BILL ALLEN: All right, welcome everybody. How's everyone doing?

AUDIENCE: Good.

BILL ALLEN: Good, good classes today?

AUDIENCE: Yeah.

BILL ALLEN: Yes? Yes, some good ones, some good ones? Good. I wanted to welcome you guys to this class, "The Future of BIM Will Not Be BIM, and It's Coming Faster than You Think." I need to start picking shorter titles, I think.

[LAUGHTER]

My name's Bill Allen, I'm partner and chief technology officer at EvolveLAB, a company I co-founded about a year and a half ago. If any of you guys want to take any pictures or doing any tweeting, Twitter handle is right there, @evolve_lab. So that's there at your discretion.

A little bit about me. Like I said, CTO for EvolveLAB, speak at some of the events, repeat for AU. Always great stuff here, always learn a lot. There've been workshops, design symposiums. So those are some of the classes and things that I'm kind of talking about and teaching on. EvolveLAB is basically a computational design and BIM consulting firm.

What I want to know is who you guys are. Raise your hand real high if you are a BIM manager at your firm. OK, good.

Raise your hand if you are an architect. OK. Engineers? OK, contractors?

OK, and any owners? OK, a couple. This is good. Welcome, guys.

So in case you didn't know what we're going to be talking about, basically what we want to try to do is understand where the industry is going, where is technology taking us? And it's really about robotics and software algorithms, generative design. You guys saw some of this in the keynote speech. And I want to talk about some of this and what it means for you guys specifically. At the end of the class, hopefully you will know what trends and technologies are coming to our industry, how algorithms and

robotics will drastically change your design/build process, understand how these new processes will affect you directly and indirectly, and then know how to best prepare yourself and your firm for these changing processes.

The first thing I want to allude to, maybe some of you guys have seen this graph, it's the idea of compounding with technology, and basically the acceleration of growth specifically. And so you have things like the printing press, telescope, microprocessors, computers, the world wide web, cell phones. It's accelerating at such a drastic pace. And so we're doing some pretty phenomenal things as a species. But what I want to do is kind of talk about what is our industry doing and where is our industry going specifically, the AEC industry? And so we've always had these kind of hand drawings, forever.

We've moved on to kind of this CAD process, start getting into things like parametricism and dynamic, building modeling, BIM, of course. Really, where I'm starting to see the trend, and I don't know if you guys are seeing this as well, but we're starting to get kind of into what I'm calling algorithmic modeling, generative design. Interoperability is really starting to become pretty common. I think almost some of us are starting to take it for granted because it's so available now, photogrammetry.

What I'm coining and what you guys will be hearing throughout this is what I'm calling AI BIM, artificial intelligence BIM. And then robotic construction, Internet of Things, these are kind of the topics that we're going to be going through. Before we go through this, you guys need to know that there are going to be haters in our industry, OK?

[VIDEO PLAYBACK]

- Robots don't feel fear. They don't feel anything. They don't get hungry, they don't sleep.

- I do. I have

even had dreams.

- Human beings have dreams. Even dogs have dreams, but not you. You are just a machine, an imitation of life.

Can a robot write a symphony? Can a robot turn this into a beautiful masterpiece?

- Can you?

[END PLAYBACK]

BILL ALLEN: Can a robot write a symphony? In Slate.com, Chris Wilson states, "Cope has been writing software to help him compose music for 30 years, and he long ago reached the point when most people can't tell the difference between real Bach and the Bach-like composition his computer can produce. Audiences have been moved to tears by melodies created by algorithms."

I think that's a pretty bold statement, to evoke human emotion based on computer algorithms. Because sometimes when I talk about this, a criticism I receive is like, well, form is subjective and there's creativity involved. But I think there is opportunities where algorithms can mimic human behavior and the process that we use in design.

Can a robot turn a canvas into a beautiful masterpiece? Pindar Van Arman, a technology artist and software engineer, has built a robot that can paint art. And we saw some of this during the keynote speech today, which I was I was just blown away by, even seeing what we're kind of doing as far as advances. So I want to ask the question, can algorithms design a building? Can a robot build a structure?

So what I want to do, which will hopefully you'll gain from this talk, is I'm going to try to bridge the gap. I want to talk about where we've been, where we are, and where we're going. And really, where we've been has been data gathering. And I'm not even going to go back into CAD. I'm just going to talk exclusively BIM, OK?

So right now, where we've been is data gathering. Where we're at right now in this point in time is data manipulation. And where we're going to be going is data optimization.

