CORY MOGK: So thanks, everyone, for coming. My name's Cory and we're going to talk about animation and how it intersects with 3D printing. So if this clicker is on, I believe it will work.

So at a high level, what we're talking about is how animation can be a great design tool and a bunch of different aspects to that. So in detail, we'll be looking at is what animation can do for helping you design movable parts. How it can apply to packing objects for more efficient print times. And how you can use animation as a tool to design interesting surfaces.

Can everyone hear me OK at the back? Good. I don't mind questions if I say something crazy and you guys want to shout it out, what are you talking about. I've also got lots of time at the end for questions so we can play that as we need to. I don't have any handouts for this, but I'll post the slides afterwards if anyone wants those.

So a little bit about me. I'm from Autodesk Research in Toronto. If you were at the keynote this morning you saw a little bit of some of the work we do with the new building, the generative design for floor plans, and some of the dream catcher stuff happens with our group. We also do a lot of things in user interface research and machine learning. The BioNano team is part of what we do. So our main thing is to shine lights in those dark corners where other parts of Autodesk aren't working so that we have some answers when these things come up.

Personally, I have a background in architecture and engineering. And when I was in high school, I had that parental pressure, guidance counselor saying you can't be an animator for a living so go get a real job. I worked my way back into animation and I was in the Median Entertainment Group for years looking after Maya and the Entertainment Creation Suites. So that's where I'm coming from.

And so if you want to know more about any of the things that Autodesk Research is doing, you can go to our website, autodeskresearch.com. The nice thing about the research group is that we publish everything we do. So just like any other academic research group, we function in the same way. So there's lots of details on all the different projects that we're getting into.

So I mentioned the AU app and the poll. We'll see if this cooperates here, I haven't done this before. So the first question I had was are you most interested in-- trying to read this-- designing moving parts, representing motion in your designs, or 3D printing in general? And it's a fairly even split, which I think is cool. We've got something for everyone here.

The other question-- so this question was just checking out people's experience. So first one was, have you 3D printed anything before? We've got a few people who haven't. Option B was yes, I've printed through a service provider like 3D Hubs or Shapeways, so no one's done that.

For me, that's a super cool entry way into this space, if you haven't done it before, because they've got the people who can spend the time and take you through it. Especially something like 3D Hubs because they connect you live with the operators and they can talk you through a lot of the details.

So a lot of people done it C, at the local maker space and half of the people here have a 3D printer at home or at the office. Good to see where we're at with things.

So what I wanted to start with, this is sort of interesting, my older daughter is in grade nine and she's studying Shakespeare. And she was talking to me about Shakespeare while I was preparing my slides. She's gone crazy. She's reading ahead. She's read about 10 different Shakespeare plays, different versions and she's comparing this one versus that one.

And I said what is it about Shakespeare? What's he all about? And she said his stories are all about misunderstandings. And I love that because I'm thinking about 3D printing and to me, there's so much challenges with 3D printing. There's a lot of misunderstandings with it. And I think that's an interesting part of what we can talk about here. So for me, this is a big question that I look at a lot of times when are doing things.

My colleague [INAUDIBLE] here, likes to say that it's not real unless there's a physical model of it. The physical model never lies. And that's kind of cool with what we found when we were doing the 3D prints of our new space in Toronto.

When I look at this, here you can see the shadows up in this top part and you start getting a feel for what the shape was like. And I could take this and put it into the real place where we're going to have this office, and I can start doing some studies on the lighting and figuring out what that's going to look like.

People also get a really good sense of scale with it. Challenges, you can see where we've got broken parts here with the railing and up in the top here. So that's sort one of the misunderstandings I find with 3D printing. Misunderstanding between me, my expectations, and what the printer is going to give me.

When we contrast that to doing CG visualization, whether that's a still render or 360 panos or getting into game engines and VR, you've got to balance these things. Because when some people look at these things, they're thinking well, what's the scale there? How far back is that really? Is this a trick because you're using some crazy field of view? So that's that thing about the physical model being true, or truer.

We have also got things like the trees out the window. Are those trees really there or are you just trying to sell me this space.

