[MUSIC PLAYING]

PRESENTER: Ladies and gentlemen, please welcome technical evangelist at Autodesk, Lynn Allen.

LYNN ALLEN: OK, well, that's one item I can definitely check off of my bucket list, isn't it? Hello, everyone and welcome to Autodesk University 2015. Yeah, so exciting.

[APPLAUSE]

And please, let's give a nice big round of applause for my escorts, the storm troopers.

[APPLAUSE]

It's so nice to see that those guys have finally left the dark side and they're working for the good guys now. And I have a feeling that you're going to see more of them this week, as well.

So, isn't it great that this is the 23rd Autodesk University? AU has grown from a single event to a series of 13 annual conferences all around the world. This year we have 23,000 people gathering in places such as Germany, and Russia, and China, and Japan, and Korea, and India, and in a couple of weeks we'll have one in Dubai, all in the spirit of learning, connecting, and exploring.

We have an incredible week planned for you this year at AU Las Vegas. More than 700 sessions to choose from and you'll see nearly 200 Autodesk partners in the exhibit hall demonstrating their latest innovations. And you can add one, two, or even more Autodesk certifications to your resume. And as you're trying to navigate all of these options, there's one tool that we think is absolutely essential and it's the Autodesk University app. So, it's easy to download, it's easy to use, and I recommend it highly for getting the most out of your experience at AU.

And this year we're also doing something kind of different for the people who are here at AU for the very first time. In other words, our freshman. So, how many people are here at AU for the first time? Let me hear you. Let me hear you.

[APPLAUSE]

Well, a great big welcome to all of the AU freshman. We hope that you'll find that your first year here at Autodesk University is as exhilarating as Pinto and Flounder did. And this year AU freshmen have special green colored lanyards so they're easy to pick out and I would love it if you AU upperclassmen would connect with them. Connect with these newcomers. Make them feel welcome and help them to get the most out of their AU. And remember, no hazing.

So, we have some great events going on this week. This year our innovation forums are being hosted by Roman Mars-- yeah, love his voice-- creator of the incredible show *99% Invisible.* Don't miss those. And tonight I'll be hosting a session on the latest technology trends brought to you by our generous Autodesk sponsors here at Autodesk University. So, join me tonight so that you can hear their vision for the future of making.

And, of course, tomorrow night we have the AUGI annual meeting and reception. So, by the end of the week you're going to be brimming with new skills, new information, new ideas, and many new connections. And the best way to wrap up your week here at AU is by going to the AU closing session, where Autodesk Senior Vice President Amar Hanspal will be presenting some fascinating people then talk all about their innovations.

And then, of course, we have the AU party. This year, the theme for the blowout shindig is Bash to the Future. This is absolutely the place for hobnobbing with some of the mad scientists here this week and enjoying them time travel-inducing cocktails. So, thank you so much for joining us at Autodesk University this year. Let's make this the best AU ever and thank you so much.

[APPLAUSE]

[MUSIC PLAYING]

PRESENTER: Ladies and gentlemen, please welcome Autodesk CEO, Carl Bass.

[MUSIC PLAYING]

[APPLAUSE]

CARL BASS: Good morning.

AUDIENCE: Morning.

CARL BASS: Morning.

AUDIENCE: Morning.

CARL BASS: Welcome to AU everybody. Great to be back. What I want to do today is I want to talk. I want to think about all of the innovative companies, all the amazing people I've come across over the years. And there's one thing that shows up time and time again when I think about these people. And it's this trick, it's the art of reframing. It's taking a problem that everyone else is looking at in a certain way and it's reframing it, looking at it from a different perspective. It's about challenging the underlying assumptions or just focusing on what's really important.

So today, I'd like to share with you some places I've been and amazing talented people I've met who aren't just working harder to solve the old problems, but they're really reframing them to get meaningful stuff done in really novel ways. So, let me give you an example of one of them. About a decade ago, Bob and Kelly here started a company called ConXtech and they wanted to reinvent the way that steel frame buildings were designed and built. They came up with this incredibly clever system for attaching steel beams to columns, and it's just based on the dovetail joint where each beam just slides into place and is bolted in. No welding, no riveting on the job site.

What's cool about it is it's cheaper to make and cheaper to build. Now they have this crazy jig that allows them to weld brackets on horizontally. Welding horizontally is 30% faster than welding vertically in the field and their precision is crazily in the thousands. But what's most clever about their system is how quickly and accurately the buildings go up. They can build 10,000 square feet in a day. For example, this building went up in less than seven hours with only eight steelworkers. And their system works even in really harsh conditions with a very small crew. Here they are at Burning Man where they built this 10-story tower in three days with five people.

Now, I saw some pretty cool stuff at ConXtech. But I'll be honest with you, it's not just the clever engineering that impresses me the most. And that's because there's this common misperception around innovation. It's not really about just one dramatic improvement on everything that came before. It's most often a combination of really pragmatic improvements combining and remixing things in really new ways. And the other thing, it's about doing the really hard work, the often unsexy work of packaging it all up and making it successful.

Unsexy work, here's an example. They got this system pre-qualified for seismic in every kind of construction throughout the US. And getting that pre-qualification was incredibly hard. So, the standard process for getting this qualification is that you load it up with 100% force in the primary direction and 30% of the orthogonal direction. But, it never having tested a system like this before, the certifying the agency was a little bit hemming and hawing about whether this work.

So Bob just looked them in the eye and said, let's just test it with 100% in both directions. And that kind of removed all the doubt. No other system had ever been tested to these limits. But there was a problem, there was a hitch here. Bob and his team had to find a rig that could actually perform the test and it turns out none of them existed. So being the resourceful guy he is, Bob said I'll just build my own. He built his own and then they passed the test with flying colors.