So how do I know we're going there? It's already happening. There's already firms that are already starting to do this, the progressives. And it's just a few more years before it starts becoming mainstream.

So where have we been? Hunters and data gatherers, this is where largely our industry has been. So hunting, assessing the model, capturing data and schedules, kicking it out to Excel, manually remodeling it, going through this design iteration process with tools that I call static modeling. And that's largely where we've been as a pulse in the industry. There's people doing more progressive things, but kind of like the mainstream, that's pretty much where we're at.

So I can only design a few options with the timeline and budget allocated if I'm doing it as a human being. If I have to design a hospital and I'm given four to six weeks to do it for the design process, schematic design, I can only crank out so many options in that timeline through that process. And then as far as data gathering, we're mostly just grabbing the data from these models, not to be cynical to some of the tools that I'm seeing even today, but a lot of is in the cloud.

It's like, well great, we're just kind of repeating the same process of gathering data. Now we're just doing it in the cloud. And so what I want to push is where I think we're going to be going, which I'll be talking about.

Static modeling versus parametricism and algorithmic modeling. So we have a lot of the static modeling tools. This is one that we did in format. And we started overlaying the idea of using Dynamo and Dynamo Studio and some of those that you guys have been using with the format.

The next step is going to be what I'm calling co-creation. And maybe you guys have seen some of these too, with some of the redshift publications. This is my own personal experience. This is a project I worked on. And this is the first hints of kind of alluding to this co-creation process or having data inform buildings.

So in this one specifically, this was a Revit family that I had built. And I was using a little bit of

trigonometry, some formulas to rationalize these panels. And the idea was just trying to create these panels along a curved surface. And it was rational, it was all the same size so that when we gave to the fabricator, every piece, every panel, was exactly the same size for efficiency of fabrication.

The challenge is, it's rigid and not intuitive. I'm dealing with this formula that's not intuitive to edit or manipulate, the fact that I have to put trigonometry into the formula or into the family itself. This is what leads to lack of adoption, in my opinion, in our industry, when you have to go through these hurdles for this.

The next example is kind of doing the same thing, but when I started using algorithmic modeling, using a tool like Grasshopper. And I'm doing the exact same process, but I'm using an algorithmic editor to rationalize the panels.

And you can see, very intuitive. I'm just moving the graph mappers. I'm updating the geometry very intuitively. And I'm not having to use any kind of trigonometry. The program, in a sense, is kind of doing that. So the intuitiveness helps with the adoption process.

And then the thing to note right here, you can see, is the panels are all planar. So I'm doing a test to say, is this planar? Yes, true.

Every single one of these panels are 100% planar. It's very easy to get triangulated panels, rationalized. It's a much more difficult thing to do it with squares and rectangles. And so this is a good example of that. Even though I'm having this intuitiveness, there's still 100% rational.

So Dynamo extends information modeling with the data and logic environment of a graphic algorithmic editor. Many of you guys are already using Dynamo and understand this. It's basically just a logic, hook up the notes, accomplish what you want to do.

So this next example is one that I did for BOMA accounts. I don't know if any of you guys have had to do BOMA. You cannot do it in it Revit. Natively, it is impossible to do it in Revit.

So the age we're in is the tool-building age. It's, if a tool does not exist and I can't do it in the program, I'm going to write a tool that can. And so Autodesk gets tools to us like Dynamo to overcome some of those challenges and limitations. The running joke always is, we'll wait till release 2017 or 2018.

Well now, as a designer, you're able to take those designs into your hands and actually create a tool to overcome some of those challenges. OK so in this one specifically, what I did is if you guys are

familiar with the key schedule hack, you basically hijack a key schedule that you're never, ever, ever going to use-- i.e., if you're an architect, say you create a pipe insulation key schedule. When was the last time as an architect that you scheduled pipe insulation? Anybody? No? OK.

So then you take that and then you can basically just put in dumb data into that key schedule. So using the Dynamo scripting, I basically ran the algorithm of doing BOMA on building areas in Revit. And then I took the data from those, did the calculations, and then pushed it into a dumb key schedule for the purposes of just keeping all of the process within Revit, not having to kick out to Excel or anything like that.

So static modeling versus algorithmic modeling. The one on the left is a SketchUp model that we had done. And then the one on the right is a vehicular canopy that I had modeled. And basically what it is, is I'm using Dynamo to edit the different beams that are associated to adaptive components and forms. And so it's started to do parametricism and just ease of being able to model multiple iterations as a human using the slider bars.