On the flip side, it's really easy to do a lot of different studies with lighting and other things. So for me, I really like to have people consider those things and what are the outputs? What are you trying to get?

What's interesting for me is with both computer graphics and 3D printing, there's a lot of cases where bad geometry is bad geometry. So this model went through a lot of different iterations with different software and people working on it and stuff. And so I naively said well, it looks pretty good. Let me print it. But you can see that the 3D printer actually picked up a lot of these triangles and badness in there.

On the back side here, we actually had places where it was too thin and the support material, this was a water soluble one which pushed it out and caused it to break and crack. So that bad geometry is the same thing that you see sometimes in the view port. I thought I could ignore it, obviously that didn't work in this case. So I like to point those things out and just have that as a base for what we're talking about today.

So when we get into moving parts-- and this is the part that I'm sort of spending the most amount of time on right now-- so I haven't finished-- I don't feel like I'm at an expert level yet, but I think I've learned a lot of helpful things here.

This is an interesting piece we're doing so I think a lot of people have heard about Dreamcatcher and generative design? Yes? So we've actually taken this in the research group and applied this to moving parts as well.

So this is a four-bar system. And the way we've set it up for designers is that the designer would design this pattern that they want the end effector to take. And the system is figuring out OK, these bars need to be this long. The pivot points will be here. So it's turning the traditional design process upside down. You don't have to think about it here's the math of how all of these angles work.

But one of my entry points into this has been a much simpler piece which was working with my kids, they were looking at Thingiverse and they found this ear bud piece and they said let's print this one. And I said it looks cool. Let's give it a shot.

But it was really frustrating when we got it out because it was badly designed and that this piece at the end didn't fully open all the way. And not to totally carve on this design itself, but the point is that we could have done a little simple visualization with this. We don't have to get into full blown visualization of setting key frames and doing heavy duty renders. We can just use whatever tools we have to just rotate things and look at our pivot points. So part of one of my things is doing these low fidelity tests as much as possible before you get into the big complicated things.

So when we think about moving parts, the biggest thing for me-- and this gets back to the misunderstandings-- is a pop quiz for you guys. Just for those who don't remember math from school, this is not equals sign. So you think about an object that you want to print. And if you're using a PLA or FDM printer-- that looks a little bit dark. You guys can see it OK back there?

The size of those filaments, whether you're printing-- usually, it's 0.1, 0.2, or 0.3 millimeters-- it's going to approximate that shape so you can have sizes that are off. Which is always a big challenge and then this gets exacerbated when you're going between different 3D printers or working at different scales.

So here if we say we want to 0.4 millimeter tolerance, which for most of the printers that I've looked at and worked with, is the minimum tolerance. A lot of them are encouraging more like a 0.9 millimeter tolerance. You've got to think about this when you rotate it and orient things differently because you're printing in layers one at a time. What was 0.4 shrinks down to 0.3. So the tolerances that you have, that clearance that you need for things to move smoothly isn't going to be as big as it has to be.

And this, I found, gets even more complicated when you start rolling in environmental factors. What's the heating and humidity in the room? That can make your print materials all work extra unpredictably.

We had a big print job we were doing in the summer and the building managers decided we're going to turn off the AC at night. We're going to save some money. And we got in the morning and our prints were melted. It was like 50 degrees in the room and anyways, that's one of those challenges we had to deal with.

So the final piece here is thinking about these pieces. Because it is a higher resolution that you're dealing with, you get a lot of friction. So where those strands-- if you just move your fingers like that, you can replicate what the prints are doing. But you can think about how you're going to lay this out in the printer. So instead of printing the two pieces side by side like this, if I rotate them, then I get a much smoother interaction. So there's tricks like that I find are very helpful when dealing with these kinds of situations.

For me, the big takeaway is that 3D printing is not as simple or straightforward as machining. If you think of drilling a hole in a piece of wood with a 1/4 inch drill, you could usually find a way to fit that quarter inch dowel in there. You sand it a little bit, maybe there's some lubricant, or just some brute force will make it happen. With the PLA especially, it's not going to work.

