MICHAEL POTTS: OK, so welcome, everybody. This is SIM20859, Crank Up Your Volumes: Revit-Enabled CFD. So you know, audit a CFD class with some Revit tips. Things like that. So quick chance. Make sure you're in the right class. You can, of course, head out anytime you want if this is not the class for you.

So this is--

MANDI EBENSPERGER: Hi, I'm Mandi Ebensperger. I am [INAUDIBLE] in the architectural department for M & W group. My hobbies include skydiving, hiking, and traveling.

MICHAEL POTTS: And I'm Michael Potts, mechanical engineer, facility modeling lead, and analysis and simulation lead for M & W group. So I'm working on integrating all of our analysis and simulation tools. You'll have to pardon me. The Las Vegas voice loss is coming down. So apologies.

So I work for a company called M&W group. We are a global company. Turnkey solution provider. We design, construct, and even operate high-tech manufacturing facilities. We bring in about $3.3 billion a year. We specialize in advanced technology, life sciences, energy, high-tech infrastructure and cleanroom technologies. So you'll see a bit about clean rooms today. So if you didn't know much about cleanrooms, you'll learn quite a bit here.

So quick class summary. We're going to take you through Autodesk and CFD interoperability. High level of detail development. Geometry reuse and replacement. And you know, what you can reuse, what you can't reuse. What you should replace. And we'll also do Revit model uses. So in the NE field, how many Revit users or do we have here? So quite a few, right?

So you guys, how many Revit abusers do we have here? There you go. Yes. Bend it to your will, that's all I have to say.

So anyway, Revit can a lot of things. It's very good at reporting visualization. You know, you put in something once, and you can view it 100 different ways. So we try to leverage that as well. So design coordination, visualization, management, and reporting.

So the key learning objectives of this class is going to be to, hopefully by the end of the class, you can develop a Revit model. You'll be able to learn what Revit information comes into CFD, and how you can leverage it. You'll see some examples of CFD or Revit geometry that can cause problems with CFD, and maybe how to simplify and address it. And then leverage Revit data and parameters to manage your CFD project, just like regular design project.

So, Mandi?

MANDI EBENSPERGER: Class poll. How many people in here with an architectural engineering firm? Quite a few. CFD service providers? OK. Facility owners and operators? OK, not many. Any firms using CFD in-house? Any firms using it, a third-party provider for CFD?

MICHAEL POTTS: All right. So we're talking to a roomful of architects and engineers it sounds like. Which is great, because that's where I came from really. I was lucky enough to be a mechanical engineer. Have some exposure to CFD in college and a couple of past projects. And then get an opportunity in our company, at a global level, especially with our licensing system, the token flex licensing system, really opens up all the software to you guys without the initial purchase. So some key things there that really helped us get started.

So I'm coming at this from a mechanical engineer, Revit expert, going into CFD. So you'll see some of the lessons learned over the past year. So this is about a one-year process, so good.

MANDI EBENSPERGER: OK, with any typical project. We have our execution plans, our basis of design, engineering narratives and calculation, sequence of operations, facility setpoints, and industry standards.

MICHAEL POTTS: Yeah, and you can see some examples here too. How many are familiar with VIM execution plans? Yeah, a roomful of architects and engineers. All right.

MANDI EBENSPERGER: Within those documents there's also project information, location and site information, staff contacts, organizational structure, BIM role, team roles and responsibilities, BIM usage matrix, level of development matrix, which is the LOD for short. Collaboration procedures, software/technology and file naming conventions.

MICHAEL POTTS: So Mandi, being an architect, I mean you're in this stuff all day. You're getting the project set up. You're working with our BIM managers, our BTC managers. I mean, this is pretty much your life, coordinating all the disciplines. So--

MANDI EBENSPERGER: Correct.

MICHAEL POTTS: Definitely. That's why I lean heavily on architecture. Partner up with your architect. Really get into what they're doing. And you'll see in a moment, with good collaboration between the disciplines, I mean you can develop workflows where the family can start in architecture and migrate through, even CFD and mechanical. So we'll go through that.

All right, do you want to talk a little bit about clean rooms, Mandi?

MANDI EBENSPERGER: Yeah. So your typical cleanroom is composed of four main components on the floor. They'll have a raised metal flooring with perforated panels and blank panels, so you allow the air to flow through. And it's raised on pedestals. And then the walls are comprised of glass panels that are four-foot increments. And then the ceiling is comprised of closed channels to make it so that the air doesn't go through other than through the FFUs, which are the fan filter units.

MICHAEL POTTS: That's great. And, of course, this is a good example of shared components across two disciplines. The architect is responsible, just like an air diffuser, is responsible for the placement of these. They own it in their model. But we need good ways to analyze that and feed that information back, so that we can iterally design this project. So, I've got a mechanical component consisting of a fan and a filter, ULPA HEPA filters for the different ISO classes. We'll get into those in a minute.

And these engineer perforated tiles that we have to have both architectural and engineering knowledge about. So sharing content.

So let me talk a little bit about cleanrooms for you guys. How many of you guys have worked in a cleanroom? Designed a cleanroom? A couple? How many of you know what a cleanroom is? You do now, you're looking at the slide. Anyway, Yeah it's just a circular flow box. So this is a pretty simple one. They get a bit more complex than this.

But basically what you have is, we'll start at the fan. And it's fan filter unit, like we just talked. Terminology is FFU, quiz later. Anyway, so they're going to pull the air in, filter it, and push it down. And then raised metal flooring. How many data center designers? Familiar with data centers? A few?

OK, so not much different than a data center, but your air motivator is different. So you don't have crack units. You've got these fan filter units now. There are other ways to design it, but like I said, M&W makes these products, so we have access to that information. And we've really refined the process to work around these fan filter units.

So the air comes down, goes all around the cleanroom. We like to keep it nice and laminar, as laminar as possible to meet our ISO classes. We'll get into those in a minute. Then they go through the perforated tile under the floor, which each of these little tools or pieces of equipment here can have up to 30, 40 connections. Lots of connections going in under these. All kinds of chemicals. All kinds of obstructions.