And so the nice thing about this, of course, is that before when it would take a long time because I would model something, and then I would have to remodel if I wanted a different design option, with tools like this, we're able to model multiple options more efficiently.

The other thing-- and by the way, we're going to get more progressive. This is just kind of warming us up to where we're at and why I think we're going where we're going. The other thing that we're going to talk about is computer-assisted craftsmanship. And you guys have seeing, I'm geeking out. Are you guys geeking out about some of the robots and stuff that were in the exhibit hall? This is pretty cool. So this is an example of a project that I worked on, it was basically a design after dark competition to raise money for a good cause. Basically what we did is I used Rhino Grasshopper to create multiple iterations of this design. So you can think about if you're doing something with static modeling, much more difficult to create all these options, definitely takes a long time, but we're able to create these options very efficiently.

And then what I did is I created a 2D template for fabrication, super advanced process you can see here, human being, just sign that thing away. But what we did is we created this template. And the algorithm numbered every single carpet tile within there, and then we were able to cut those out for the finished product here.

And so this is just one example of a mundane task that you might number these individually. It

assigns it to the template. Nothing super progressive, but it is fulfilling that task.

Here's another example of, so this is a video, so you can kind of see. So as I'm modifying this, I'm able to modify the geometry in real time and crank out all these different design options based on moving the graph mapper. And you could see the information updating instantly. And so what I could do is I could take one of these, kick it out, take another one, kick it out, take another one, kick it out as a human.

The next step, which we're going to be going into later in the talk, is really having the computer create all these design iterations and giving us the information back. So this is kind of building up in why I'm saying, this is the bridge. I say, bridge the gap between where we've been. This is where we are, this is the transition period of parametricism, computational design, whatever buzzword you want to use. And then where we're going to be going is the computer's going to be going through these different design options and giving us feedback on those.

When I did this one, I've talked about this before. And one of the criticisms I received from a structural engineer was well, this is great, like it sped up your design process. But think of the documentation. Every single one of these beams, you're going to have to document the radii, you going to have to document the tangent points, all this information that I'm going to have to document to give to someone to actually fabricate.

And I said, no I'm not. I'm going to give every one of these beams a unique number. And then we'll give it to the CNC fabricator, and then they're going to go ahead and fabricate the beams. So then we also augment the efficiency, not only in design, but in documentation as well.

So where it's going is starting, and you guys saw some of the robotics, CNC, computer system fabrication. What's nice about some of these tools is it doesn't necessarily matter what the shape is, because you're not paying for human labor to follow the curve or follow a straight curve. The computer, the robot is going to cut those. So what we're going to see is projects-- you guys saw the earlier example, I was talking about these panels had to be very rational so that way everyone was the same for the fabrication, cost efficiency. It's not going to matter in the future-- and even now, actually, to be honest, it's pretty much the future is now-- where you're able to create these fabricated members and the robot or the CNC is just going to go ahead and cut those, and it's going to be the same price it was just for a regular one.

Someone told me once, renderings don't count. So this is example here, actual project. So this is

one that was actually executed. And you can see there's people here, it's not a rendering, actually CNC fabricated, and it was published.

The other thing that I think we're going to start seeing is greater interoperability, and I want to show you how that's already happening today. So many of you guys are familiar with the term, construction waste. And it says, basically the excess building material that's destroyed from a building, people are starting to get more into prefabrication and composite housing and composite buildings. But it's basically this idea of just this material waste.

And so what I also talk about is data waste. So we have this process that I firmly believe is an issue in our industry. And it's data drops, it's data waste. And so what happens inevitably is that you have your program area.

Let's start at the very beginning. And so what happens is you've done your space program in a tool like Excel. Most likely there's some other programming tools. Say you're using Excel.

And what happens? How many times do we see it? We go by coworkers desk and here's Excel on one monitor. And here's Revit on the other monitor. And they're manually trying to coordinate the programmed area in that Excel document with their design.

And so the idea is well, now you're having to recreate that data. Why not just push the data into Revit and you can get your affinities, you can do departmental adjacencies, programmed area, actual area. You can take all the information that's in Excel, push that into Revit, and then you're able to overcome that data waste. And it's the most simplest example, that's one.

We talked about parametricism. What I want to talk about is basically the idea of taking information from one design tool and publishing it into another tool. There's a lot of people that are doing this already. There's tools like Hummingbird and Flux that have already come out.

And this is an example of one that I was doing just as a proof of concept a couple of years ago. And the idea was to try to create a parametric building. And you can see, it's an office building. And here I'm getting real time feedback as far as programmed area for this building. Excuse me, actual area.