It takes a little bit of a different mindset to approach this stuff. And that, to me, is the other part of the misunderstanding where I think a lot of times 3D printing is shown as this super cool solution. Press print and it works, but it's not always that straightforward. So always thinking about tolerances and scales is super important.

The other thing for me about the moving parts is looking at what's out there already so you don't always have to reinvent the wheel. For example, TinkerCad has a bunch of preset pieces here, ball and socket joints, that you can use. And they're set up in a way that the scale works properly so you can integrate those right into your models.

Likewise, Thingiverse, everyone-- so for me, it's amazing to look at all these different systems people have created on Thingiverse and see how their designs are iterating, and how people are taking those and tweaking them and making it better. So I think it's always worth doing some research that way when you're looking at some moving part that you're designing, to go and see what other people have done. How they've solved those pieces.

What's really exciting for me is the idea of integrated assemblies so printing a whole model in one shot that is moving and doesn't require assembly after the fact. Has anyone seen this kind of device before? Most of you.

So you can see the dark spots in between here which are the tolerances, and because it's printed up in the layers, that tolerance is modeled all the way through. I've seen people who've actually tried to 3D print actual ball bearings out of the plastic, but it's so rough and rigid, something like this works a lot better.

This one's even cooler. See if I can find the cursor. So that's 28 years printed all in one shot. And as you can see here, no assembly required and disassembly is impossible. At least impossible if you want to keep it working. And so this stuff to me is really exciting one, just because of the challenge it takes to build these things, but it's also quite useful when we think about print times and waste materials that come from things.

So this is a project that we did a couple of years ago. This bunny that you can see in this example, it's got this nice branching structure of support. This is available in Meshmixer software now. How many people know Meshmixer? A lot of you. So those who don't know it, you can go to meshmixer.com. It's free software that we make, runs Windows, Mac, and Linux.

And if you look at that branching structure compared to the typical support structures, what we're seeing in terms of print time is three and a half hours versus four and a half hours so we're saving almost 25% of the time based on reducing the amount of support structures in there.

And when we look at the waste, we've got a quarter of the waste compared to the typical support structure. So when you get into these integrated assemblies where you're printing bigger pieces, you can actually reduce waste and increase your print time. So it's cool if you can find the way to make those things work.

The other thing that we've looked at a lot with our 3D printing is orientation. So I mentioned that idea of when you've got the friction this way, if you rotate the pieces, you get a smoother friction. Rotating also helps to make your objects more structurally sound.

So with this camel, for example, printed in the typical orientation where people would think, it stands up this way, I'm going to print it that way. You can see that the legs are pretty brittle. Versus changing the orientation, it takes almost 10 times the force to break those legs. So really cool trick that you can think about when you're making these structural pieces that are going to be having different forces exerted on them.

And then, of course, there's things like the nervous system dress. I know a lot of people have seen this, but I don't know that everyone knows the full story that it's printed in a small space.

So it's not printed full size like that because of the dress, all the pieces fold. They've actually got folding algorithm that prints it down into a little softball sized piece. And so you can pull this whole thing out of the printer. They usually do this in a SLS kind of thing. You blow away the support material. And just shake it out and you've got the whole dress. So to me, that's the ultimate moving parts.

Some people call this 4D printing. I'm not hugely fond of the 4D printing. I think 4D printing kind of gets into some space age thing. I would think 4D printing is more like these robots that they showed in the keynote where it's got computer vision and it's reacting to things in real time. But we've done some of our own versions of 4D printing.

So if you think about this light here on this side, you could print it like this. You're going to have a whole bunch of support material with that. You may run into issues with being difficult to remove the support material or different things failing. So what we did was we said why don't we put some notches in here and then melt it. And so what that looks like is this.

And what was really fascinating about this, so just like with the camel where the orientation of the filament and the layers makes it more rigid, the same thing happens here. So you can get stronger prints by following this kind of process. So again, it's a faster print, less material, and then, it comes out stronger. So pretty cool things to consider. Yes?

AUDIENCE: [INAUDIBLE]

CORY MOGK: So you're thinking about this part here? It varies a little bit. We did some studies with different degrees of cut out and stuff. Usually, we're looking at somewhere around half a millimeter plus. This research paper is up on the website. It's called Meltables. So you can go through and there's full details on what we did in terms of looking at different materials and temperatures and process.

