[MUSIC PLAYING]

PRESENTER: We make things. It's our nature. We take pride in being able to say, I can make it myself. This is the story of the craftsman.

For most of human history we made what we needed or we traded with local craftsmen. Over time, we began to specialize in skills an apprentices learned from masters. Many of them were family trades where knowledge and skills were passed down from generation to generation.

A couple of hundred years ago, water and steam power started taking hold. We can make it together. This is the story of the Industrial Revolution. For the first time, work could be done independently of human labor.

This started the trend of specialized machines replacing specialized people. Electricity would spark the next major shift. Large factories were built near cities with harbors and railroads. Containerized shipping took off in the second half of the 20th century. And manufacturing began to move into locations with even lower labor costs.

We can make it anywhere in the world. This is our story now. But there is another great shift on our horizon.

New technologies, new materials, and demand for customizable products are creating new opportunities. These changes move us towards more local, agile methods and provides the chance to work from anywhere, across specialties. To combine technologies, become even more efficient. The new industrial revolution is here. Are you a part of it?

PRESENTER: Ladies and gentlemen, please welcome hardware sorceress, Downtown Project Las Vegas, Jen McCabe.

[APPLAUSE]

JEN MCCABE: Good morning, everyone. My name's Jen McCabe, and I live and work downtown, about two miles from here, with Tony Hsieh, the CEO of Zappos. I'm privileged to be a part of one of the most amazing design build projects in the world. We are literally building a city as a startup. It's a $350 million experiment with a allotments toward small business, technology. And we're figuring out how to reconfigure community in a way that makes everyone who lives and works there smarter.

Why is this interesting for you as an audience? We find that manufacturing and thoughtful design really matters. Today advances in technology are transforming the way we make all kinds of things.

From a new spoon that you can take camping to a city. Promising new technologies such as additive manufacturing, 3-D printing, and advanced robotic automation like the Bot & Dolly robots have the potential to change how objects are fabricated and assembled. New open and crowd sourcing platforms are transforming the way that companies do business. And they're creating new workflows for manufacturing.

Intelligent materials are enabling a new breed of manufacturers to create products with new properties. Today you're going to meet five speakers who will introduce new trends that you should be paying attention to. The first one is crowd sourcing. We're going to have Ben Kaufman the CEO of Quirky tell you about partnerships with larger companies like GE and how releasing a patent library into a community of thousands of makers creates really interesting and amazing new products.

Then I'm going to tell you about crowd funding. This is a viable new business model for starting and growing companies. And there's probably more money and innovation moving through the system than you realize. Then we're going to tell you about democratizing access to the tools of manufacturing that have traditionally been siloed behind large assembly and manufacturing lines. Many of you already know Mark Hatch from TechShop, and he's going to show us some fantastic examples.

Then we're going to have David Benjamin from Columbia and a company called The Living. He's going to show some amazing new tools of infinite computing that mimic the design processes of nature to find optimal workflows. And finally we're going to close the Skylar Tibbits who is going to blow your mind.

He is building machines that assemble themselves. Forget human automation, forget human robotic interaction. What about having a building that actually constructs itself from the ground up?

There are a lot of interesting ideas that will be shown on stage today. But I want you to keep one question in mind as we go through this. The speakers today will show you that the New

Industrial Revolution is already here. What I want you to think about is how will you be a part of it? So now I'd like to bring up our first speaker. Ben, come on up.

BEN KAUFMAN: Thanks

JEN MCCABE: Thank you.

BEN KAUFMAN: Thank you. Hey, guys. Good morning. This is going to be fun. We're going to have fun.

So I come from New York. We're based right in downtown Manhattan. And every morning if I turn my head just the right way and look out the window I look at this fine building. It's the Empire State Building and it was built in just 410 days. 410 days to build one of the most iconic buildings in all of the country.

I'm also inspired-- my grandfather was in World War II. He always told me the story of the Lockheed P-80 which was built in just 143 days. From the moment someone said, let's put a jet engine in this guy to the moment the first fighter jet was flying. That's crazy.

Our neighbor, OXO International puts bicycle grips on potato peelers. And it took them 3 and 1/2 years to figure out how to do that. So Empire State Building, 410 days. P-80, 143 days. 3 and 1/2 years in order to make a consumer product. That's the state of invention today.