And so, I think this story is illustrative. It fundamentally shows that Bob and Kelly reframed the way they thought about their work and thought about innovation. They understood that the innovation wasn't just about great engineering, like that dovetail joint. It was also working through all the really difficult details and making the commitment and doing all the hard stuff that was necessary to actually make it happen.

Now sometimes we need to reframe our basic thinking about entire industries. And sometimes that shift is so big, it's hard even to see it. So, this happened to me recently. I visited the construction site for the new Apple campus in Cupertino. The thing is crazy big. It's three million square feet. It's a big donut. It's a mile in diameter and to build this thing it's going to cost $5 billion It's going to house 13,000 Apple employees when it's done.

Now Norman Foster and this team in London came up with this incredible design. But as you can imagine, Steve Jobs had a lot to say about how it would be made. He treated it like making a MacBook or an iPhone. You know, all in all, it's a totally amazing design project and seeing it up close and personal was really an awesome experience.

Now one of the things I saw was this precast concrete panel being installed. I was talking to some of the guys on the crew and as we were talking it starting to sound more and more like they were talking about aircraft parts instead of concrete panels, parts that were coming out of a factory. Now each concrete panel is made to super precise tolerances, each one has an RFID tag, and its tracked throughout the entire process.

But this panel was going to go in a parking garage. And so first I thought, wow, this is silly to spend so much time and energy and money on something that no one's ever going to see. I didn't see a good reason for it. But it turned out there was a really good reason. It's building and manufacturing are converging. That reframing of it solved the riddle for me. I realized that the Apple construction site is actually just an open air factory and that's how hard it is sometimes to really reframe things.

For example, for years I've been telling anyone who would listen that the building industry was going to look more and more like manufacturing. But when I saw it in front of me, I kind of dismissed it. Now many of you have been there leading this convergence of industries, putting all of the pieces together to make it a reality. And thanks to you, I think we've reached a turning point where you don't have to be Apple to create a building like a great product.

Now sometimes our reframing is inspired by some provocative new data. So last year I met a guy named Kevin Zinger. In 2008, Kevin was working in China basically trying to save the world. He was building a mega factory for electric car batteries and he thought he was focused on the right problem. But in 2009, just a year later, a study came out with an environmental life cycle analysis on cars. Well, it turns out the moment a car rolls off the assembly line it has already produced roughly one third of the environmental impact that it will generate in its entire lifetime. That's the car's embodied energy.

Now this is particularly important right now because in the next 35 years we are going to make more cars then we have made in the entire history of the automobile. And so putting these two facts together, it changed Kevin's life. He walked away from the battery factory business and decided to create a whole new category of cars and a new company called Divergent Micro Factories. He made this super cool chassis. It's made of carbon fiber tubes and 3D-printed metal nodes. And with this new approach, Kevin is building a car that's energy efficient in the making, not just in the using, of the automobile.

Now the thing I took away from this was all the time we've been ignoring a big part of the problem in terms of cars and the environment. If our goal is to reduce the impact of our cars, our focus shouldn't have been just improving mileage and tailpipe emissions. We should have also been looking at the data on the embodied energy in vehicle manufacturing, reframing the way they made so you could reduce the impact of all types of cars. Doesn't matter if they're powered by gas or electricity or even French fry oil.

Kevin's story is about making cars, but it's also about making sure we're working on the right problems. Now as CEO of Autodesk I'm always asking myself that question. Are we really working on the right problem? Now most the time the answer is yes, but sometimes the answer is no. And that gives us a chance to reframe our thinking and get to work on what really matters. So the question I have for you is, are you working on the right problems? AU is the perfect place to ask that question and look for new ways to reframe your thinking.

Now here's a story that starts with me as the customer. I was in my shop using my CNC lathe and something just wasn't right. The machine was screeching and I was making some really crappy parts. But as I try to tune the machine I thought, this is crazy. Why do I have to do it? Why can't the machine fix itself? So, being the resourceful guy I am, the first thing I did, which is, I know, it's everyone's natural reaction, I took the cell phone out of my pocket, I put it in a Ziploc bag, and I duct taped it to my machine, and I recorded the sound it was making. I then took that and I compared the sound it was making to some sounds of machines cutting I found online. And I could actually see the problem, but it still didn't tell me how to fix it.

So, being resourceful, I took the IMU off a drone and put it in that same Ziploc bag and taped that to the lathe. And so I basically MacGyver'd a makeshift internet of things to diagnose my problem. Now coincidentally right around that time, I met a little startup working on the exact same problem and they're actually doing a much better job of it than I was, or at least they got rid of the Ziploc bags and the duct tape and all the rest of the stuff. And what they came up with, what was interesting, a set of jaws that listens for changes in the sound of the machine. And it can reliably tell the operator when the tool is getting dull.

Now the system as just enough intelligence built in to recommend that you need to change the tool. Now that's good, but what I'd really like is a machine that listens to itself, changes the dull tool automatically, and adjusts speeds and feeds on its own to make a great cut. And that's where I think we're really going. And this hints at the future of the internet of things, where these closed loop systems can collect data, analyze data, and take the appropriate action all on their own.

Now here's a commercial version of the same problem. It's a nasty problem that I bet a lot of you have suffered through, airplane deicing. So, back in 2008, there was this big storm in Seattle right before Christmas and there was a glitch the deicing operations at the airport. So 450 flights had to be canceled, 4,000 people got stranded. And it turns out the entire nightmare happened because they ran out of deicing fluid.