So this looks nice and open. No. Spaghetti. So you get through there, and all of those obstructions are restricting the airflow. Goes back up the return air chase. A few restrictions in the return air chase, but we iterate with design to optimize the volume without taking up too much footprint. And then right back into the interstitial, and it just flows right around.

So we've talked a bit about ISO classes. So these ISO classes here. I'm going to give you an example of an ISO seven. Now you're going to see I've got them highlighted on the board there, but ISO seven particle ranges from 0.5 microns to 5 microns. And that's going to give you an idea. So per cubit feet, you're looking at about 350,000 1/2 micron to about 3,000 5 micron particles.

There are some general guidelines. So this is an ISO standard for cleanroom. ISO 14644 and FS209E are some good resources if you ever want to dig in and find more. Information is fairly available, but there are some publications for purchase as well. So there are some guidelines. So this is really our baseline, how we start out.

You've got 10 to 15 feet per minute vertical velocity. That's just keeping the air moving, you know, no dead air. To stir up the particles and get them through the floor. Then you got 60 to 90 changes per hour. So that's the volume of air in the whole room, 60 to 90 times per hour turning over.

All right. And then generally a good starting point is 15% to 20% ceiling coverage right there. So over her on the right, you see the range. So how about the range? This is our design range. 0.5 microns to 5 microns. So that's really dust, human dander, hair. So humans are the contaminator of these environments really. Despite the bunny suits, the white suits. They look like a bunch of ghosts running around the place, but you still get particles out.

One of the biggest challenges, we covered FFUs, we covered perf tiles. We'll I'm going to talk to you a little bit about passive cooling coils. So to cool the cleanroom, we don't want water in the cleanroom. So we select these coils above their dewpoints. So it's dry cooling coil, so there's no condensation.

But they're a passive device. So again, what's the air motivator in a cleanroom? Shout it out.

There we go. OK, now, now we have the communication. We'll catch a group here. Don't worry about it.

So anyway, yes the FFUs move the air. Well that's separate, right? So we have to deal with, this device is pretty much a passive heat exchanger. OK, well, there's not one preconfigured in CFD. However, you can obtain a passive heat exchanger result by approaching it from a k factor.

So what we do is, we know the close range. And the K factor gives us a pretty good relationship within the known range of flow that we're going to get through this device. So what we know from mechanical engineering, or when I talk to myself alone at night, I know that my design criteria is on 0.1 inches of water column at about 400 feet per minute.

So with that, and the handy dandy Autodesk CFD help file, F1 for help. I think that's common knowledge. You can calculate the throughflow K factor to enter into CFD later. So just take quick notes. I'll show it later, but our K factor is 10.1, based on that criteria.

So you've got this date going in. It's coming in from all directions, right? If you don't have a good coordinator or you're not integrated in that BIM and collaborative delivery team, you may or may not be getting information from one person or 10 people. So, on the architecture and engineering side, we have more control over the information. And that's a benefit of doing it in-house, right? There's even challenges in-house though, right?

OK, so we know the sites at 500 feet, 99,000 pascals. When you get into CFD, you'll start feeling more comfortable in metric. But I've tried to present some of the information here in English units as well.

Just from ISO guidelines, what we determine is 160,000 CFM is the worst case driver. And MMW FFUs perform really well on a wide range of pressures at a thousand CFM. Good pressure range. 800 to about 1200, 1300 is their range before you have to start adding more of them.

So we're going to go, we're going to start this analysis for 160 of these guys at 1,000 CFM apiece. Nice round number.

OK, so perf tile-free area from the cut sheets. I don't know if you picked up on it earlier. The cut sheets are in the support docs if you want to download them. We'll learn a bit more later. About 30% free area.

Now there's also something called a head pressure loss chart. A bit more accurate analysis. This isn't bad for starting up. You'll get better performance if you'll use that pressure loss chart. But for our demonstration today we're going keep it simple.

OK, so just based on a target pressure drop of 0.06, that puts us about 200 feet per minute is our target, and 800 CFM per. So 160,000 divided by 800 is going to be 200. So we're going to start with 200 perf tiles. There's our buddy. 10.1 K factor. Pull quantities from our mechanical engineering. They've done a high level, load calc on it. Just a block load.

They're saying I need 10 coils at 40 square feet apiece. So they've done a coil selection. They kick back that information to me. And that's five coils for every return air chase.

And then OK, now I want to spend a little time on this. And you'll learn more about it. But you really need to establish a threshold, a lower end minimum object dimension, in your CFD model, a Revit model.

I've gone through eight of these facilities this year. And what I've kind of narrowed in on is about six inches. What you really want to stay away from is modeling anything that's isolated below six inches. It's not going to really affect your results. You can test it. So all this, feel free to challenge and test. OK? That's a big thing. You want to do you want to do microanalyses, test these little areas. And then you can back up your assumptions later in your reports. But I'm trying to share some experience with you guys that I think, maybe give you a low kick-start here.

So 6 inches. All right. So I'm going to flip a slide. And what's the minimum dimension?

Six inches.

There we go. All right. Yeah, it's an important number to know, and I'm going to show you why later on in the presentation. So CFD engineers, dedicated guys, know that a ton of work flows to model the air volume right in the cab. Revit, when it translates to CFD, hooks the name of that air volume and it pens to the name of the Revit family. So you end up with this long family name in there. I'll show you later.

So you really want to, I prefer not to model the air volume, and just build an airtight box, if I can. So this is going to do a couple of things. It's also going to maintain better associativity when you make changes and update your CFD model from Revit. It has less to manage. It doesn't have those proximities.

It uses some kind of proximity algorithm, I think. Maybe my tech support can answer that better later, how that actually is working. But it seems to maintain a proximal relationship to all the objects. And that's how it maintains associativity. So you don't want to-- it'll save you some headache if you don't model the air volume. So, Mandi, do you want to tell us a little bit about the level of development, LOD?