It's slow. It's incremental. And we can't get out of our own way.

You see, we're all inventors. We're all creative people. We're all born with that passion. We're all kids with tin foil jet packs. But at some point we stop.

And we stop not because we lose our creative soul. But we stop because invention is hard. It's hard to be an inventor. It's hard to push a consumer product out there. This is an abbreviated list of all the things you need to know just to push one brand new product into the world.

Now, it's not just money that's the problem. It's not like you can just grab a bunch of money and then have a product that's able to sell and be successful in retail. It's the coming together of all of these different disciplines that makes it so hard to push a consumer product out there.

But invention's so incredibly important. It's what drives us forward. So we started Quirky five years ago with a very simple mission, to make invention accessible. To make sure that the best ideas in the world's ship, regardless of luck, or circumstance, or pedigree. In order to get my first product off the ground I had to ask my parents to re-mortgage their house. And that's not cool, I don't suggest it.

We launch three brand new consumer products a week at quirky. Three brand new products. And we're just a bunch of people locked in a glass conference room in Manhattan.

How do we do it? People come to our website. People all around the world. Hundreds of thousands of people. I think our community is about 700,000 people now, growing by 2,000 to 3,000 creative people a day. They submit their great product idea. They vote on which one is the best each week.

We go through a really collaborative process that helps us vet great ideas to collaboratively discuss everything from naming, to colors, to tag line, to features, to engineering, et cetera. We then do all the heavy lifting, all the sourcing, all the manufacturing, all the retail negotiations, the marketing. And at the end of the day the entire community cashes in and that product is shipped and made its way to the real world. Invention is all of a sudden accessible.

To bring you through this I'm going to introduce you to this goofy guy from Wisconsin named Jake. He was a high school student about five or six years ago. And NASA, like spaceship NASA, came around trying to inspire Midwestern kids to be creative and be engineers. They asked the kids in Jake's high school to try to invent and design a product, and submit it to a NASA product design competition.

He did that. He went home. He looked on his floor. He saw a power strip with six outlets. He could only use three of them though because this big charger blocked the other one.

So he had this great idea for an articulating power strip. He made this tri fold board. He submitted it to the NASA product design competition. He actually won.

Do you know what he got? He got a t-shirt. He got a pat on the back. They said, good job kid. Follow your dreams.

But Jake couldn't commercialize a groundbreaking power strip with a t-shirt. So he sat on the idea. He sat on the idea for a number of years until he heard about Quirky. He submitted the idea on Quirky on a Monday. By the following Thursday it had gotten enough votes to come to our Thursday afternoon live product evaluation meeting. This is a live debate that we stream all around the world where we discuss and debate the top ideas of the week. And the purpose of this is to crown three to five brand new inventors and then begin the process.

We started working on Jake's power strip. Everything from how many outlets should it have, to how long should the cable be, to what should the angle of inflection of the actual strip take itself? Even something like naming a product we make into an interactive game, where we have thousands of names submitted. And we AB test names against each other.

120,000 interactions on an average naming project. This reduces the amount of politics and crap that goes along with all marketing departments, and so on and so forth. And just surfaces a great name and a great idea that we know we can believe in. Because our community believes in it.

We don't just leave the community alone, though. We pair the community with a group of designers, and engineers, and researchers that we have in house at our facility in New York. It's just like what we were saying where it's not just the machines. There's not just the community, but it's everyone coming together. It doesn't matter where a good idea comes from as long as it ships.

We then put Jake's product through a series of rapid prototyping and design activities. This is the first test print of the product. We got it through all the regulatory bodies. This is not something Jake would have been able to do with a t-shirt.

They didn't know how to test this product. It was so new they needed to create a testing process for it. We set up production lines in China. We did everything associated with the product. And finally, we launched a product named Pivot Power just a few years ago.

Now Pivot Power became a product with Jake's face on it. That's Jake. That's a stick figure of Jake. Instead of having a logo as a company we let our inventors draw themselves as a stick figure and we stamp that on the product.

We got a lot of press for it. Put it in 35,000 retail stores around the country. We've created a whole line of products based upon Jake's original idea. Rugged ones, international ones, travel ones, all sorts of different versions. And now Jake's a millionaire, which is kind of better than a t-shirt.