Now Premier Deicers is the company that made the trucks that ran empty that night and because of what happened that night, they questioned their entire process, the workflow, the supply chain, all the logistics involved. And the solution they came up with was essentially the internet of things for deicing. They basically instrumented every component in the process and then they aggregated all of the data produced by those sensors in one place using RC control software. And now they had the data that's critically valuable to everybody in the process.

So for example, the airline can see within a handful of seconds of each deicing how long it took, how much fluid was used, and how long the aircraft had to wait. The EPA can monitor the use of these toxic chemicals and the guys operating the trucks know exactly how much material they have left and where the next load is coming from. And this is a kind of value I think we're going to see from the internet of things.

Now so far I've been talking about reframing our thinking around technology and processes, but we also need to reframe our thinking about people. There's a lot in the press these days about the future of work and how jobs are going to disappear. But I don't think that's going to be the problem, especially not for those of you in this audience. The problem isn't going to be a shortage of jobs. It's going to be a shortage of people. And there's a drought of talent coming and all of us are going to be competing hard to get the best folks to come work for us.

So, how can you compete? So first, think about why people come to work for your company. Now I had this really interesting experience this summer. I visited Facebook's headquarters. Now that's a place where a lot of people want to work, right? But I saw some stuff there that was kind of crazy.

So first of all, they have Silicon Valley standard, three meals a day for all of their employees, there's ping pong tables and video games everywhere, there were free snack machines everywhere, free dry cleaning, and even a dentist. But there was one thing that stuck with me. It struck me the most. And that was they have a lot of bars. There are bars everywhere, even one just outside Mark and Sheryl's office, there's a bar there. Now, I'm like everyone else, I like free food and I can see going for a cup of coffee and a snack. But the idea of going to just talking to your friend going and having a bourbon outside the CEO's office, that just seemed kind of weird. If you think about it, what's really wrong with just going to a real bar? So, it just struck me as odd.

So, in some ways it was incredibly impressive, what they did for the employees, but it left me

with this funny feeling. Is that really the best way to get the best and brightest people working for you and not just attracting average employees? If you think about it, I bet the rock stars that work at places like Facebook, or any company for that matter, don't really care much about those kind of perks. They care about something else and that's about doing meaningful work.

Now right around the same time I had that visit to Facebook, we had our class of interns at Autodesk show off the projects that they've been doing this summer and they did some totally amazing work. Now one team came up with a bicycle helmet that's a foldable geodesic dome made out of biocomposites. You can just store it in your backpack. Another intern built a system to design directly on the body and you then use a robot to 3D print that design right on to the person. We also asked the interns to give us feedback on their experience and what it was like to spend the summer at Autodesk and we heard two pieces of feedback very consistently.

First, they wanted more free food. OK, fine, Facebook got that part of it right. But the really important thing they told us was they wanted to work on things that mattered. And I brought that back and it made me reframe my thinking about how we go about attracting great people to work at Autodesk.

I think that old way of recruiting in some ways was an effort to coerce people to join you, to bribe them to join you, and that's what the free food and the ping pong and the bourbon is all about. But now I think it's really about creating a business and a mission that naturally attracts people who want to do their best work. And I'm already seeing this approach payoff for us. So let me give you a couple examples.

This is Lucas. He's one of our most recent hires. He just graduated from Stanford with a master's in mechanical engineering. Six months before graduating, he already had four job offers, one from Apple, one from a hot design consultancy, another from a promising startup, and the fourth one was from Autodesk. And he chose us. Why? We didn't offer him the most money. We don't have all that gourmet food. He didn't have the cachet of working for a brand name company like Apple. But we did offer him a chance to do meaningful work that he was passionate about that really can make a difference.

Here's another young person that helped me also reframe my thinking about who and how we hire. This is Brittany. Brittany's been a summer intern with us for five years now, ever since

she was in high school. This past summer she and her project partner, they designed a pair of mecatronic gloves using fusion. So, one glove records the first person's hand motion and the other glove is robotically actuated to move the second person's hand in the identical way to the first glove. And that's a pretty good project for two interns in two months of work.

Now Brittany is graduating from Stanford with a degree in biomechanical engineering this coming summer and she already has three options. Option number one is she's been accepted into a master's program at Stanford. Not bad. Option number two, she's been offered a Rhodes scholarship to study at Oxford. A little bit better. And, of course, she has the best offer, which is to come work with us. She has a job at Autodesk whenever she wants it.

But my point is, both of these young people could go work anywhere but they've chosen Autodesk because they know it's a place where they can work on things that are personally important to them, that they are passionate about, and in some larger sense really matter. So, how can you reframe your thinking about people? And so, are you building a company, a team, a culture that's going to attract the best and brightest to do the most meaningful work of their careers? As the leaders in your field you should be thinking about where your future talent is going to come from and what kind of work you're going to ask them to do.

Now I started today by thinking about reframing problems is often the key to doing real innovation. And I hope you're inspired to reframe some of your own perspectives. And I think there's no better place to do that then to do it here at Autodesk University. Now before our CTO, Jeff Kowalski, comes on stage to share his vision of the future with you, I'd like to welcome my friend Andy McAfee from MIT to give us his thoughts on the evolution of work, technology, and business. Andy.

[MUSIC PLAYING]

[APPLAUSE]

ANDREW MCAFEE: Carl, thanks very much for having me here today. Good morning, everyone. Let me ask how many of us have ever been at a really boring dinner party? Kind of every show? Yeah, fine. Let me give you a tip. The next time you're at one of those here's the question to ask. Just ask your fellow guests what they think the biggest stories, the most important developments in human history have been. Because it turns out everybody has a strong opinion about this question, and they will just start popping off on it.