MANDI EBENSPERGER: Yeah. For this example that we're using for the presentation, the LOD, level development, is 300 to 400, which is pretty detailed. It has all the components built in. Within the ceiling you can see the hanger wires, and the fan filter units are very detailed themselves. You can kind of tell that at least they have some volume to them.

The walls have their individual panels that you can see are split up right there. Down to the floor we have individual tiles for the base metal flooring panels. And then underneath, there's also the pegs, the pedestals that the floor sits on.

MICHAEL POTTS: So I don't need all that. I'm a simple guy.

MANDI EBENSPERGER: Yes.

MICHAEL POTTS: And you know me. Simple minded. Easily entertained. But anyway, so I don't need all that, right? Really, one of the things you want to do is idealize and simplify. You're going to take it down to its basic elements. Remember, if you're on a micro scale, you can add more detail. But as soon as you start getting to a macro scale, you want to simplify this stuff.

So you'll notice that my corresponding elements, and I'm going to go into a little more detail here in just a moment. But very simple cubic volumes. Hence, the title. Crank up your volumes, right? Just 3D volumes works really well for us in the CFD world. And if you didn't know it, I'm an LED 200.

So again, I've got some links to level of development and BIM execution plans in the handouts. Go hit those links. Learn a little bit about it if you don't already know it. OK, Mandi, tell me about that cleanroom wall.

MANDI EBENSPERGER: OK, cleanroom wall panels are split into four-foot wide segments. Within these walls, we usually have the doors, mechanical louvers, and then occasionally solid panels if we don't want any light or anything to enter.

MICHAEL POTTS: So, see all those little panels up there? Each one of those would come in as a separate volume in CFD. Trust me, I tried it. It failed. So I simplified it. I didn't really show you much about this, what I get for mechanical. But a little tip, because I got my own wall, I can host my own window.

Well, a window makes a great coil. It cuts it. There's no geometry clash. It's nice and clean. So be creative. You're going to get into this. I had to be creative, out of just pure necessity. So when you get into this, keep an open mind. Look for other resources outside of your discipline that you may not be into. Again, LOD 200. So she's singing the LOD 3, 4 song, and I'm singing LOD 2. All right.

MANDI EBENSPERGER: OK, here in the ceiling you can see the hanger wires a little bit better, the channels that make up the ceiling. And you can see the fan filter units as well. They're a little bit more detailed right here in this image. The ceiling itself is gasketed too, to keep it sealed.

MICHAEL POTTS: Yeah, and notice something else. Keep this in mind. These ceilings are walkable. So if you're not into cleanrooms, I mean, you're walking on these ceilings. There's diamond plate. I mean, us country boys from Oklahoma, we love our diamond plate. So I just see all this diamond plate, see a diamond plate up there, and I'm just, Oh, yeah. So, anyway, and then I go back to my truck, and there's not enough chrome.

But yeah, walkable ceilings. Scary at first, but you get used to it. So I take her families, we'll show you the process in the demo, but I'll copy paste right into my model. And change the type. So Mandi and I have worked together. We know what we need in each other's environments. And I've got a simple workflow where I copy paste, she links in my model. If I make moves, she moves to that. She can copy and paste back, which she never does. She doesn't take my stuff.

MANDI EBENSPERGER: No.

MICHAEL POTTS: I don't know. I think we have a one-way relationship.

MANDI EBENSPERGER: We do.

MICHAEL POTTS: No, just kidding. Anyway, yeah, she likes to keep her house clean, so I understand. All right.

MANDI EBENSPERGER: Raised metal flooring. So here you can see the individual pedestals for the two-foot by two-foot tiles.

MICHAEL POTTS: Yeah, and again, you have some channel there, right, Mandi?

MANDI EBENSPERGER: Yes, yes.

MICHAEL POTTS: I mean it's this system that's constructable. And it's built into our families. And it's great for construction, saves us lots of time. Because we're M&W. We use our same products. We know what we're going to throw out there if we can get it. We don't have to put it out to bid very often. So anyway, again, generalize. You know, what do I do with her perf tiles? Anybody want to guess? Control-C, Control-V. Copy, paste. You'll pick up on the theme here. We got a groove going.

MANDI EBENSPERGER: Yeah.

MICHAEL POTTS: Yeah, go ahead on the equipment, Mandi. That's nasty looking stuff, isn't it?

MANDI EBENSPERGER: It's a mess. OK, so when we get our equipment layouts, we have to coordinate and make sure that the move-in and move-out paths are listed or shown, and that everybody can move around the tools.

MICHAEL POTTS: Yeah, and again, simple guy. I just want volumes. So for airflow, for heat at a macro level, you really don't need that detail. Makes very little impact on your CFD at the macro scale, even if you narrow it down between tools, there's really not much impact on it.

So, what we end up with is something like this. And you know, I'm going to preach it. This is, I really want you to use your Revit plan sections, 3D views. Even though you're not in the design, and you're not publishing design docs, you do have to publish a report. And you have engineers and architects reviewing your reports.

So if you put this in the context, in an environment that they're in, they're going to digest it better. , Potentially they can get the information, if we make the trip back, by any set of Excel tools or whatever. You know, they can see it right in the model. But, yeah, again, you tag something in

Revit, it's going to show up the same in view. Revit has levels that I align with architecture. Reference planes that I connect my CFD walls too. So if she just makes a slight shift, like maybe this chase gets a little wider, a couple of feet, because I told her, hey, you're choking me down. Open up.

She can move her wall, and I'll just move my reference plane and align to it. So I recopy, so I have two possibilities, right? I'll copy when it makes sense, usually for my first or second iteration. Then just adjust to the line through the link.

So this is my hero. This will solve a lot of problems before you ever get into the CFD environment. And that is the Revit Interference checker. It's a simplified interference checker, and honestly, in design and construction, they can use it. But things start to get complicated with other disciplines, and they tend to go to Navisworks.