So we did things like the little heat gun that you see here. But we also put it the toaster oven and tried some other ways to do that melting. This is a little bit more predictable than putting it in the oven, just for those who are questioning or curious. But you can see, we did this at 150 Celsius, or 300 Fahrenheit, to get that going.

Any other questions on this so far? We've got time at the end as well if people are curious about things.

So let's move on to dynamic packing. One of the things that I did a while ago was printing out a bunch of small objects for people to give as giveaways. People don't understand what the 3D printer is, they see it working, oh that's cool. Can I have one of those to take home or show my friends at school, show my kids, whatever it is?

And so a bunny like this takes about 20 minutes to print. And if you've got a print hundreds of these, you're going to be back and forth, back and forth, back and forth between the printer all day long. So we started getting a little bit smart and said OK, how many can we fit out in a plane? How many can we start stacking up?

And we got to add a decent amount of time where five and a half hours, I could kick one off in the morning. I could kick one off at the end of the day. I didn't really want to stay 11 hours in the office so we didn't push it further than that.

So we had this idea, what if we put the bunnies in a bag, and shook them up, and got them to settle? And so what happened here with the bunnies was a super good case because we almost doubled the amount of bunnies that we could fit in the time, in the volume, and the print time didn't go up incredibly. So that's enough that I could kick one off in the morning, kick one off in the night, and there's not a lot of downtime for the printer. And my time as the operator is fairly efficient. So really cool thing to think about.

Sometime after this, Netfabb became part of the Autodesk family and Netfabb has some dynamic packing. I haven't gone back to compare how our results were. On average the increase in terms of density, we got about a 30% increase on average. Some shapes, like the bunnies, do a lot better job. And you can see here, they actually make just nice little sculptures for showing things off, so you think of different dynamic things that you would like to illustrate. It's a really cool process for that.

So we also looked at doing it with some other shapes and I think this one is a good one in terms of the illustration. Because a human skeleton doesn't fit very well in most 3-D printers that people have. So you've got to find ways to crunch that down. Now with this, it's a bit of a nightmare to put it back together unless you've stamped the pieces and know what they're going to do. But I think it's a great example for the process.

And so what it looks like is this. So we put an initial explosion on it just to push the pieces apart. And there's that funnel and the box around to guide them into place and drop them down. This worked pretty well, we thought. What happens is that that initial explosion takes more time than we actually needed to do. And so we simplified it just by rotating the joints a little bit, think of the long bones on the leg, we rotated them so they're a little bit more parallel to the floor of the print bed, which sped things up.

And you see an initial little puff at the beginning there. That's just where the pieces were an intersection and the solver just pushed them apart for us. So we got a much faster solve out of that. These images or movies that you're seeing are pretty much in real time, give or take screen lag based on the screen capture software. So it's a very quick thing to set up. It's not super magic.

AUDIENCE: [INAUDIBLE]

CORY MOGK: I did not try that. That's something I should try later. I tried a whole bunch of different objects. The skeleton was one of the latter ones and it was just a nice example. But running upside down, I'd like to see what that would do.

So in this set up is relatively simple. I used Maya for this with the Bullet solver. So it's as simple as grabbing all those bones, setting those active ridge of bodies. The box itself and the funnel are passive ridge of bodies. And you can pretty much set it to solve.

The big thing here I'll point out-- I don't know if you guys can read this-- there's collider shaped type. I set that to hull. So hull does a nice tight packing around the object as opposed to a bounding box or a bounding sphere. You could use bounding boxes and bounding spheres, and we tried some with that. The trade off is that you're going to get more support materials and then, longer print times again. But it can give you a little bit more confidence if you're worried about breaking things and taking them apart.

So the third part of this is talking about how do we represent motion into 3D prints? So a number of years ago, we changed all our splash screens and started getting these very evocative dynamic motion images. I don't know if anyone knows the story on these?

AUDIENCE: [INAUDIBLE]

CORY MOGK: Anybody else who wasn't part of the team? You'll get the adoration of your peers here in the room. I know the answer. I'm going to tell you guys, unless you want to throw it out?