So you'll get people, first of all, the philosophers will manifest themselves and they'll talk about transformative schools of thought in both the west and the east. Other folk will say no, the big stories in human history are the stories of divine revelation, are the stories of the world's great religions. And the more truculent folk will say, actually, the big stories in human history are the stories of war and empire and conquest. And there's always some cheery soul who says, don't forget about the plagues.

Other folk will talk about the opening up of the world and the great voyages of discovery. Some folk will talk about fundamental insights into the nature of math and science. And other folk will talk about the flourishing of the arts at different periods. This debate will go on forever. And there's no resolution to it unless you're lucky enough to have a geek at the dinner party, because the geeky approach here, I think, is the right one. The geek asks a really important question.

They ask, well, what does the evidence say? You're asking a question about the stories and the developments that have bent the curve of human history. Cool, let's draw that curve. In other words, let's try to turn this timeline into a graph and it turns out you can actually do that. We have pretty good data going back a long way about some things that we should care a lot about. How many people are there on the face of the planet? How wealthy are they on average? And how advanced are the civilizations that we're creating? It actually doesn't matter which of these lines you try to draw because they all have the same shape and that shape tells you, honestly, that none of these things has mattered very much.

Wars and empires and philosophies and conquests and-- none of that has bent the curve of human history very much. And when you look at it, you see that there was one point in time when human history changed just about 90 degrees and the curve went from horizontal to vertical. No surprise to this audience, that story is a technology story. It's the story of the steam engine and the Industrial Revolution. The ability to overcome the limitations of muscle power put humanity on a completely separate trajectory and put us in this era of industrial capitalism that we've been living in for about the past 240 years.

Now, this has been a profoundly beneficial development for humanity. It has made us wealthier. It has improved our material standard of living, even as that population has exploded. But I think all of us would agree, it's not unambiguous good and there have been some negative consequences to this crazy period of global growth and industrial capitalism that we've seen. And some of those consequences are easy to identify. In many parts of the

world we chop down just about all the trees. Across most of the world we killed almost all of the whales. And then more than one place, we made the moral mistake of putting children to work in factories.

In other words, this error of industrial capitalism seem to have this endless thirst for resources. So, we started diluting the planet to satisfy that. One obvious solution is, let's be more efficient about our consumption of these resources. But in the middle of the 19th century there was a guy named William Jevons who had a really unsettling observation. He said that efficiency improvement that we get from science and technology, it doesn't work. Because what happens is, even as each individual device or each individual machine becomes much more efficient, we just build more of them and so aggregate consumption goes up.

He saw this first with coal consumption in the UK and he noticed that even as the furnaces became so much more efficient, we kept on building more and more of them to build, make more and more iron and steel, and the use of coal in the UK just kept rising. So, efficiency is not going to work our way out of this problem. This thirst for resources appeared to be bottomless and by the 1960s or '70s there really did appear to be this deeply pessimistic view about the future. And if you read the books from that period, you come up with this rough formula and it goes something like, global population growth plus resource constraints and resource scarcity takes us into a really, really unpleasant place where we're literally going to have to make decisions about who's going to survive the coming famine in America.

And what's so deeply weird to me is that this is not at all what happened. In fact, something really close to the opposite happened. We have not experienced famines in America or almost anywhere else around the world brought on by resource constraints. Instead, we've become healthier, we've become wealthier, we are eating better and more varied diets, even as population has continued to explode since the mid 1970s.

In other words, this pessimistic formula was deeply, deeply wrong. And it's worth asking, what happened instead? How is it that we've enjoyed this period of, not just crazy prosperity but, ridiculous improvement in our standards of living, again, not just in the rich world but around the world? The number of people living in dire poverty is going down more quickly than ever before in human history. This pessimism has turned out to be dead flat wrong. So, the fundamental question for me is, what on earth happened? How did this really happy situation come about?

I think there's about a three-part answer to what happened here. The first part is something that we continue to underestimate and continue to lowball even though it's been going on for the entire period of industrial capitalism, which is just, something that Carl talked about, good old-fashioned innovation. It turns out this is what our systems are really, really good at.

And when whale oil, for example becomes really expensive, we turn over and we start lighting our lamps with kerosene. When wood becomes really expensive because we've chopped down just about all the forests, we start making ships out of different materials, we start making railroad ties out of cement instead of wood. This has the benefit of lasting forever and never rotting in addition to being cheaper and easier on the environment overall. So, we continue to innovate our way out of some of our toughest problems. Again, that's been going on for about 240 years.

The second phenomenon, I think is, we're just becoming aware of it and it's profoundly weird in a good way. Carl talked about how sometimes we go through these big transformations and we cross these turning points without even becoming aware of them. We crossed one just a little while back. It's a phenomenon some folk are calling dematerialization. And what it means is that just in the past couple of decades, and especially since the turn of the century, we are learning this really happy fact. We're finally getting past the problem that Jevons identified, this increased resource use no matter how efficient we get. That's not the case anymore.

This is my all-time, whenever I'm in a bad mood, this is my all-time favorite graph to look at. I'm probably not alone in this room that I turn to graphs for consolation when I'm feeling bad. Here's my favorite graph to look at. This is total US consumption of some pretty fundamental inputs to economic activity, like basic metals, fertilizer, some pretty fundamental things. You notice that we are past the point of peak use of these materials. It's not because our economy has been in constant recession since 2000. That's not the case at all. Our economy is a great deal bigger in dollar terms that it was at the turn of the century. We are making less use of some of the most important building blocks of an economy, material building blocks of an economy, year by year.