But for me, for what I'm doing, I'm coordinating with myself. And I have to make sure I have no clashes, no geometry conflicts before I got to CFD. And I won't get errors, I won't get stalls in CFD. So again, you keep your house clean.

So it's a simple select. I'll show you how to do this in a minute. And you go down through here, and hopefully you get the happy sound right here. No interference detected.

All right, we're going to move pretty quickly. Launch it. Get a view open that has that open. You can actually have multiple views. There's a nice workflow I discovered that you can build up your environment. You can start with the recirc components. That can be the OO recirc. I'll show you that in a minute.

And you can start building up complexity. So start simple. Build up complexity. Then you can have another view, and it's going to respect the view that you're in, that you turn on the equipment. And you can have another view where you have all the little obstructions modeled up under the floor. Turn on that.

And then you can duplicate the design over in CFD, and run multiple designs. And it's a good base point.

So we imported into CFD. I'm going to show you a bit about the geometry tools. It's an automated message. And again, when we import in, because we modeled no less than six inches, we have no errors. OK, great. So that was a benefit of limiting it to six

Setup tasks. Just know left to right. You start with geometry tools. You're going to cruise through these, guys. It's very logical. So don't be too intimidated by the CFD process. There's a lot you can get into, and you can make it as complex as you want to. But you can also take a simple approach too, and get some very good results.

And we set up our environment. That's back from our spreadsheet. We knew the cleanroom was 70 degrees. Cite pressure was 99, 507 pascals.

So, we're going to do something here. And I'm not going to take it through each one of these, but I want you to remember a couple of things. We're going to Select, Group, Assign, Hide. So, what are we going to do?

- Select, Group, Assign, Hide.

MICHAEL POTTS: See, you haven't even seen it yet, and you're going to do this. You're already experts. OK, so we're going to go through the coils. We're going to go through the equipment. We're going to go through the FFUs. And we're just making these groups, OK? Pick and group, pick and group. And it'll solve you a lot of headaches.

So, we'll get into the mesh diagnostics. Because we have done such a diligent job getting through, and we know our minimum dimension that is six inches. You know, we're not going to have these meshing errors in the diagnostics, and we'll set those settings below that threshold.

We'll get into the mesh, we'll run automatic mesh, we'll refine the mesh. One thing I want you to remember when we get into it. This is straight from Autodesk documentation. For coils, the perforated tiles, and any other resistance volumes are what these things are called, as well as a fan filter unit as an internal fan, the minimum number of mesh elements through it is three. So you have two magic numbers, 3, 6.

If you remember that, that's going to get you a long way through this process. OK, and then we're going to solve [? evection two ?] works well for convective heat transfer is really what we're doing. And then, and I'm going to show you that you can actually start viewing the results at the preliminary iterations. You don't have to wait till the thing runs. Because these things can take minutes, hours, days, weeks.

I haven't gotten into weeks though, so I'll say days. Sorry. Some of you may have gotten into weeks. I have the bane of my existence project that I suspect at 75 million elements might hit a week. So, somebody can relate to that. I haven't even gotten into yet. OK, and we'll go through the results. And again, we're going to keep this simple. We're not going to deep dive into results too much because it's very robust.

You can extract data from these planes. Slice, dice it. I mean, I feel like the Ginsu chef up here trying to sell you the latest, greatest. But I mean, it's just like Revit, right? You can slice that Revit model up any way, but when you slice CFD, you get the creamy filling. You get the data. You get the data, all the nodes, all the mess that you set up.

And you can pull it out. There's some scripting. There's API. So maybe that's next year, right?

OK, so time to rock the demo. Let's go to work. Can anybody tell me what those are? tombs? No, those are magic bottles. They make the beautiful sounds. OK, we're going to switch over. The sounds of rock.

So what I have open here is my CFD model, and it's fairly developed. I went ahead. I've got my ceilings. I've got my walls. I've got my airtight box around it. And I went ahead an migrated into the tool. So what I'm going to show you is bringing in the FFUs and bringing in the perforated tiles from the architectural model.

So here we go. Cool thing about Revit 2017. You can actually have in the same session of Revit, have the model linked in, and it won't unload. You can have it open, and it won't unload for you. That was a thing in the previous versions where it would basically unload it.

So I'm going to jump back over. That's my secret tag. Let's get out of that boy. OK, so here's our architectural model. Yeah, so look at that. Look at all that. I mean, you don't want that in CFD at all.

So quick tip. Get a couple of view open that are at the same level. This will make your life simpler. So I've got a ceiling view. Luckily Mandi and I talk. I know what her levels are, that we're working in. And she knows what mine are, so we can use bi-linked view if we want to, and make this a little faster.

So I get that open. We'll get the corresponding level 4 ceiling. We were really coordinated on this project. We had exactly the same view names. All right, I like to use work sets. I personally like every Revit model to be work shared because I can color code by work set. You can use parameters. There's other ways. So again, be creative. Use your Revit tools. There's different ways to manipulate visibility graphics.

So all right, what am I going to do? Look at you. Right click, Select all instances, Visible and then View. And then a Control c. You got it. Control c. There's enough people in here. I think we got plenty of prizes for everyone. So we don't have to get competitive.

So there's a cool little tool here, I use it all the time. My current work set is CFD FFU. And under modify and paste, you have a line to current view. That's going to slap it right in. Popcorn's popping. All right.

Luckily these things are still selected, I don't even have to do anything. And look, we have the magic number 160. Because--

MANDI EBENSPERGER: We talked.

MICHAEL POTTS: We talked. Imagine that. Architectural and mechanical talking. OK, so I'll just change the type. CFD FFU. All right, moving on.

Let's go those perf tiles. Let's get those out of the way. So switch back over. Want to go to RMF is raised metal floor, so I do get kind of short in my terminology. Right click, Select All Instances. And there you go. You've got it. All right. Easy peasy. No big deal.