Now that's Jake. And that's one guy and one product. One guy, one product. But the story isn't just about Jake. 709 people on our website made intellectual contributions in order to push that product out into the real world. Everything from my grandmother sitting at home by clicking on the naming game to a person that helped us figure out a huge engineering challenge inside the actual product.

These people are coming together and helping us make quick and awesome decisions. And every time one unit of Pivot Power sells at target, all 709 people get paid in real time based upon how much of an impact they made over the successful development of the product. That's one product, one community, one thing. But we do that, we do that Jake story three times every single week.

We've done hundreds of products. We've paid millions of dollars to our community. And we do this because we believe that the best ideas in the world don't come from settings like this. They don't come from boardrooms. They come from living rooms.

And Quirky and our community are in those living rooms listening to each other's ideas and making sure that no matter what that person can do, no matter what that creative soul can do, all the other stuff will be supplemented by both Quirky the company and Quirky the community. So what does this mean? How's it going? What's the latest and greatest?

We were here at CES, I guess it was like 10, 12 months ago now. And I was joking the whole show, they should change the name. There's no electronics here. Everything is just cheaper, thinner, and faster than last year. Why do I keep coming back out here?

But there was a little dark horse, the category. In a small little corner of the south hall there was the connected devices. Things that were smarter because of their connection to the internet. Now we had been starting to see a lot of invention ideas on quirky.com that were connected devices. But we didn't yet green light them or do it because we were still trying to understand the landscape.

But at CES this year a light bulb went off. We realized that everyone's calling it all these different things. There's 55 different names for what this category is. We like to just call it The Jetsons. There's lots of great products out there, but there's no interoperability.

If the internet of things is truly going to be a thing, we need to talk about a few things. And this is the main point. Number one is everything should work with every other thing. Number two is if you're going to buy a door lock that connected, chances are you don't want to buy it from a company called Quirky. You'd want to buy it from a place where you trust a lock from.

So we started to have all these thoughts of how can we build an ecosystem around this? Not just launch one-off products, but build a full ecosystem of connected things. And bring all the large manufacturers in the country together. This was in January. In February we said, let's call GE. We called GE. We said hey, we have this idea. What if we take on this category together?

It took us three weeks, only three weeks, to get a deal going with GE. And on day one we had a press conference with Beth Comstock a Mark Little. And we said we're going to take on a giant category together. We're going to build a line of connected devices. And hell, it's going to start shipping this holiday season. We're going to build a line of connected gifts that are going to ship this holiday season.

Now, this was in mid April. We had no ideas, we had no products, we had no manufacturing plants. We had no software. There's a whole other part of this, software.

So we started out. In week one we got not only a lot of press, but we got something like 1,800, 2,000 connected product ideas through the Quirky and GE submission page. We held a product evaluation that was that night. And we chose 16 that were chosen for development. We've since chosen 55 products in a connected space in tandem with GE.

We partnered with a great company named [INAUDIBLE] to help us bring the Wi-Fi stack to market quickly. We started engineering products in month two or three. Our community was helping us pick colors.

In month four we said, well we should probably make sure this stuff has a place to sit on the shelf. So this was around August. So we went down the Home Depot and we said, hey, we've got this whole line of devices. You're Home Depot and everyone's talking about this is connected home. What your strategy?

And we helped them think through an open strategy where everything at Home Depot worked with all the other things in Home Depot. And this was month four. We were so excited about what Home Depot represented for this market that we decided to fly a plane over their headquarters that said Quirky and GE instantly connected just to make sure they realized how excited we were.

It was a company flag football game. And they got kind of upset. But it worked out.

So we got the order the next day. We sent a good portion of our team out to our factories. Check out this guy on line with the Hawaiian shirt. Isn't that hysterical?

We started shipping products. But before we did that we started getting the buzz going. So we put the product on Leno. We flew our inventors in and did photo shoots with them. We started shipping the product.

And if you go into a Home Depot right now, anywhere in the country, all 2,049 stores, this is what you'll see. You'll see a full end cap of gifts that are connected, that were invented by people at home. People that without Quirky, without GE, without the coming together of all this community goodness would not exist.