This dematerialization is a profound trend, deeply under appreciated one, and it makes me fundamentally happy. I think it's the best news on the planet these days. But it brings up another question, why is that going on? Why are we just recently in this period of dematerialization after 200 plus years of industrial capitalism? And the answer, honestly, quite frankly, is Autodesk.

I'm only being a little bit facetious about that. What's going on? Well, it turns out actually if you weigh total consumption in the advanced world country by country, we are literally consuming less year after year. Why is that? It's, honestly, it's because of Autodesk and the other technology makers, the other technology providers out there.

The phenomenon that we're experiencing in this era of the computer, in what my co-author, Eric Brynjolfsson, and I call the second machine age, the phenomenon that we're experiencing is of large scale substitution of code and information for atoms. It's letting us tread more lightly on the planet. It's letting us dematerialize the economy. I honestly find it almost impossible to overstate how profound this phenomenon is.

Here's another graph that I love to look at. This is total, almost since the entire postwar period, US corporate spending on digital hardware, on computer hardware. And, OK, maybe in the era of the cloud and very cheap devices maybe that budget is kind of plateauing a little bit. Here is a kind of budget that's not plateauing. Here's what US companies are spending on software year after year.

And what I think is going on is that the bottomless thirst for resources is being replaced by a bottomless thirst for software and information or code. This is a deeply, deeply happy state of affairs and it's happening in every geography I've been to and every industry that I know anything about. Around the world we are actually giving land back to nature every year. Even though there are more people, they want a better and more varied diet, we're able to take care of that need while giving land back to nature every year. And then Carl gave a couple examples. Here's one more, one of my favorites. We are actually building gorgeous buildings with the aid of very sophisticated software that consume less resources while they're being built and use less energy while they're running.

I'm a huge, I hope you can tell, I'm a huge optimist about what we're going through these days but I try not to be a utopian. So even in the face of this ridiculous progress there are still, I believe, two big challenges that we've got to face. The first one is the one that's on everybody's minds and it's absolutely fair, we have to stop cooking the planet, pretty clearly. And we have not yet innovated our way at scale out of this dilemma. I fervently hope we'll get there in the 21st century but let's not kid ourselves, we have to address this problem.

The other one is a phenomenon that Carl alluded to. The more I look at the evidence about jobs and wages, not just in the US but around the world, I don't get a lot of optimism there.

And I believe what's going on is that one of the resources that we are needing less of as we invest more heavily in code and software and technology, as technology can do more and more, we need some kinds of labor to do less and less. And for me that helps explain a lot of the pressures on the American middle class.

I'm going to draw one more graph and before I do that I actually need to make something pretty clear to this group. I am personally not a communist. The reason I feel the need to say that is I'm about to draw a graph of the differing trajectories of capital versus labor and when I do that everyone expects me to have a Che t-shirt on and start chanting Marxist slogans. I'm not going to do that. But we do need to confront some pretty important changes going on in our economy.

This is one measure of the returns to capital. This is US corporate profits for the entire postwar period as a percent of GDP. Woo hoo. Corporate profits are in a really, really healthy place. Look how quickly they came back after the Great Recession. So those are the returns to capital. Here's a measure of the returns to labor. This is a measure of the total amount of GDP that gets paid out in wages every year. And you see that the blue and the red lines are doing a dance back and forth until just around the turn of the century, when their trajectories have diverged quite a lot.

This is a challenge. When we were writing our book we came across a great quote from Voltaire the crystallized this challenge. He said, work saves us from three great evils, boredom, vice, and need. Of those three, need is going to be the easiest one to take care of. We're a wealthy society. But I do worry about what happens to people when they find their skills and their human capital getting left behind as technology races ahead.

Now when I talk about these two challenges, about global warming and about technological displacement of labor, sometimes I hear back, OK, great. Let's just unplug all the robots and go back to this happy pre-industrial time. What a deeply terrible idea that is. We do not want to go back there at all. We need to keep Winston Churchill's advice in mind.

The only way we're going to make things better for us and for the rest of the people and for the rest of our planet is by tireless improvement of all of our means of technical production. And when I talk to my colleagues and my friends at Autodesk and when I hear about the work that the people in this room are doing, I come away convinced increasingly. This quote from Freeman Dyson, this is actually not hyperbole. I believe this is a plain statement of fact.

I want to wind up by showing you two pictures that leave me really optimistic about this profound, this beneficial period of change that we're living to. Picture number one, we are restoring forests all over the world, including my state of Massachusetts. Picture number two, the whales are coming back to New York City. Thanks very much.

[APPLAUSE]

PRESENTER: Ladies and gentlemen, please welcome Autodesk CTO Jeff Kowalski.

[MUSIC PLAYING]

[APPLAUSE]

JEFF KOWALSKI: Thank you everyone. Over the course of the next 20 years, we're going to experience as much change to the way that we do our work as we have in the past 2,000 years. The future of work is arriving with lightning speed, and if it feel sometimes like we're at the dawn of a new era in human history, it's because I think we are.

There's been four major historical errors defined by the way that we do our work. The first, the Hunter-gatherer Age, that lasted a few million years, and then the Agricultural Age, several thousand years, the Industrial Age, a couple of centuries, and the Information Age has lasted just a few decades. Today, we are on the cusp of the next great era of human work. Welcome to the Augmented Age. In this new era, your natural human capabilities are going to be radically augmented by computational systems that help you think, robotic systems that help you make, and a digital nervous system that helps you connect to the world far beyond your natural senses.