I do want to change my, and this gets me all the time. But we'll change it to the RMF perf, and back to Modify, Paste, Align to current view. But you see the process, right? I mean, just talk to the people you are working with. Try to use what they're using. understand how their stuff is created. And you can generally make a corresponding CFD counterpart. If we're really good, we'll integrate it into the same family, but right now, we're not quite yet.

Oh, look at me, I escaped out before I changed them. That's OK. Select all instances, and View. Switch it over to my CFD counterpart. Now, see the six? That's my 6 inches. Hers are only 2 inches thick. Mine are going to be six. I'll take you to the section and kind of show you how it looks.

All right, that's all the Copy, Paste. That's the simple part. Really it's not too bad once you get your head around it. So you kind of see here, where I have 20-inch FFUs. I have a 20-inch ceiling. What I found was the air between the FFUs didn't matter to me, for what I was going for. Makes life easier on the solver if you don't have these gaps between elements.

And then Mandi threw me a curve ball. I don't know if you caught this mess. Dag gummit, Mandi. Look at that? Look what she did to me? Two inches.

MANDI EBENSPERGER: Yep.

MICHAEL POTTS: So, anyway. It's just how it is. You can't always get what you want.

MANDI EBENSPERGER: Got to keep it interesting.

MICHAEL POTTS: I know. So let's get back to our model here. So anyway, I push the ceiling up to the CFD. When I suppress this volume, you'll see me suppress it, it's not going to calculate the ceiling in CFD. And it will ignore that two inches.

This time we're going to get a little air, because we're way, way below. But I'm going to ignore it, because the volume in between them suppressed. Same with the perf tiles. These can get really close. Now, some of you may be thinking, CFD. Why don't you just treat the whole floor and whole ceiling as a single flow motivator?

Because we have the ability to modulate these FFUs individually in a control system. So in the facility, in a control system, these are networked. They all have addresses. And if a space gets too hot, they'll ramp up and down. Or I may cluster a few together. So I want to have individual control so that I can be very agile. When floor updates come, floor plan updates, design updates.

People are-- I got Mandi in architecture, and I got mechanical engineering throwing changes at me. And I can use this Copy, Paste thing if I model it all together. But with some good practice, you can keep that workflow and keep very agile. And maybe reap some of the benefits of either in-house CFD, or even third-party CFD. If you can integrate in their processes, it's really key.

So anyway, we'll keep moving here. I'll get off my soapbox. I guess. These are my cooling coils, six-inch walls, six-inch coils. Getting tongue tied here. And everything. You guys saw this before. I think we're ready to go to CFD.

So here's my view. We're going to hit the magic button here. Launch active model in CFD. And cross our fingers. No, it's pretty reliable. oh I guess we have to put it somewhere, don't we? I've got to put it in my documents. Might as well put it in my project folder.

It's got that fresh folder smell, doesn't it? I just made it. Does anybody know what a manila folder smells like? We're all paperless now. I miss the smell of manila.

So it's going to crank up here, and we're going to get into those geometry tools. And we're going to make some adjustments here. So while that's going, we do have some freebies up here. If you guys want to stop by, you need a charger, a pen or a screwdriver, tape measure/bottle opener/flashlight. Who doesn't need that? I mean, I want to measure things in the dark.

You and me going taping in the dark. So anyway. So we'll let cook for a minute. Let me take you back in. So one of the things, again, I say. I'll take you back to this floor plan, because some of the other things that we won't get to today. But we have to deal with the heat loads on the tools. So these are in schedules.

Right now it's a generic 3000 watts to the space. These tools will actually extract some exhaust of their own from the space. So you'll need to know your inlets and outlets to your domain. And these tools actually take exhaust out. So, of course, you'll have to have outdoor make-up air to go into the domain, as well. Which we don't have modeled in the session.

But honestly stuff like that is available in other Autodesk tutorials. You've probably seen the big open space with the diffusers coming off and the outlets outside the sides. So there are some tutorials. But, yeah, look no issues. Even at 3 inches.

It's going to crunch a bit more, so-- But, yeah, you can leverage it in tagging. You can leverage it in schedules. There's all of my equipment. I can schedule my tiles, my flows. I actually don't have them scheduled. But again, you have all of this right here. You can export this to Excel. With another application, you can export to Excel. Manipulate, Import.

So, you know, engineers love to work in Revit. So if you're getting data in Revit, you can start developing look-ups to CFD, and syncing up your model. So you can get really creative. And then you can actually report their data in your model and have a level of confidence. And the data is right in front of you when you're making those assignments. You don't have to go digging for it in another non-graphical environment.

I hate going into schedules, and then looking at the tags. Because these numbers are not the same for 16 pieces of equipment in a manufacturing space, I'll tell you. So, use leverage Revit scheduling. I manage an issues list in Revit too. So if I know the equipment layout is going to change, I'll put a date in here when to expect that change. And I'll track it. I'll generate reports from it. So you can leverage Revit just as you would in a design environment.

So, let's see how our buddy is doing? Did we get it? Are we in? We' in. All right, OK. What am I going to do next. The four-step process, I'll give you a hint.

AUDIENCE: [INAUDIBLE]

MICHAEL POTTS: Yeah, so we're going to Select, Group, Assign, Hide. No, close enough. I was expecting today. So, you will have to get used to CFD's navigation process, but it's not so much different. There's a couple of things. Escape doesn't Unselect, OK? You have to hit Deselect All to get that unselect feel.

But you don't have to hold down control at the same time, so just click, click, click. Smack it up a bit, rub it down. There we go. Flip. OK, so we got our envelope. Group, Group. Name it. What do you guys want to call it? The show? The boundary? The border? No, let's call it the envelope. Manila envelope. Let's do that. Seems to be my thing. OK, manila envelope.

Oh, and that works because, you know what? I have a material called suppressed that is manila color, almost. So you'll learn your materials. The stuff is very stock in CFD, and you can learn quickly about it. You can suppress anything you want, but I leverage suppress so much that it necessitated a material for it. So, suppressed. It's going to turn it yellow. And this is how I'm tracking all my suppressed volumes at a single glance.