AUDIENCE: [INAUDIBLE]

CORY MOGK: This one is actually inspired by Usain Bolt so it's the first three steps of his takeoff at the sprint line. The Maya one at the top, you can see the motion of the wings of a bird coming down. And right here at the far side is where it touches down, and the talons go into the water and grab a fish, and it takes off.

So we were looking at these things and we had a lot of people wow, we want to start building these kinds of shapes. And at the same time, we started looking at-- this one is one of my favorites. Has anyone seen this one before? So the story here is that the artist who created this one, it's a commentary on Wall Street and the financial people who are playing some funny games with the world.

But we started looking at these things in the context of these are just amazing pieces of art, but also, in the context of 3D printing, how does 3D printing apply to a design process like this and what could we do to represent these kinds of things? And in looking at these things, we found a number of types of qualities in them. This is our take off on the bull.

So we found motion stamps so where you've got copies of an object through space. In the middle, we've got motion trails and sweeps. It looks a little bit hard to see on the projector here, but there's trails off of there like you would see in the comic books when you got the punch and the trail. And then, using natural effects like particles and fluids to inspire things.

So with stamps, one of the things we looked at was Eadweard Muybridge and his awesome photography. And there were some people around the time-- we didn't know until we got into this-- who were actually making sculptures based on his photographs. And so we tried to replicate one of these.

And so this one's done with an eagle. The company that printed this one for us is called L'il 3D Printing. L-I-L as in little. L'I-L. They've got a great service where they're doing a lot of these kinds of things and they've got a nice process. I don't know if it's coming through here, but they do special wax casting on there to get that sheen on it. So if people are looking for a place to do color 3D prints, I recommend them.

But in Maya it's fairly simple. We go to our Create Animation snapshot and we just copy-- it does the work for us of filling in the gaps on the geometry. So we just had to set the start time and the end time.

When we got into it, there was some extreme poses that you can see with the wings down here and the wings at the top where we actually went from instead of one frame between, we went down to half frames to make sure that we captured it because it was moving so quickly.

And then we, of course, had to do work with taking those feathers and thickening them up, and making sure all the tolerances were correct for the printing.

With the backhoe, this was really cool. Again, you think of that thing where the physical model never lies. It gave people different insight compared to looking at a computer visualization on a flat screen. And when you think about the work we had to do afterwards of just taking pictures and stuff, it was really nice to take this model around and just drop it into a bunch of different environments versus how much time would it take to go and replicate a dirt pile on a construction site in a farmer's field in CG.

This model came from TurboSquid so luckily it was rigged for us. So all the black lines are the controls. So it's fairly easy to animate. We had a few pieces we had to clean up, but if you're going after one of these things you get, there are some challenges in terms of that rigging that you've got to consider.

The other thing, you think about that motion that the arm is taking. It's not just me as a person now, it's me as a person spread out and moving. So we've got a bigger volume that we're trying to print so the scale becomes another consideration. And so things like the rivets that you see holding the glass on and the side mirrors there, those details are things that we lost as we scaled it down. We could have thickened them up but it was a trade off of if that mirror is super thick and chunky, that the printer supports it doesn't look right or wrong. And we felt it wasn't a detail that was super required.

So the next thing we got into was the motion trails and sweeps and we looked at that with the backhoe. And part of what we found with doing the sweeps is finding what is the key parts on the object to represent the motion there. So in this case, we picked some of the rivets or bolts on there to be those points. The idea of these small round things are nice and it makes sense to make tubes out of them.

We also did it with this beast character here. So he's throwing a tire that he's taken off of a car and getting it down the street. But you think about in that extreme pose when he's like this with the throw, what are you going to do with that wheel?

You'd have to come over here and you'd have a support structure holding it up so it kind of ruins that illusion of what the animation is or what the structure is that you're trying to show. And so that's where the motion trails came in. And the beautiful thing was that motion trail connects it, no support material. So you get a really strong pose and strong print out of it.