Let's start by looking at how augmented cognition is going to radically upgrade the way that we think. For the last 3 and 1/2 million years, our relationship with tools has been basically directive because the tools that we've had have been completely passive. They do exactly what we tell them to do, but nothing more.

Our very first tool, it only cut where we struck it. And the chisel today only carves where the artist points it. Even our most sophisticated tools, they're useless without our explicit direction. But today, technology is making a quantum leap from passive to generative. That's why Autodesk has been one of the pioneers leading the way in generative design.

Generative design uses algorithms to synthesize geometry and all it needs from you is your goals and your constraints as input. This approach allows computers to go off and explore the entire solution set, the whole solution space, and come back to us with ideas that we by ourselves might never have imagined. And what I'm most excited about right now is that generatively designed things are making their way out into the real world.

And today, I'm thrilled to share with you some generative design work that we've been doing in partnership with Airbus for the past five years. Back in 2011, Airbus shared their vision for the future of flight in 2050. And this concept plane this a long way off, but we've been busy developing the technology and techniques to make it real one part at a time.

The first component that we've been working on is this partition panel. It divides the cabin and supports the jump seats that the flight attendants sit in during takeoff and landing. Now the current design of that partition, which has been flying in the A320 successfully for decades, it's already strong and lightweight. Made from a modern honeycomb composite, there is nothing wrong with it. But clearly, Airbus isn't interested in what's merely good enough. They want to explore the limits of what is possible. So they gave our algorithm the performance goals and constraints for this partition and it returns tens of thousands of options, all of which fully met those goals. And then through a collaborative back and forth between the human design team and the computer, the optimal design was chosen. And here it is.

This is the first time this project has been shown to the public. Maybe afterwards. This is Airbus's bionic partition. It weighs half as much as the original and yet, strangely, it's even stronger. Each partition installed into an A320 will save 25 kilos in weight. Imagine the impact of redesigning the entire cabin this way for every Airbus 320. Airbus estimates that this will save half a million metric tons of CO2 per year. That's like removing 96,000 passenger cars from the road.

Now the other cool thing about this project is the synergy between generative design, additive manufacturing, and advanced materials. Well, the great benefits of additive manufacturing is that complexity comes for free. And generative design is the perfect tool to take advantage of that flexibility.

It can make designs that are even more optimized. And beyond that we can also take a look at new materials. In fact, Airbus developed a brand new powder alloy called Scalmalloy that specifically takes advantage of generative designs. This new partition, which Airbus is making

entirely out of Scalmalloy, it's now being tested for flight readiness. It's passed all of its preliminary tests and one of the last steps in certification, a 16G crash test, is scheduled for next month.

Now this all sounds like it's part of the future, but it's not. The plane that you fly to AU next year might very well have this bionic partition in it. So our computers can now generate. They can come up with their own solutions to our well posed problems. But they're still hardly intuitive. They still have to start from scratch every time and that's because they never learn. Unlike Maggie.

Maggie is smarter than our design tools. What do I mean by that? If Maggie's owner picks up her leash, she knows with a high degree of certainty it's time to go for a walk. And how did she learn that? Simple. Every time the leash got picked up, they went for a walk. She just had to do three things, pay attention, remember what happened next, and create and retain a pattern in her mind.

Now here's the crazy thing. Just in the last year, advanced machine learning systems are starting to do those same things. They're learning to learn. Never before having seen these photographs, the system can describe and label them with no human intervention. How? The same way you did when you saw those images. It remembered, just as you would, everything it had seen before and used those patterns to describe new scenes. This ability to learn is now making computers better partners for design. Giving them some of the intuition that we humans have.

Here's an example. Would you cross this bridge? Most of you are thinking no way. And you arrived at that decision in just a split second. You did not need to go stop and do a deep analysis, build a BIM model of the bridge and set loads and run analysis. You just kind of knew intuitively that that bridge was unsafe. And soon our deep learning systems will have the same kinds of instincts about your designs. You will literally be able to show something to the computer, something that you've designed, and it will look at it and be able to tell you that will never work, or hey, that looks good. And when that happens we'll finally have a true partner in design.

Those first three levels of computing, passive, generative, intuitive, they're all just computer science, right? There's no people required. But now we're bringing the human into the algorithm, as well. And I mean that very literally. This is called empathic computing. It's the

incorporation of human responses into the system so that it can make better decisions that are better aligned with your decisions.

As a system listens to you and learns about you, it comes to understand your likes and your dislikes. It starts remembering your tastes and your aesthetic preferences so it can give you not just what you asked for but what you really want and maybe what you really need. How many times have we talked about learning a design tool? What I'm talking about now is a design tool that learns you. So, this is how I see technology augmenting us cognitively. Computers aren't just going to be working for us, they're going to be thinking with us.

Now let's take a look at another category of technology that augments us physically, robotic systems. Now there's a fear that robots are going to take jobs from humans. I believe that more interestingly, humans and robots will evolve their capabilities by working together. I don't think, especially for you in this room, that you're going to lose your job to a robot. But you might lose your job to someone who is using robots in clever ways to augment their capabilities.

We have an applied research lab in San Francisco where one of our big areas of focus is robotics, and specifically, human robot collaboration. And this is one of our robots over here, Bishop. We wanted to build a robot to help a person working in construction do repetitive, high precision tasks without the need for robotic or computer expertise. Tasks like cutting out holes for outlets and light switches in drywall.

And we put a trim router on the end of Bishop's arm and gave him natural language interface and artificial sight. That way, Bishop's human partner can tell him what to do in plain English and with simple gestures, the same way that you might talk to your dog. And you'll note that there's no CAD and there's no cam, not even a computer to interact with there. Just you and the computer, you and the robot.