OK, so Select previous, and Hide. Now left clicking in the space. Get you a little shortcut here. And this is Hide. And it's got some nice mouse over tips, so you'll start to catch a groove. But there's different ways of hiding this stuff, but I like to just click the left click and hide.

After I get to this point, I do like to go transparent, so I can see my visual roadmap, how I'm going to drill down through this thing. So the next big thing is the air. This is the air that CFD put in. I mean, it's very functional. This is what I would have modeled anyway. So again, there was no need, since I sealed up the environment, and I was confident in the airtightness of it, that I can trust that CFD would put in the right volumes.

What am I going to do next?

AUDIENCE: [INAUDIBLE]

MICHAEL POTTS: Louder. There you go. All right, and we'll call air, air. If I had roses, I'd call them roses. OK, and it's my materials. Default for air, it's going to read the scenario environment, which we need to configure.

So 99506. Five I've only done this 100 times. 70 degrees Fahrenheit. All right, so that's our baseline domain. You know, with the heat loads and the space and things like that. It's just going to start from there and iterate through and get that.

Select previous, I use this a lot. And then Hide.

OK, all right. Let's go for all those little architectural walls and stuff that I really don't need the heat transfer across because they're so insignificant compared to the heat load of the tools. I'm not holding Control, by the way. Just remember.

All right, all together now. Group-- I didn't say name it, did I? I'm going to change the lyrics on that one. OK, all right. And-- Assign. We'll get there. I'm going to suppress those guys. Solid, Suppressed. And then we're going to Hide. OK, you guys got it. You're pros. And use the [INAUDIBLE] key. I mean, this thing is slick. Cool thing about CFD that I actually like is it's very smooth and fluid, similar to Navisworks. I think the graphic engine, I like the feel of it. Feels better than Revit.

But left or right, it's like a window crossing. You don't have to window around things. This is good and bad. You'll find this out. But, yeah, I can just barely touch it. And you'll get some things that are really close together, and you just barely window the right way. So it's all about how you look at it. So if you can't quite get it in one direction, flip it around. Try another way. Go ISO, pan around. Try to get in there so your little windows grab more than just what you want.

But, yes, notice it does select all the way through. So I did get all 10 of those coils. OK, so we're going to Group. Yeah, OK. Coils, plural. There's more than one. OK, and then we're going to aah. Edit, oh, let's say edit. Yeah, because that's what the dang tool says. OK, I've got to rewrite this one, don't I?

All right, so default materials. Sorry, my materials, I apologize. It's a resistance, and again, the K factors. OK, I've got a bit of time, so I'm going to pop this up.

I keep a certain group of coils. I have some typical coils on every project, different K factors, different selection points. I like to be descriptive in my names, personally. Little tip, and I've got to credit Mark Decker, with SIM specialists for getting me through this one. Which I don't think they're the same company now. Capitalized on my AutoDesk consulting credit. So if you're enterprise, you've probably got some consulting credits there. You don't have to tackle this stuff on your own. there are ways and means. And they'll probably even help you anyway.

These guys, one of the best group of guys. Our AutoDesk managers and development team. They don't want you to suffer this stuff alone. They know it's complex. They can help you get through it. So anyway, I digress. Back to it.

So a nice little tip here is we want the air to flow straight through the coils, because there's fins in the coils directing the airflow. So we don't really want air going all kinds of directions. We want it to go straight through.

So a little tip. About five times or more the K value will force the air to go straight through that coil. You're basically, I can't even think of a good analogy, so I'm just going to stop. All right. So that's that. Apply.

I'm going to pick up the pace just a little bit. Select previous, Hide. We're going after those FFUs again. Everything's conveniently in a nice little row. Just to show you I got them all. You can also look at the magic number, a little preview down here, kind of like Excel, kind of like Revit. It shows you how many you have selected. It's you friend.

- Is there a filter?

MICHAEL POTTS: I haven't found a filter. Doesn't mean there's not one though, But, yeah, I wish there was a Revit filter. But that's why we're grouping. Because we're going to keep selecting and modifying later. So you make up your groups.

So speaking of groups, let's do that. FFU. Oop, failed. FFU2, and I'll find FFU1 later. OK, anyway, edit my materials. This is an internal fan and pump. [INAUDIBLE] Remember that. OK, so I already have one set up for 1,000 CFM. Let me get you behind the curtain here. You can set this stuff up yourself.

Constant volume, thousand CFM. I don't have these things modulating in the CFD environment. This rotational speed. If you don't need the rotation, if you're not just analyzing one fan, and the internals of that fan, set it to zero. Because that will make CFD do some crazy stuff inside that fan. Just set it to zero. Because we didn't model enough detail in that fan to let the centrifugal forces push it, motivate that air around and down. Because it's in a square box, it's spinning it around a square box. It does funny things. Don't do it. SIM factor one is fine. And click OK.

We have to set the direction. Which way are these fans blowing? Down. We have a Cartesian coordinate system. That's the z direction. So pretty intuitive, right? Z. And then down is minus. That's our direction, we just set it. Apply. Select previous. Hide. OK, and same with the tools.

Now I'm going to assign heat loads to these later. I'm not going to make them suppressed material. I'll make them steel. So group tools. Assign. Edit. And the default is fine for this one. Man of steel. So they're all steel. They're all nice and shiny. Notice the legend is starting to populate down here. You can really get a feel for how your model is developing at this point, right?

So Select previous, and Hide. All right, last but not least, our perf tiles. There can be thousands of these things. So you'll get into a situation, I don't have it here, but very often, I just barely have to bring that window down and just touch the top. But it says I have 200. Yes, I know my model, I know how many are in there. 200.

OK, so this is my last time, so let's do this together this time. Let's all sing it. What are you going to do? Group, yeah, you got it. So create a Group. Perf, I'm going to abbreviate because I'm lazy. Perf tile.