The other nice thing was we have this physical model, we can do some interesting things with photography and lighting and trying different things with it that we really didn't think about doing in computer graphics version of it. And sorry this is a little bit washed out here on the screen, but what we did was ended up painting this and we smeared the colors at the edges just to start showing the fade out of the color on the arm like you would have in a comic book.

So this workflow, again, fairly straightforward. We would key frame the tire. And I created a curve, this is just a very simple representation, just created a curve and parented it to the tire so that it's going to follow along. And that's where the animated sweep tool comes in. So just like the snapshot, it would copy the place the curve is in space, but it's keeping that in memory and then lofting that surface to create the end result.

We did some comparisons with this compared to typical tools like a loft or an extrude and stuff. And the beautiful thing with using animation to do this was the control that it gave us over the shapes. So really, animation can be used as a parametric modeling tool when you think about it.

Another simple example here just to really show the point, if you think this is time zero where we are now and this is three seconds in the past, we can take this one shape, this little circle, and animate it over time so that the shape changes. And you get these very dynamic effects out of the end results.

We also looked at more complicated things like taking the flight path of a moth around a light. This one was going to be a gigantic chandelier and we ran into another scale problem where we couldn't get a 3D printer big enough. The ones that were big enough were going to charge us over $1,000 to do it. So we backed off on that a little bit and scaled it down to candle size.

And the nice thing here, scaling it down and simplifying it, we actually started to explore how do the trails and the stamps work together? And we could explore the moth actually has the wings flapping and you see it changing over time, which was pretty nice. And so what this ended up as was a nice light covering and you get a pretty cool effect out of it.

Louis, your class is tomorrow, right?

AUDIENCE: Thursday.

CORY MOGK: Thursday so Louis's doing a class on Thursday about building a roller coaster in VR. And I think Louis's using some of the similar techniques to this and it's all in Max, I think, for your part, Louis? So he's going to go really into detail about some of these tools of how the stamps and the trails work. And how you can use that to really build out something complicated very quickly. So I just want to do a shout out on that one.

So particles was our last one and again, this came into being very useful for us in terms of hiding support structures and also showing more of what's happening. So you think of a rocket where you might be concerned about a blast area and illustrating a safe zone. Instead of just having that straight trail up that would be very brittle and could sway, the particles smoke started to give it more strength and ground it a little bit more.

With this guy, when we do a lot of these things, we have artists come in and test them so we provided the character just in a straight pose and the animator went and did this crazy thing in about 20 minutes with the tools we created, which was super cool to see.

If you were doing this without the tools that we used, it's very simple animation. Again, it's just an S-curve on the particle emitter. So in Maya, what that would look like with the end particles, you've got this threshold setting here which is looking at how the particles blend together or not. So how smooth that transition is. Blobby radius is the size of the particles.

And next one, the motion streak, you'll see here, that's just trying to do a motion blur between the particles over time so it starts to spread that out a little bit. And then got the mesh triangle side so you can really dial in some precise kinds of effects with this. So that's that one.

And so what we did was we took all these tools and because those workflows aren't really obvious to people, was to wrap it up into a new UI. And this is what we gave the animator with our gassy friend and some of the other tests that we did. So we took all this stuff and put it into a single interface that you can see here and made it really simple and easy to create these things. So that's just a little taste of how that looks. And you can see more about this on our site if you look up ChronoFab.

So that brings us to the end of what I wanted to talk about. My contact info is here if anyone wants to get in touch. Just in terms of a wrap up, we talked about 3D printing versus doing computer graphics visualization which I think is always a good consideration. We talked about designing for moving parts and the key thing being to think about your tolerances and scales and materials that you're using. Dynamic packing is a way to get more bang for your buck out of the print time and then, representing our motion in 3-D prints.

So I have lots of time here for questions, however long until they kick us out of the room. For those of you who are leaving now, if you fill in the survey, I'd love to see how I did and I'd love for the Autodesk University people to be able to tune things for the future that meet your needs. But if anyone has questions, throw them out.

[APPLAUSE]

CORY MOGK: Yes, sir.