And Bishop is actually the busiest robot in our lab and he's been working on another project for you here at AU. And the goal of this project, which we call The Hive, is to prototype the experience of humans, computers, and robots, all collaborating on a complex design problem. Hive is a pavilion that will be built here at AU under the direction of an artificial intelligence program giving guidance to both the robots and the humans. And the interesting thing about this pavilion is that it could not have been designed or built by either humans or computers working alone. I invite you to take part in this experiment and tell us what you think. Hive will

be just outside the exhibit hall all week.

Now I've been talking about how robotic systems can augment our capabilities through human robot collaboration. Now I'd like to introduce someone uniquely equipped to show us the ultimate potential of this partnership. Ladies and gentlemen, please welcome to the stage Dr. Hugh Herr.

[MUSIC PLAYING]

HUGH HERR: Thank you, Jeff. Hello, Autodesk community. How are you doing today?

[APPLAUSE]

I can't hear you.

[APPLAUSE]

So, I do not build buildings or bridges. I, in fact, build body parts. In the transportation business, I build bionic legs that augment human physicality. You can see on the screen that I'm wearing two bionic limbs. I invented these limbs. Six microprocessors, 24 sensors, muscle tendon-like actuators, I'm basically a bunch of nuts and bolts from the knee down. With bionics, I can run, I can hop, I can skip.

[APPLAUSE]

Thank you.

[APPLAUSE]

I lost my biological legs due to tissue damage from frostbite mountain climbing in 1982. This photograph was taken shortly after my limbs were amputated. I woke up one day with a very new body. Just a few weeks after my legs were amputated, I asked my rehab doc, what will I be able to do with my new body? I want to return to my chosen sport of mountain climbing, I want to get back on the horse and he said, without hesitation, that will not be possible. Ladies and gentlemen, I'm happy to report that the doctor was very, very wrong.

[APPLAUSE]

He was wrong because he viewed my body as broken and I disagreed. I said, my body is not broken, the technology is broken, the build design world is broken. In fact, if we innovate, we architect a new design world, we can ultimately eliminate disability.

Using that powerful and simple idea, that led me on this pathway of designing my own limbs. I developed a series of robotic bionic extensions to augment my physicality. I viewed the missing biological part of my body as an opportunity, a blank palette for which to create. I imagine as a young man, well, perhaps they'll be so technologically sophisticated I'll be able to run and perhaps faster than a person with biological limbs. Maybe they'll have wings and I can fly.

I developed all these devices. Think Inspector Gadget. Here I'm a towering three meters tall able to reach everything. So through this design process, I actually climb at a more advanced level with artificial limbs that I'd achieved before the accident with normal biological limbs. From this personal experience, I realize that technology has the power to heal, to rehabilitate, and to even extend human capability beyond innate natural performance levels.

Today I'm at MIT professor working in the new emerging field of bionics. Now bionics is this interesting interplay between biological science and design. The bionics practitioner does design through the lens of science and asks the question, how do humans work? The goal is to create a digital human that will inform the bionic structures that fundamentally augment our physicality, sensory experience, and cognition.

So at MIT, we're mapping the body. Ed Boyden and colleagues is expanding complex tissues, brain sample tissues, and using imaging, imaging down to the nanoscale. Such biomolecular maps will guide future bionic interventions to better guide re-engineering brain circuits to treat a whole host of conditions.

We're also understanding what happens when we walk, how are our muscles controlled by circuits in the spinal cord. This is informing the design of bionic limbs like I'm wearing. And we're building crazy robots to map the body by mechanically understanding how stiff we are, our tissue impedances, which drives digital representations of our body, and discussing how we can optimize using those models and build synthetic skins, a mechanical interface between the built world and the human body.

So, by creating and mapping the human, from the nanoscale the whole way up to the organismal scale, we're advancing extreme interfaces, mechanical, electrical, between the

human body and the built world. These extreme interfaces will give us all one day new bodies with new capabilities. Ed Boyden and colleagues are developing small implants that will go into the brain that will serve as co-processors, getting information in and out of the brain for the treatment of a whole host of brain conditions.

We're also growing nerves through micro tubes and the nerve grows through and attaches to muscle and skin cells. In the tubes, in the channels we have electrodes that we can sense how a person wishes to move, send that out to a machine like I'm wearing. We can also on adjacent channels stimulate into the nerve and take sensory information from the bionic limb and reflect it on the nervous system, closing the loop between the human and machine.

These technologies are allowing incredible control fidelity for bionic devices. This is Steve Martin, not the comedian. Steve was hit by a bomb blast in Afghanistan, lost both limbs, and through bionics now he's able to run up a rocky path. We're also building exoskeletal structures to be used by persons with normal biological limbs to lower metabolic cost walking and running and to lower stress levels. In the future, you'll walk down the streets of Vegas and it'll be commonplace for people to where bionic devices with their nervous system extended out to the synthetic world. Profoundly augmentative.

I'd like to finish up with a discussion of new identities. So, in the twilight years of the century, each individual have a plethora of bionic interventions to augment themselves. The future human will sculpt their body, creating new physicality, designing new sensory experience, new cognitive capabilities, and also, adapting and designing the very human identity. Clearly, in the future, the designer will design himself.

I've experienced this identity switching in my own life. As I told you, after my legs were amputated I climbed again. Twelve months after my legs were amputated I was climbing at a more advanced level. I was climbing rock walls that no one else could climb, whether with biologic legs or bionic. First ascents.

