a skeleton of my lateral girder, so it can be used as well to create some over beams, Not just for tunnels, but it can be a proof of a model. So then I get the skeleton and just have to pick the line. And enable 3D snapping here, and it will create directly my object in Revit. So be careful about the justification So let's say it's bottom here. So I've got all my girders. So it's pretty fast to create your girder. You can create also a rag bolt. So it's exactly the same concept. It's an adaptive component by three points, so I can put wherever I want.

So the shift is one meter, the spacing is two meters. And it's a Revit model. It creates a rag bolt so it's dynamic. This family here can be edited, you can change the numbers of your rag bolts. It's a 14 or 17. It's completely dynamic. You can't change it.

And then we have to assign the phases for each of these elements. But before, we have only one block here, one big solid. So in Revit, if you just hit the create [INAUDIBLE] button. And because it has been created of may solid, Revit will create the part for you. So here I've got my parts already created directly. So then I can assign for each solid a specific phase. So this is the trick you have to create in the same family and different solid phases. So you have to think about your phases before creating the big solid.

Then I can also cut both parts because I'm not going to excavate. So 40 meters long. So I just select, for instance, a shotcrete layer. Intersect I would create just the grids here. Hit OK, and then done. Revit just splits this solid in three parts, and then I can assign for each solid a different phase.

So now this is the final one. So all the correct phases, all the girders, all the rag bolts, you can see every phase is here. So phase 1, phase 2, and so on. So you've got nice two phase filter in Revit directly. So you can't move to the phase you want. For the construction of this kind of tunnel and section as well, you can put some label if you want to. This is Revit so you can label what you want, its objects, you can extract quantities. You can-- it's Revit, so it's Revit native now so it's very powerful.

We can also create some schedule. It's very easy. For instance, for the structural framing, we show the girders. I can just add the count of them, the type, let's say, the length. And the volume as well, the still volume. So then I can add the weight. It's pretty-- it's just a formula.

So now I can filter all of my schedule by phases. So for each phases I can get the information of the amount of steel, amount of girders, the amount of concrete. So I'm out of cast in place concrete. I can have cumulative phases because I can use exactly the same phase filter that I got in the views. So for phase five, for instance, I've got 2.07 cubic meter of steel And I can also do a part schedule here. So for each phases, for the concrete, for the shotcrete and so on. And then I can export it to Navisworks, for instance, if I go into some Gantt chart or something like that. But if you want to do a linear schedule, like in tunnel industry, it's not possible in Navisworks, but you've got to chainage position of each tunnel, of each section. So you've got the information.

So this is a quick video of a simulation, construction simulation, directly in Navisworks. So you can do [INAUDIBLE] like that or simulation like that directly in Navisworks. So now we've got our Revit model, and the final step is to send it to Lucy and to InfraWorks.

LUCY: I hope what you saw here was the power of Revit. It was amazing how he could phase this for construction and take out the things that would be difficult to do, the detailing and the BIM attribution that you can't do in Civil 3D. He did a lot of things there very, very quickly. But in essence, he was able to generate a timeline here just based on the tools that were in Revit and starting with that simple model. So by using the power of these tools, it is amazing.

So, here is InfraWorks. Now, one of the important things that Safi did was he said up a base point. He used a coordinate in Revit to tie his models to. When I take the Revit model and import it into InfraWorks, I have to put this in as the offset. I'm going to put his survey point, northing and easting in as the offset. And then-- this is a bug in InfraWorks. When you bring in a Revit model, you have to bring it in under this thing of interactive placement. No matter what unit the Revit model is in, use xy international feet. OK? It's a little bug, but no matter what your units are just put in international feet.

And so when we have this, let's take a look at that tunnel. I have a bookmark at the beginning of the tunnel. There's our Revit base point for the tunnel. And let me put this in a conceptual view, and put it in engineering view, and that kind of makes the surface transparent. And we can see underneath, there's where our section is starting at chainage 2000 is. And we can see our tunnel coming underneath this neighborhood in Paris. And if we go to the bookmark of the nearest station, there is the station. This one was brought in as the IFC file, and remember we made the change in the profile so that what? That our tunnel would intersect and go through the building.

So, in a nutshell, I hope that you've seen an overview of how we pick the best of both worlds to make a very good start of a BIM for infrastructure model. Civil 3D and Revit. Safi and I will hang around in case you have some questions. Other than that, thank you so much for attending and enjoy the rest of Autodesk University. So thank you.