Total square feet, square feet per level. I'm able to change the number of floors. I could change the building footprint. And the square footages update. And then I can push this information into Revit.

And so in here I'm using the add-in Hummingbird. And what I want to show you guys that I really want you to pay attention to right here, that's a real Revit floor. So there's some different

interoperability tools that are converting a mass from one tool to a mass in Revit. That's great, but you're still going to have to recreate those systems in Revit. You're going to have to recreate the wall, you're still going to have to recreate the floor.

And so here we're able to actually create real stuff, real Revit systems within Revit, with this interoperability tool between the two programs. The other thing we're mitigating is the data waste. The idea that you have to model something in one tool from a designer and then have to remodel that is going to be going away. The interoperability is going to be vastly improved in the next year because it's already happening.

Here's another example, a real project up in Breckenridge that I worked on as a facade. And so what we tried to do is create this facade that emulated the mountains in Breckenridge. And again, I'm using an algorithm editor, Grasshopper to do this. And here's an example of it, parametrically updating.

So you can see I'm updating the count. I'm able to take the graph mapper. I'm able to update the midpoints. And very efficiently. I want to point out, if you had a model this thing as a static thing, it would take a very long time to try to create all these different design iterations.

So here's all the different design iterations. And then I'm going to publish that now to Revit, again using the add-in Hummingbird. And then here, I'm able to create real Revit stuff.

This is going to be a Revit-adaptive component. And it's recreating everything over on the right that is on the left. So I'm avoiding and mitigating the data drop again from the design side into the production side and saving time on that.

And by the way, I'll have questions at the end. I have a lot of material I'm going to try to get through. So if any of you guys are itching, we will take questions at the end. But I'm trying to get through everything, just so you know.

OK, so where are we going now? This is the next step. This is AI BIM, is what I'm calling it. It's basically the idea that you're not only going to have these parametric pieces, but there's going to be computer logic, algorithmic thinking behind that that's going to feed the parametric modeling moving forward.

Really, where we're going is algorithmic optimization. We're going to be optimizing these buildings moving forward. So in the very, very, very near future, we're going to be having this integrated team. It's going to be the designer and the computer.

And I want to give kudos to my good friend Nate Holland. This was part of his project thesis. And just so you know, this is like a five-year-old thing. He was so ahead of this, and we're just kind of as an industry catching up.

Like I said, it takes a while for us to become mainstream. But I want to give credit to Nate for this. He did a really good job.

And so this is project that he worked on. And it was the idea of, we talked about an integrated team. And so the integrated team is the designer and the computer.

And so in his presentation, he talks about being able to use Galapagos, which is an optimization algorithm in Grasshopper. And in here he's trying to find the affinities, the optimized location for real estate developers, viewpoints to the ocean, retail, all of that. And the algorithm is processing all the information based on the rules that he's fed it. And then he has this override feature that he's able to manipulate the geometry based on where he wants to use it. So this integrated team with both the computer as well as the designer.

And so in here he's able to also then from a floor by floor, see, site to waterfront. So you can see the lines as they're connecting with the points. It's giving the program real time feedback. And he's able to go through all these different design iterations. Think of you as a human being, if you had to go through every design iteration and try to figure out the viewpoint to these oceans. He's able to do that using the algorithm.

So optimized for retail, optimized for views. And then there's going to be, I think there's another, one optimized for views as well. And so just kind of goes through, and based on where that floor plate exists, you have these different floor plates. And every floor is optimized based on its location geospatially.

Not only that, starting to lay out floor plans. So we looked at per floor. But now the computer is actually starting to lay out that floor plan and actually space out whether it's a one bedroom or a two bedroom using the programmatic information, the requirements, and is actually able to tweak those, optimize them based on their location and the information that's being fed back. And again here, individually, kind of per space.

So it is possible, we've been hearing the idea of generative design for a while now, last couple of years. But there are people that are able to do this. And this example, as I was talking about earlier,

you guys saw how I was manually updating this information. And here he was actually able to kick out, here's every single one of these options. And here's the data supporting, based on the optimal solution for whatever rules that he fed the computer.

And then here there's cost that outweighs benefit, benefit that outweighs cost. And here's the information, the data. So you're actually able to not just say well, this looks good, but we're actually able to take data and have that inform the design and our decisions moving forward as a designer.

And so this is a Grasshopper example. What about Dynamo? Dynamo actually has some optimization algorithms.