These are some of the products we developed. We developed Spotter, a multi purpose censor that makes anything work with anything. You could sense temperature, humidity, light, sound, et cetera. People are putting it on the garage doors, on their mailboxes, et cetera, to let them know when the mail comes. The possibilities for this product are pretty endless.

We did this, which is the smartest alarm clock in the world that actually takes all of-- it's called Nimbus-- takes all of your cloud data. How many Tweets you have, how many emails you have, et cetera, and it puts it all on one physical dashboard and physical display. Not only did we build the hardware that goes along with this, we had to build the software as well.

And this was a fun project that we did for, lack of a better term, shits and giggles. Where we said, well what would be a funny thing to put the internet in? And we built the first internet connected egg tray. Probably the first and last internet connected egg tray.

Where you actually, if you're at the market and you want to know how many eggs you have, you can pull up your phone and see how many fresh eggs you have. As you pull up one of the eggs it tells you which one's the latest. So it promotes good inventory practices like FIFO.

A full collection of product, again, created together. It's not about just GE or just Quirky. But it was the start of an ecosystem. So what we started with GE was a collection of gifts just to get the excitement going from a community prospective. But this software, and this technology, and its backbone that we built is now an open platform that we're encouraging some of the largest manufacturers in the world to connect into.

It's about open. This is about collaboration. And we're doing this together. Again, not to just build a great product business, but to make sure that invention is accessible. To make sure the best ideas in the world ship.

Oh yeah, and this was just a couple days ago. They said our connected platform was the simplest and easiest to use. Yeah, this is *Fast Company*. So not only did we build it quick, but we built it well.

Part of the reason why I started with the Empire State Building example is I think a big thing in product development is people thinking that if you go slower you'll get better. And I think that there's lots of examples in our country's history and great company's history where going slower did not necessarily mean better. And by putting constraints on yourself, by publicly standing up at a press conference with officers of GE and saying, yeah, we'll ship by Christmas, it forces everyone in the organization to do good.

So the New Industrial Revolution, that's the title of this session. I'm going to do my best to synthesize my observations of what this all means. The first is exactly what I just said. Constraints are king. Constraints allow you to be your best.

Boeing, we just talked about the example of the P-80. I think Boeing just spent $8 billion over the last 10 years increasing efficiency of their planes by 2% or 3%. Now again, the first fighter jet was built in 143 days.

Now, constraints. People were dropping bombs on our ass. We needed to build the fastest and best plane in the world, quickly. Constraints drive us to build great things.

So whether or not you have real constraints or artificial constraints, putting boundaries on yourself and saying, this will happen and it will happen well, and set those goals publicly, will drive you and your organization to build some really great stuff.

Number two is the best feeling in the world is when you can say, I made that. Now traditionally, I made that is a phrase that's been reserved for crazy engineers, and scientists, and people intimate in the product development process. What Quirky represents-- there's lots of other platforms represented as well, crowd funding, et cetera-- is the fact that that word, that phrase, I made that, can be distributed to hundreds, thousands of people per product.

The most pivotal moment of my life was sitting on a subway six months after I launched Mophie, my first company, and seeing someone use my product. The realization that that is the best feeling in the world made me believe that if we could distribute that feeling, not only will we have a great set of products and a wider net of ideas, but we'll have true evangelists hoping for the success of each product from the very beginning. And then the last point is that data absolutely obliterates politics.

One of the reasons why Quirky can go so fast is all of our decisions are grounded in data of what the world wants and is looking for at any given time. So we don't have to deal with scary situations like this again. We can know that if the world says, call it this, and we feel good about that, and it's a brand fit. And it fits IP clearances and stuff like that, then we'll do it.

It's not about egos. It's not about anything. It's about making sure that the best ideas in the world actually get out there. So invention is a collection of these three things, people, data, and constraints. And if you can do that well, you can build entire product lines.

You can revamp everything. You can move from an incremental product development process to one that's truly inventive. Now, there's one threat to this equation, one threat to this giant invention equation. And that is the state of the intellectual property landscape.

What is once formed as a blueprint for future inventors, the patent system is now just a base weapons of corporate warfare. Now, it's one thing to say we want patent reform and so on and so forth. But I think you can actually put patents back in their place without changing anything.