And we're going to Edit. Yes, edit, really easy. Yeah, these are volumetric resistances, volumetric resistances, volumetric resistances. But I'm not using defaults because I have special ones. Perf tile, 30%. Behind the curtain, this is all we have. 30% equates to 0.3. Again, I even kept the other ones K factors, at the same level. It just forces the air straight through the tile. So, OK.

And what direction?

- Negative z.

MICHAEL POTTS: Correct to negative z. But because these are passive devices, we don't have to force it. There is a potential for these things to flow the wrong way. So if have too many obstructions, air can come back up through the [INAUDIBLE], so you've go to watch that. Click OK.

Let's Show all. I'm going to go through this fairly quickly, guys, and I apologize. But let go into meshing. Diagnostics. OK, so diagnostics is all over here in Autosize. So focus on this area, Autosize. You've got the Autosize button, and mesh. So I'm going to go through this pretty quickly. So for this exercise, I do like to have the outline view on, so I can see it the little arrows that it's going to put in if I have problems. So diagnostics.

We're going to go, what's our magic number? Six, all right. All right. See all those arrows we got? CFD is just cussing us out right now. Like, you are a fool. But we'll go five. We'll go below it, you can go 5.5 if you want to get real testy with it. And then you can hit this Use Highlight link, which is going to set this for the mesher.

And we're going to get some surfaces. Again, it's trying to work with us, but it's still a little high, so we need to kick it down to 5 too. OK, we did that. Now because we have those little two-inch gaps, it's saying that I might have some problems with the surface. But because I know I suppressed that volume, I'm pretty confident I won't have any issues.

Now, so definitely there are exceptions to the rule. And maybe it likes [INAUDIBLE] so close together. So close. All right, so we do need to suppress. We talked all about the suppression. I made a family. I like it. So just so you see, maybe we'll do the group here. Go back to transparent. And it highlights all the suppressed volumes. Right click, Suppress.

All right, so you get a line through an item if it's suppressed. this is a benefit of-- because you can have lots of materials. This is why I make my own material. One for visualization, two for organization.

We're good. We're suppressed. We have our groups here. We're going to Autosize. So we're going to go back to mesh sizing. Autosize. This will take a moment, but it's not too bad, especially with this size model. That went pretty quick right, right?

So, quick question. How many elements do I need through my volumes and my internal fan? Three. You got it, you got it. OK, so because we made all of those filters, let's cruise through this real quick. So, if you right click while you're in mesh mode, you can go straight to your groups. So let's do those FFUs real quick. OK, so I got the FFUs selected, it says I've got four volumes selected. Hang on, Deselect all, because I can't hit escape.

Oh, that was my wrong group. Oh, man. Nothing's perfect. What do you guys expect? OK, FFU2. you guys are paying attention, though. Man, I'll give you that. All right, moving on, we've got to a cruise. So Edit, just like materials. It's very-- Select, Edit. We already did our grouping. It's like, it's rinse and repeat. You know, girls do it for their hair. I do it for my hair too. I'll rinse and repeat once in awhile, I'll wash twice.

Anyway, let's go. All right, I like to use uniform just to make sure I have-- it's the same element, and why not? And then I just drag the slider till I get three elements through it. So quick tip, each of these dots are a seed. The analytical element between the seeds are the mesh element. So right now, I have three seeds. But it's only two elements, so I've got go bring it down. I know it said crank up your volumes, now you've got to crank them down. Don't just me.

Apply changes. And you can hit spread changes, that's what I would do next, it will take up a bit of time. I'm already at 1.4 million elements, so you have a nice little preview of how big your model is getting. And this is important to understand.

There's an AutoDesk guideline for hardware on computers that, it's recommended that for models every 1 million elements, that you have two gigabytes of free RAM. OK, so it's important to know your hardware when you're doing this stuff. So I have 32 gigs of RAM, so if I start getting close to 15 million elements, I know I need to coarsen it up a bit. I need to be maybe use the cloud solver. We can talk about that in a minute.

So anyway, I won't hit spread changes. That takes some time, but know I did that before. OK, got to keep drilling down. I'm not going to hide in the mess mode though. Group, perf. Zoom in so I can see what in the world I'm doing. Edit, Use uniform. Bring it down, down, down. Wait, I'm not paying royalty on that, just because I sang--

Got it, OK. So four seeds, three mesh elements. OK. Apply changes. You can hit, please hit spread changes, it does make a difference. It basically cascades those changes to the surrounding elements. Apply.

OK, we need to do the coils. Right click. Group, not group. Not make a group. We're going to the coils. OK, zoom in on these guys. Edit. Use uniform. Drag the slider. I like to click the slider. You can click it in the line. It'll go down. See my elements are getting up there, but we are there. All right, four seeds, three elements. You've got it

OK, so we're ready to solve. Yeah, now, you can put more diligence into isolated areas. If you have a complex model, you can really refine the mesh. You'll run it. You may want to refine it more. But for this, just one thing I want to point out is the solver window here.

For, again, Quebec conductive heat transfer, which is what we mostly do in the AC industry, you need an invection scheme. I always get tongue tied with that one. Invection. An invection, too, you can do some research on these too. And the Autodesk help files OK. Click OK, click OK.

And then, I'll hit-- now there's a couple of workflows and a couple of schools of thought on this. You can run for a couple of iterations and stop and check out and see what's going on in your model. I'm about to show you that, even while the simulation is running, you can look at the results and make sure your air is going the right way, and you can stop the run.

For most of my models, they take somewhere between 150 and 500 iterations. Autodesk CFD will stop when it reaches what's called convergence, when the solutions to the numerical equations start to converge within the tolerances. So you can do some research on that. So crack open your numerical methods book, or google it. You can do that.

I'm not going to hit solve. What I do have going on in the background right now during this whole time, is I've had a CFD model running. And this is what I wanted to show you guys. I started it an hour ago. This thing's been cranking.