There's one that came out, I think it was two years ago, called Optimo. And that one works well for Dynamo as well if you want to try to accomplish similar tasks kind of like Galapagos was for Grasshopper. Optimo is a tool that you can do similar type of tasks.

OK, so the problem with algorithmic modeling is intuitive, intuitiveness or lack thereof. This is my personal opinion. I feel like we have all these awesome tools at our disposal, but we're kind of ad hoc piecemealing these things together because nothing exists yet that allows us to accomplish this. And so the problem in my opinion is the intuitiveness of this. So there are some of you guys that are like me, that geek out, love Dynamo, can do this stuff.

But if you gave it to the designer in your firm, they're going to go, no thanks, I'm going to use SketchUp. Right? Yes, I'm getting a lot of head nods. Or I'm going to use Formit, or whatever design tool they're comfortable with.

Again, the interoperability is going to help us overcome some of those tools, though. So it's not going to matter as much. But what I think, what we're going to see in the next couple of years is this becoming more intuitive.

So as an example, some of you guys have heard about Project Fractal. It's an Autodesk product. And what it does is it's option engineering. And it uses Dynamo as, basically feeds the UI. But this is the UI-- much more intuitive, not a big spaghetti mess.

So for designers, this is a little bit more intuitive to be able to pick which options that they want. And you can see based on height, floor plate, radius, et cetera, you can change these different-- I don't know if you'd call them sliders, but you can change these and it updates and gives you an output for those different options. Look at all the options we were able to create in what, a couple of seconds

here. There's some logic and stuff going on under the hood with Dynamo. But you're able to create all these design options extremely efficiently.

What about stadiums? So think about the seat count and the field of view and all this information. You can feed this into the model, and I can quickly create many, many, many options based on the information that I'm feeding the program.

And so you can see in here I'm able to create all these different options based on the sliders, the data that's pushing it. And then from there we can kick these out, we can get data from them, feed them to the owner. Say, here's the top five, what are you thinking?

And this one I just saw today, I just added it today. It was in the exhibit hall. I don't know if you guys saw this. It was like, oh my gosh, it's like, here. It's here today.

And so I just added this, it was pretty frickin' cool. And basically here's the space planning for this project. And there's tools that Autodesk is talking about Dreamweaver and some of this generative design. It's taken the information, creates the different space plans, and gives you the information, the data.

Did anybody see this in the exhibit hall today? A couple of hands? Go check that out. I always thought that was pretty cool.

And so in here, here's all the data associated to those design options. And then they have a physical model, which is kind of cool, to support it. I can't tell you like how how excited I am right now to be alive.

The things that are coming out, is this not fricking cool? We're so fortunate as humans to be able to live in this time. It's pretty cool.

The other thing I think that we're going to see is computers take over mundane tasks that you have to do as a human all the time. Printing, who loves printing? Who loves going through on Friday? Right, it's 1 o'clock, I get to get the PDF sent out for my consultants. I've got to get my models detached, I've got to get my CAD exports.

I don't know if you guys have heard of Clarity, I've been using Clarity for a while now. And it basically is AI BIM basically for task automation. And so maybe it's pushing a little far, but it's pretty cool. If you have a set of CAD backgrounds that you're kicking out to your landscape or civil crew every Friday or

you're detaching Revit models or you're creating these PDFs, Clarity is actually able to automate that process.

So at 1 o'clock in the morning, a computer fires up in the office and it creates your PDF set. And you just set up these tasks, and you're able to save so much time and money. So just as an example, I did an assessment on the firm I was working with. And we said, OK, how many hours does the staff spend printing? How much time does the staff spend creating these exports?

And assigned a billable rate to that, and it was around half a million dollars per year. And granted, you are still going to manually print sometimes. You are still going to go through and manually create some of these CAD exports.

But let's say, even if you tempered it by 50%. 50%, it's still a quarter million dollars of time savings. And so we're going to see computers doing more and more of these mundane tasks that we don't want to do.

The other thing it also does is automate reports. So room data sheets, furniture information, it also automates and creates those. I was working with a colleague of mine and I kind of showed him how this worked. I said OK, so we set it up, we ran the task, here's your room data sheet, kicked out at 8 and 1/2 by 11, of the room. It has the wall parameter, the doors.

The computer did this, it just created this PDF. And then it had all the data that was in the Revit model. And it was a good 500 page PDF, and with every room cropped. And he was like, oh my gosh, this is awesome. And I'm like. yeah, but if you want, you could probably just continue manually printing all those individual rooms and cropping them.

He was like, no way. This is at our disposal to be able to save so much time on mundane tasks. So computers are going to start taking over and doing more of that as well.