Companies create intellectual property. And they do that because they want to set the ground rules for the things they invented and prevent their direct competitors from competing with them. Now, GE create tens of thousands of patents. They have patents developed for synthetic jets and crazy stuff. Now, they're not worried it someone puts their synthetic jet technology in a household fan, because that's not why they developed it.

So GE was the first company to sign up with Quirky to launch what we call the inspiration platform. We have tens of thousands of GE patents available on quirky.com for our community to invent with. So not only are we listening to the world and their ideas, but we're also inspiring them with lab proven technologies. You can go on the inspiration platform, browse lab proven technologies, and use that as the catalyst for your own consumer product ideas.

Now chances are it's not going to interfere with GE's MRI business. So what do they care? All they care about, again, is making sure invention is accessible. Making sure that invention is commercialized.

That's all I got, we're good. See ya. Thanks, appreciate it.

JEN MCCABE: Thank you, Ben. That was absolutely amazing. How about Quirky, guys? Empowering everyday Jakes to become individual inventors and get paid for it?

Awesome. Let's give him another hand. This is groundbreaking stuff.

So part of the recurring theme that I think you'll see today is empowering an n of 1. Either an individual inventor for an individual company to deliver a product. And in manufacturing some of the most interesting innovations have been about delivery. And they've also been deceptively simple.

56 years ago, a trucker from Carolina named Malcolm McLean invented the shipping container. He wanted to ship goods in a faster, more efficient way than throwing sacks onto ships or driving trucks through muddy rural highways. It's just a metal box. But it revolutionized the way that we deliver goods.

And the new business models that are driving reshoring mass customization are all about delivery. Take the example of Shapeways. Raise your hand if you've heard about Shapeways? Yeah, good, about a third of you.

So Shapeways is one of the largest 3D printing marketplaces in the world. It enables designers and engineers to submit designs and then customers can go to Shapeways and either download those designs if they have access to a 3-D printer on their own. Or they can pay Shapeways to 3D print and then deliver that good to them. The entire company is about the n of one.

Printing on demand. So each order is customized and highly personalized. Now, Shapeways is not doing small volumes. They're printing over 100,000 items a month. Makers, engineers, designers, and artists all over the world upload 80,000 items every 30 days. This is big business.

And that brings us to crowd funding. Crowd funding started, and it seemed like a very, very small innovation with a tiny market. If a team of people, they want to build something maybe for themselves. They want to sell it to a few friends. So they upload an image, or a sketch, or maybe a little bit of a video to a website.

And then other people can pledge an amount of money with the hope that the team will actually build and deliver that product. Crowd funding has come a long way in the last two years. It is now a viable way to start and grow a big hardware business. I'm going to give you some examples.

This the current crowd funding campaign that is up right now. It's a company called Kano. Has anyone here backed Kano? Yes, awesome. OK, me too.

It's a $99 kit to build your own computer. I'm going to build it with my niece Ellen for Christmas. She's five. The interesting thing about Kano is that with 15 days to go 9,000 people have backed this project. And the team based in London has raised over $1 million, exceeding their expectations 10 x.

Another example. Canary, a connected home device. Raise your hand if you've backed Canary, anyone, on Indiegogo? No? I'm also the only geek who backed that, OK.

Canary has sensors in this array on the left hand side, the white tube, that track motion, temperature, and sound. They raised $1.9 million on Indiegogo. This is a series A. And it's all coming from customers who want this product to be real.

The team will now have the very interesting challenge of manufacturing and delivering Canary to more than 7,000 people. And I talked to the founder, Adam Sager. And he says he chose Indiegogo and crowd funding because the company itself put resources toward helping the Canary team figure out this new business model. But also because it was the best market research he could possibly devise. He now has 7,000 people in a highly personalized focus group that will help the company figure out how to grow and expand.

Yet another example. These are robots Bo and Yana. And if you think crowd funding is just for kids out of college or working out of their garages, I want you to think again. Bo and Yana were designed and manufactured by a team in California called Play-i. The whole goal of Play-i is to make programming accessible to people of all ages, especially kids.

And Play-i's founders are not fresh out of Stanford, or Columbia, or a community college. They're team headed up consumer payments at Google. They led the engineering team at Frog Design. They directed the software team at Apple and launched 10 iPods in six years. And other founder built Symantec's global e-commerce platform.