AUDIENCE: [INAUDIBLE]

CORY MOGK: So the question was what I did Maya, was that out of the box or did I write code for it? All those tools I showed were out of the box Maya tools. What we did with the ChronoFab project was to wrap up those tools a little bit more. So where you saw the particles, you saw how many attributes were there. We created a new UI that abstracted it and just brought out the four or five that we were actually changing. But most of that's out of the box.

And so the big challenge in doing those things with vanilla Maya is dealing with the complex data. You can imagine with that eagle, it was modeled-- each feather was an individual piece so the eagle itself was more than 100 nodes. You copy that 20 times and you've got this data explosion. Gets really slow and laggy, so that's the challenge.

Did I use other software to clean up the geometry? I did some work in Meshmixer, but that's about it. So Meshmixer for some of the pieces to generate the supports. And Meshmixer has a nice tool for thickening and making objects solid. So when you think about that eagle where each feather is its own piece, Meshmixer's got a really great tool for turning all those five feathers into one wing assembly. So I highly recommend Meshmixer for those cleanup tasks.

AUDIENCE: [INAUDIBLE]

CORY MOGK: So is the simplified UI available? It's not available yet and that's why I went into the details of how I did those different effects. One of the things that we do in the research group is try to get it into product, but there's always that tension between all the other things that our customers want and some of the things that our dev teams want to do.

AUDIENCE: [INAUDIBLE]

CORY MOGK: Tinkercad.com. Tinkercad. C-A-D. Tinkercad is super fun. I had a bunch of grade nines come into the office two weeks ago for take your kids to work day. And I showed them very simply how to build a key chain and then they started building all these crazy things, skateboard wheels and castles. So it's an amazing tool to get kids into 3D.

Was there a question over here?

AUDIENCE: [INAUDIBLE]

CORY MOGK: So did I send the packing of the skeleton as one STL and the answer is yes. For those supports, I would do in Meshmixer. Any other questions? Yes?

So I've used a whole bunch of 3D printers. The print studio team is actually in our office in Toronto so they've got a lab of about 40 different printers. In a high level, we've got three types of printers. We've got the PLA, FDM printers like MakerBot and Dremels. We've got resin printers like the Autodesk Spark and form labs. And then we've got a couple object printers. So more SLS kind of printing.

Based on the nature of all these different printers, that's where sometimes you get into these things of you've really got to think about the tolerances. And was this piece modeled to go through this printer or that printer. You think about the spark printer's really designed for very high resolution. It's got a print bed about so big and it's really focused on how would you design things like jewelry that need a lot of precision. So if you're designing for that, right off the bat you're going to be in pretty good shape. But if you start from something more coarse like a MakerBot, it's going to be very blobby when it comes out of the spark.

The interesting thing about the object printer is that we've got some that do multi-materials. The version of the moth that you saw, the lamp covering, that was done from the object printer. So we had the clear resin around black softer material on the inside.

And then the fourth printer, those color prints that I did, we did that with a service. And so those color printers, it's basically sandstone that comes out of it. They inject it or cover it with a glue-like material to hold it together. And then, the process of the guy used-- that we used-- he dips it in a wax coating to keep it extra shiny and keep the colors more vibrant.

He's got a cool thing going. He goes to a lot of the Comic Con shows and takes pictures of people in their costumes and then 3D prints them for them. So they're getting customized action figures of themselves. It's a super fun business. And his gallery is really cool.

Anyone else?

AUDIENCE: [INAUDIBLE]

CORY MOGK: For these things? I guess part of it would go back-- for me, so where does the inspiration come from? Part of it goes back to being curious and just trying different things. For us, we've got a very diverse group of people so I'd say the majority of the people in our group in Toronto have PhD's, but they're across widely different things.

So we've got people who are doing machine learning. We've got people who are doing heavy duty math, geometry, physics. We've got a guy on staff who's a biomechanist. We've got our synthetic biologists. And so it's really interesting, these conversations that come up in the kitchen. And you start trying things or seeing things.

And the other thing is just, I think, having the tools. It sort of invites you a little bit to play with them and see what you can do.

Well, if anyone wants to talk more, I'm happy to do that and you can contact me offline. Thank you for coming and I hope you enjoy the rest of AU.

[APPLAUSE]