This is another one that we did at EvolveLAB. It basically auto-created these rooms. And it was a Dynamo exercise. Let me make sure this is going through, there we go.

So you pick which rooms you want to elevate and then you run the Dynamo script. And pay careful attention, it's kind of small, it's hard to see. But you'll see these little rooms will pop up in elevation. Boom, real tiny.

And so here it dropped in an elevation in every single room for this project. So think of like, and you could prepopulate this. Think of the typical rooms that you're always doing, right? You're doing

kitchens, you're doing bathrooms, those are the rooms that you're elevating. And so as part of your programmatic requirement, you could just include that right so you don't lose the data drop included in your Excel spreadsheet.

These are rooms, this is the room type. Push that into Revit and then run the script, and it will auto-elevate every single one of those rooms so you're not manually dropping in an elevation and elevating it. So it's going to aggregate that efficiency for documentation as well.

The other thing, I want to give kudos to these guys. It's building systems plannings, their [INAUDIBLE] MEP tool. Check this out. The autoroutes based on information, so here's the beam.

And what it does is it automatically will miss those beams as they're routing it. That's pretty freaking cool. I don't know about you, I'm geeking out about this. It's like, oh my gosh, it started to become object awareness. And the information now is being fed based on the routing preferences and where information exists.

I had this kind of grandiose idea that in the future, we'd have our clash detection model. And basically the computer would run through the clash detection. Instead of sitting in a room for an hour talking about all the issues, wouldn't it be cool if we fed the computer set of rules and the duck would automatically miss the beam and then the ceiling would modify? You'd have to check it, but it would be really cool.

And then I saw this and I was like, oh my gosh, you almost don't even need that because the tool already knows where the stuff is. So there isn't even going to be a clash to begin with. So I think in the future, you know this one, there's still some picking.

You're picking on different things and telling it where to go and depending on you and over a beer we can talk about how much you want to let the computer do this versus how much you want to do yourself. But I think it's in the future, what you'll see is you'll be able to send the computer your room types, the load capacities, thermal performance, things like that. And it will autoroute this information based on the information you would feed it.

The other one is [INAUDIBLE] tech, advanced BIM design there. They created a tool that manually-- or excuse me, automatically analysis. So manual analysis and modeling is going away. They created a tool that does the analysis for your 3D cage reinforcement.

And so it's design-driven reinforcement, does the calculations. The Autodesk Revit structure does

some of this as well. But then it automates the documentation production of the reinforced concrete columns, beams, and footings. And we did this too for another client of ours, did this autosectioning and elevation.

But it's really cool. No longer are we going to be going through the model and cutting sections and dropping elevations. We'll just run the algorithm. It's going to autoelevate, it's going to autosection, and it's going to document it for us.

The other thing that's important that I don't want to lose sight of is code. There's still code requirements. So if you just let a computer go nuts, it's going to design some things that are not code-compliant. And so I think if you're able to feed the computer the set of rules, the IBC data, egress pass, things like that, it's able to make sure that it does not exceed that egress.

The other thing we're going to see is daylight in optimization. And we saw some of this earlier today in the key note. And so we'll be able to send the computer the rules. It'll kick back you know 1,400 different options. Here's the optimal daylighting-- the top 20, your optimal daylighting model based on what you fed. And then from there you could pick which one is best, and then you'll have all of the data in there.

You can't talk about the future without talking about virtual reality and augmented reality. So obviously, it's here. It's been here for about a year or so. It's starting to catch up, people are starting to adopt it. The problem is, it's heavy, it's clunky, it's tethered. And so the challenge is putting on-- this is me, by the way, little space trooper swinging these around.

And so the problem is, it's kind of clunky. It's this bulky thing. And it's awkward, and people are talking about like, there's no way that I'm going to be sitting in my cubicle with this thing sweating on my forehead for eight hours. There's no way.

And so that's the challenge with some of these. But I think in the future, we'll have one pair of glasses. And they'll be able to support either AR or VR. It won't be mutually exclusive.

So you're not going to have to pick between the HoloLens or the HTC Vive. You're going to have a set of glasses and you'll either be able to do your augmented or mixed reality. Or if you want to do the VR, I think you'll be able to do almost like we have with Glass, Frost. And this stuff will disappear, and then you'll have that virtual reality environment with one pair of glasses. They'll be light and they'll be comfortable.

So now I want to transition into robotics and construction. So how will robots drastically change the

construction industry? So we've seen 3D printers, right? We have these cute little boxes that sit in your office that prints the models, right? Did you ever think about 3D printing a road?