Just 12 months previous to that, the world was saying that I was weak, that I was crippled. So I augmented myself through technological intervention in a very short period of time. This is a threat to my climbing competitors. They actually accused me of cheating and threatened to cut off their own legs. I'm serious.

So what do you see in this photograph? Do see weakness or strength? Do see an end or new beginning? Do see weakness or the potential of a transcendent augmented human? What is

my identity? I think you know what I see. Because of inadequate technology, each condition results in a disability and a poorer quality of life than is [INAUDIBLE].

But technology can overcome disability. In this century we will systematically develop bionic platforms that will eliminate disability after disability. I cannot with a straight face look in the mirror and say that I'm a disabled person. The technology has freed me from the shackles of disability. I climb mountains, I run, I do whatever I want to do. If you take the technology away from me, I'm crippled. With technology, I'm freed. So I dream of a world without disability. Autodesk community, today here and now, imagine that future world with me. Dream with me. Thank you.

[APPLAUSE]

JEFF KOWALSKI: Thank you, Hugh. That was incredible. So far I've been talking about how technology can augment us cognitively with computers or physically with robotic systems, but what about our ability to sense and control? What about a nervous system for the things that we create? A nervous system for all of our created objects and environments and machines and systems.

Now our human nervous system tells us everything that's going on around us, but the nervous system of the things that we make is rudimentary at best. A car does not tell the city's public works department that it just hit a pothole at the corner of Fifth and Market. A building doesn't tell designers what its occupants like and don't like about being there. And a toy manufacturer doesn't know how a toy is actually played with, how often, when and where, and if it's any fun.

You know, designers imagined this kind of lifestyle for Barbie when they designed her. But what if it turns out that Barbie is actually really lonely. If the designers had known what was really happening, they could've used that knowledge to create an experience that was better for the kid and better for Barbie. What's missing is a nervous system connecting all of us to the things we design, engineer, and make. How would that change the way that you work? Now I'm not a Barbie expert, but here's a couple examples I think that we can all relate to.

What about the nervous system just in our hotel rooms here? Let's start with the minibar. It's got a nervous system but it's tuned to all the wrong things. It uses its hair trigger sensitivity to charge me $16 for that tiny bottle of gin that I disturbed while I was reaching for the $4 bottle of water, or vice versa.

Now I know that gin bottle monitoring is very important to hotel operations, but what about connecting that nervous system to something that's important to you, the guest? Like in the bathroom. Why is it that housekeeping always shows up at the wrong time? Hotel already knows that I'm in there because the bathroom's got a sensor that turned the lights on for me. Why not also turn the Do Not Disturb light on outside my door?

And maybe some of you stopped off at the restroom just before main stage this morning taking your seat and met up with one of these. What do I need to do to get the so-called smart machine to give me a towel? Do I have to do the frantic wave on this one, or maybe I do the blessing, or does it need the gimme gimme?

[LAUGHTER]

If this machine were part of a nervous system that connected its designer to the things and she designed, she would know better what to do with the next design that she made. Or maybe they could just download a patch to make it operate better.

I've got some great news though. There is a whole group of people, a whole discipline, in fact, that we can learn from as designers. They've built and leveraged these kinds of nervous systems continually to adapt their designs to the reality of their use, and they're called web designers. Now think about a modern website. The entire site is instrumented down to the pixel. Designers are constantly using this data to make every interaction on the site better, more relevant, more useful to its users.

What if all of you had that kind of information flowing to you from the things that you create that are out in the real world? Now you'd know if your design works the way that people need it to. You'd know how much they like it and you'd know what to do to improve it. Of course, when you're connected to your creations even after they're out in the world, your responsibility for them and will no longer end just when you ship that product or launch that service, which I think opens up a very interesting opportunity. It means we can finally shift our focus from making people want our stuff to making stuff that people want.

So what happens when this nervous system doesn't talk to just the designer though and instead it talks directly back to the thing being designed? You remember that generative design example with Airbus? A human design team had to give the computer all those goals and constraints and that's actually harder than it sounds. For example, if I'm designing a new car chassis, I need to tell the computer how much force the suspension joint is going to be

subjected to and knowing things like that takes a lot of expertise. But if you give the computer a nervous system, it can provide all of the necessary data directly to the design.

Now we've been working with a group of crazy guys called the Bandito Brothers and their team down in LA. And one of the things that they do is they build insane cars that do some truly insane things. They've got the Guinness world record for the longest car jump, the first corkscrew, and the world's first double vertical loop.

Now we've been working with the Banditos to build a car with a nervous system. It's a traditional race car chassis instrumented with dozens of sensors. Then we put a real world class driver behind the wheel and drove the hell out of it. And that driver was having a blast but the car was recording everything that was going on, all of the forces that the chassis was being subjected to. We got a ton of data from this nervous system, which we plugged directly into our generative design tool that we call Dreamcatcher.

So what do you get when you give a design tool a nervous system in the real world and you ask it to build the ultimate chassis? You get this. Something that is impossible for a human to have designed, and yet a human did, but only when they were augmented by generative design and a digital nervous system. And guess what? The Bandito Brothers are here at AU. You can go talk to them about this in the exhibit hall all week.

So, this is the future, the Augmented Age. We're going to be augmented cognitively, physically, and perceptually. Our technologies aren't going to replace us. They're going to help us to do things we never could before. And I can't think of a better place to start building the future of the Augmented Age than with all of you here at Autodesk University 2015.

This is my 10th AU as CTO of Autodesk and knowing what we've got in store for you this year, I know that this is going to be, hands down, the greatest AU ever. So have a great time at Autodesk University 2015. I'll see you outside. Thank you very much.

[APPLAUSE]

[MUSIC PLAYING]