But as you can see, these lines will kind of go up and down. But they'll start to straighten out, they'll start to converge, OK? Let me make this a little smaller. So this is running. You can look at the legend and get an idea-- you knew what your opening sizes were. You probably had a good idea of what your velocities were going to be in this space. So that's a good indicator. That may-- if you're running Mach, or you've got-- even if you're 5,000 feet per minute or something like that, you want to stop the run.

But I'm going to go to planes. I'm going to add a plane. I mean, Autodesk CFD leverages the physical cores, and most Windows operating systems have hybrid threading. So it leaves those virtual cores. So this is a four core computer I7. Four cores, the physical ones are tied up in CFD, but there are some resources available where you can keep working. I mean, I've been working in Revit, presenting. And it still leaves resources available. I really do appreciate that about Autodesk CFD.

Yeah, so again, I'm in my plane here. We've got about four minutes left. But I want to cut it the other way. So you do have to change the normal. Or I have to change normal. So again, [? cartisian. ?] The normal's in the y direction. Close that. Look at the top. Again, you can just kind of drag things around. It's actually really cool.

So I kind of want to cut, personally I like to cut through a coil, a perf tile, and an FFU to get a really good idea of what's going on in this thing. OK, so that's looking pretty good already. It's going through the coils, the velocities are in a nice range. We're picking up a little high velocity with the coils, which was expected. And I need to see some vectors. I need to see some arrows here. So let's turn those arrows on.

So on the vector settings, or you could have done it up here under vector. Right now, it's set to none. If you do a velocity vector, you get kind of a 3D arrow, so you can tell if the flow is in and out of the page. I don't know if you remember that from physics classes and inductors and things like that.

I know I'm looking at the xy. zy or zx, I think I'm-- so it's going to throw some vectors in. Sliders, I mean we're dragging sliders here, guys. It's really not too bad. So I'm going to bring them down in size, and I'm going to kick them up in density. But that's good.

So you can kind of see right here, even at a few iterations, I mean this thing's working the way we want to. It's coming right through the FFU. Nice, good flumes coming down. Coming through the perf title. It's turning under the floor. Going up the chase. And right through our cooling coil in a nice linear uniform flow. So we've got a good base circulation model.

So now that we've established this, we can duplicate the designs scenario over here. Right click, I won't do it. it's actually grayed out. But you can clone the scenario. And now you can sync up your scenario clones with those views back in Revit, and have them named the same, and go to another view that has more content. You're building it up. You can put your obstructions in the next one. Then you can put your air inlets and outlets in the next one, and get in and out of the domain.

So with five views and five design scenarios, you can really build it up from an empty shell all the way to a fully filled out cleanroom. And that's very valuable in a report.

We only a have a couple of minutes left. We'd like to try to take one or two questions if we can. So--

AUDIENCE: [INAUDIBLE]

MICHAEL POTTS: Oh, thank you.

MANDI EBENSPERGER: Thank you.

MICHAEL Survival kit. Appreciate it. Well, that's great. Questions? We've got a couple of minutes. And I can

POTTS: meet you guys outside too. So we don't have to get it all here. I'll stay freed up. Yeah?

- [INAUDIBLE]

MICHAEL POTTS: You can. Very good. So you can copy monitor. So I can copy monitor those walls, right? So your gears are turning. Yeah, so that I can do too. With lots of walls, it gets pretty complex. But that's great. Because I got walls in my model, she's got walls in hers. That's a great idea. Yeah.

Any other questions? Yeah?

AUDIENCE: [INAUDIBLE]

MICHAEL POTTS: Good question. So you could do room by room, if you want to really nail down that you are diligent and you've designed a pressurization. At that point, you would really simplify this stuff. Your rooms would just be single blocks, and you might do boundary conditions between them, pressurized boundary conditions. Or just single air inlets and outlets, because at that macro scale, you're looking at the whole building, right?

You can do one air inlet into the room, and then a crack. You can model cracks, like stick a door in there and put a little crack around it. And so you would model your cracks. And then you also have procedures rooms, right? You have to keep those clean as well. But the bigger you get, the more simple you want your geometry to be.

AUDIENCE: [INAUDIBLE]

MICHAEL POTTS: They do. That mesh size goes through the roof, but you get a feel for it. It's not too bad. Any other questions? All right, I really want to thank you guys. We have a couple other slides here. Let me go back to it. It's a little quiz. It is 4 o'clock, but we'll let's see if we can do this right here. Go ahead, Mandi.

MANDI EBENSPERGER: , OK, who can tell me whatever FFU and RMF stand for?

MICHAEL POTTS: We can answer as a group.

MANDI EBENSPERGER: Yes.

AUDIENCE: [INAUDIBLE]

MICHAEL POTTS: Excellent. OK, everybody gets a prize on that one. and next?

MANDI EBENSPERGER: And next, what was the minimum dimension of any object in the CFD model?

AUDIENCE: Six.

[INTERPOSING VOICES]

MICHAEL POTTS: Go ahead.

MANDI EBENSPERGER: What is the minimum CFD mesh element quantities through a resistance volume or internal fan?

MICHAEL POTTS: Three. OK, right.

MANDI EBENSPERGER: Good job And who is the guitar amp manufacturer of the Autodesk wall of rock on the key learning objectives slide.

MICHAEL POTTS: Marshall. All right. We got some winners. Very good. We took the questions. Anybody get the cor chart reference? Yeah, it's there.

Please give me some feedback. Class survey, you can do it on your Autodesk app after your session.

MANDI EBENSPERGER: More questions, visit the AU answer bar. It's open daily from 8:00 a.m. to 6:00 p.m. on Tuesday and Wednesday, 8:00 a.m. To 4:30 tomorrow. It's located at Hall C, level 2. And help shape the future of Autodesk. Connect one-on-one with everybody at the idea exchange. You can earn Amazon gift cards and enter our GoPro sweepstakes.

MICHAEL POTTS: So everybody can do this, right? You think you can do this?