So this company, GSX, they have a road printer. And so you can see the humans are feeding the blocks. I don't know what it would take to actually-- I don't think it would take much, actually, to find colors in a robot to put those bricks in there in the specified location, and then it would feed and then print a 3D road.

The other thing we're going to see is for fabrication of structures. So in Zurich, Switzerland-- hopefully I'm pronouncing that right-- they designed this facility, basically has these swing arms. And so you think of automanufacturing, and you would have this assembly line.

And the car would be fed through. And this robot does this and this one does that, and it goes through further. And it's basically this linear process.

And I think what we're going to see is these arms. This one specifically has 40 axis array, like the ones we saw in the room earlier, the exhibit hall. In there, we're going to have the same type of thing with these robotic arms assembling this information, especially in very complex things, very complex buildings. It's going to help with that process. And the reason is because it can be efficient.

So here's a semi-automatic mason, SAM. And SAM costs $500,000. A skilled human is able to do 500 bricks max a day. SAM can do 800 to 1,200 bricks per day. And this is where it starts to become pragmatic, when you start doing your ROI and you're figuring on how long it takes a mason to assemble the bricks and the mortar. When it starts becoming efficient and cost-effective, this is when it's going to start making sense for dollars and cents.

To take it another step further, Fastbrick robotics has designed this one. And Hadrian does 1,000 bricks an hour. And it has its own custom grout, you'll see here. And it's able to lay those 1,000 bricks per hour.

3D printers will be leaving the office. I don't know if you guys get these Facebook feeds. I saw this one, I was like, oh my gosh, I've got to include this. So 3D printers are leaving the office, and they'll start actually building these structures outside and in real scale. So this is an example.

I don't know how pragmatic this is yet, 3D printing drones. Gensler, they had this work in progress. But they have designed a 3D printing drone. So you can see it has a laser range finder, GPS

coordinates, and then the printer. There's all kinds of challenges that this poses-- battery life of the drones, weight capacity of concrete on a drone.

[LAUGHTER]

But I think it's pretty cool what they're trying. I almost wonder if you could do a hose, and it's kind of feeding it so it's not carrying the full capacity. But maybe just as a transitional device that kind of transfers the information or transfers the concrete, the materials to the spot. That might be a little better. But it's pretty cool what they're doing, or at least trying to do.

The Internet of Things, we're going to see some pretty cool stuff happening with objects. Cars are already doing it, it's coming. It's just a matter of time before cranes, SAM, the skilled autonomous laborer does this. It's just a matter of time before the construction site is going to be filled with these objects that are aware of themselves. So Internet of Things is the internetworking of physical devices, vehicles, also referred to as connected devices or smart devices, buildings and other items-- embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data.

So here's an example of one right here. Architect Ammar Mirjan-- hopefully I'm pronouncing that right-- programmed a small collection of drones to fly hundreds of these blocks into a formation to build a six meter tall tower. This was like, the first for a drone.

So you can see that it's already starting to happen. It is coming. And they're totally aware of themselves.

Immersion, so we do this 3D scanning with our camera. And what's pretty cool is you're able to create these 3D models from photos, it stitches all the photos together. And I believe we're going to see a huge overlap with photogrammetry and immersion. This is a construction example that we had done from one of the general contractors. And basically they wanted to understand where all the piping and the electrical and everything else was before they drywalled the project.

And so you can see through here, I'm able to see all of this information-- the electrical, conduit. The process they used before, they communicated was with their smartphone. They would go out to the site and they would just take thousands of pictures. And then they go back to the office and try to remember where that picture was taken.

And then they were like, well, we need to do something better. Maybe we'll do video. And so we have

this floor outlet down here.

Well, let's go ahead, let's look at the video. What did the video show? The outlets down here, let's check it out.

OK, the video-- oh yeah, that's awesome. It just looked at the ceiling, totally missed the outlet. It wasn't working. And so this process of being able to do a scan of the project and have a 3D photo-- I mean, not even 3D photo, it's this 3D model using this technology. You're able to have this immersive environment and experience it, and it catches everything.

So inevitably whenever I talk about this, this is where it goes. So with all of this automation, what will we do? And there's other people that are talking about this. I don't know if you guys caught the NPR special, but Martin Ford wrote this book called *Rise of the Robots*: *Technology and the Threat of a Jobless Future*. OK And so in his talk, he talks about fast food workers, writers, legal professionals.

In this day and age, if you want to become incorporated as a company, you don't need to go to a lawyer. You just go to rocketlawyer.com, you download the document, and it's done. And so there's all these websites and algorithms and robotics that they're talking about will be putting a lot of these people out of jobs.

And so the question is, well, what about architects? What about contractors? What about fabricators?

Elon Musk, there was an article I just saw. And in here, Nate Church interviewed him on his website. And he said, automated robots will lead to unemployment, universal wage coming from the government. It's like, well, that's kind of a downer.

And so what I want to do is, I want to ask a question. Really, for us, for our industry, there is this disruption that happens. What happened when Netflix came out? Where's Blockbuster? There does happen to be this disruption that happens to industries, and it's real.

And I think that for ours, I don't think it's going to be where all of us are going to be without jobs. I think there's going to be a lot of opportunities for us. So how do you best prepare yourself and your firm for these changing processes?

[LAUGHTER]

Is that how we do it? Is that what we want to do?

AUDIENCE: It would be fun.

BILL ALLEN: Yeah, it would be fun. [LAUGHS] I don't think so. I think we're still going to need computational design specialists. We're still going to need virtual design construction specialists.

We're still going to need computer programmers. We're still going to need people to drive the software. I think it's going to be a long time before any of these tools are going to be putting us out of a job. I think the tools are going to help us become more efficient.

I appreciate what the CTO said today for Autodesk. He said, it gives you super powers. To be able to assess multiple buildings, that's not putting you out of a job. It just gives you a more efficient way to design your building. And it gives you a more pragmatic way to design your building.

So you're actually able to optimize the design based on the tools that exist. It doesn't put you out of work. It just helps you to do your job more efficiently and design buildings better.

So how do you best prepare yourself and your firm? Buy a drone.

[LAUGHTER]

I'm halfway kidding. They're a lot of fun, but learn some code. Take a class on digital fabrication and robotics. Take your knowledge from AU back to your firm. Become the expert.

The other one I would say is, don't wait for someone to ask you. Just become the expert. Learn the knowledge, implement it on your own projects, show why it's pragmatic and why it works. And then others will follow and take notice of that.

So these are some of the ways that I think are very tangible ways that you can actually start using this technology. Download Project Fractal and start playing with it. Get used to Dynamo and doing these different tools. And with that, I'm going to go ahead and open it up for some questions. So if you guys have any questions, we have microphones. This is being live streamed, so you want to make sure we come up to the microphone and speak loudly. So any questions anybody wants to ask? Don't be shy, go ahead. Who has a question? I know you're thinking about it. Yes.

AUDIENCE: OK. Well, thank you for the presentation. I'm curious in terms of code, we hear a lot about different languages. Which language should we pursue?

BILL ALLEN: So I would say it depends. So the question is, which code language should you pursue? And there are a lot of different ones out there. I would say Python is a pretty easy one to start getting into if you

want to start dabbling in code. So yeah, that's what I would say. I think Python is probably the most introductory one. If you starting to do more advanced stuff, you can start learning other code, C# or C++. Other questions? Yes.

[LAUGHTER]

AUDIENCE: With SAM, I know that it can produce a lot of blocks real quickly in places real quickly. The question is, how much time did it take to set up SAM so it could do exactly that? I think we lose sight of-- the technology is there to help us, certainly. But we can't always think that-- just because it does one task really efficiently, what was the other part to get it there so it could actually do that?

BILL ALLEN: Definitely, yes. So I don't know the time that it takes to prepare SAM. I don't know if you guys noticed in the video, but there are other workers. So again, the robot's not putting the workers out of work. They're still feeding the robot the bricks.

And so I think there is some preparation. I think there's a start and stop that's kind of manual, that you're able to say, start and do this row of bricks, this is the length. And then it can start over and start over and start over. But there's still a process of feeding a lot of these tools the material, is what I'm observing.

Other thoughts, questions? OK. Thank you very much, you guys, appreciate it.

[APPLAUSE]

I want to encourage you guys real quick. Please fill out this survey. All of us are super competitive as speakers. If you guys enjoyed this talk even a little bit, I would so greatly appreciate you filling out a survey.

If you email me, I also have some business cards up here you're welcome to take. I'd love to meet you guys. If you email me and let me know that you filled out a survey, you get put in a drawing through Autodesk, but I want to throw another $50 Visa gift card if you guys win. So I'll do a drawing, we'll see who filled out the surveys, and then I can send that your way if you win as part of an auction off of that. Thank you very much, you guys, really appreciate it.

[MUSIC PLAYING]