10,994 of these tiny blue robots were ordered in a month through a crowd funding campaign that Play-i ran. And interestingly, Play-i did not use Kickstarter or Indiegogo. They ran the campaign on their own website. In one month they raised $1.4 million. And even more interestingly, the consumers who backed Bo and Yana are waiting until the summer of 2014 to have their orders filled.

But I also want to make the point for you that crowd funding is not just for toys. This is Scanadu. And this is the Scanadu Scout. Crowd funding products are breaking into formerly entrenched industries like medical devices.

The Scanadu team actually built this device and raised $1.6 million. Then they used that as proof to raise a $10.5 million series A round, with investors including Tony's on Vegas tech fund. The device is about this big, and you put it on your forehead for 10 seconds. And it measures your heart rate, respiratory signals, even your blood pressure. The whole point of the Scout is to empower you to become the first responder when your health stats change.

Now, the best way that I can emphasize to learn about crowd funding is to actually do it. Has anyone here actually run a Kickstarter or Indiegogo campaign? Awesome, you and I are going to get along for sure. Big companies are trying it. Small companies are trying it.

My background was with a company called Romotive that built this little blue smartphone robot, Romo. It took us two years from our Kickstarter campaign to figure out how to design, build, and deliver Romo at scale. And this holiday Romo is finally going into Brookstone stores and apple.com.

What we learned when we were building Romo. This is actually the second generation robot that we built. The first generation with a small laser cut acrylic kit with a LiPo battery and open ports to the circuit board. You could assemble it yourself. So we would send it to you in a UPS box with a little number one screwdriver.

And you could build it in about 11 minutes. And we did that because we didn't really know how to assemble 2,000 robots and fulfill the campaign at the same time. But what we learned is that people love things that they help build themselves. If you back a Kickstarter or Indiegogo campaign you're more committed to the project and to the company, because you feel like you had a part in building it.

There's a greater sense of ownership. It's almost a patronage system. There's an actual phenomenon that's now being studied called the Ikea effect. So there are two scientists, Michel Norton at Harvard and another scientist who are looking at how self assembly and kit assembly is actually creating a new breed of prosumers.

As you know if you've backed a project, there's a very different feeling than going to store shelf, putting something in the cart, and taking it home. I'm sure that the contributors who help design Quirky products feel the same way, a unique sense of ownership and commitment. So why is this important to you?

We saw Jeff in the opening keynote talk about looking outside for innovation. Some of the most innovative teams, people, products, and companies are available as free market research to you on Kickstarter and Indiegogo. And it's important to look at those teams of people because they are already teaching themselves how to build new manufacturing processes.

How to bring new products to market. How to short circuit the complicated logistics and 3PL delivery process. What I want you to do is focus externally on the teams of people that are building really amazing things already. Because they have to in order to get those products into the hands of consumers. If you don't look outside to drive the New Industrial Revolution, I worry that we'll have beautiful advanced factories that are empty.

And the reason that this is happening is because we aren't waiting to hear from larger companies how to do manufacturing. We are hopping on planes. We are figuring out shipments. We are learning how to write our quality control standards, our online tests. How to re-engineer processes.

We're working with large partners like FedEx even as startup teams of three people. I want to emphasize that the most promising thing you can do as a company, as a designer, as an engineer to advance the New Industrial Revolution is to fully engage with the risk that is involved in working with people from the outside.

There are lots of fresh minds working on building hardware. This is a make-a-thon that Motorola held at a college. Kids love building things, as we're finding out. And there are more and more products to encourage family innovation. You'll hear next from Mark Hatch of TechShop who is building labs and manufacturing technology in people's backyards to enable community creation. He is democratizing access to the tools of production in a very, very interesting way.

Why is all of this important? I think that we actually have to think long and hard about what the factories of the future will look like. I don't believe that they will look like this. I don't believe that they will be human powered final assembly lines. It's getting too expensive.

I also don't necessarily believe that they will just be fully automated factories with robots running every process. What I think the factory of the future will look like is this, humans and machines working together side by side to build and assemble new products. Our challenge in advancing the New Industrial Revolution is building technologies and processes that enable people like me, people like Kickstarter and Indiegogo funders, people like Quirky inventors to join with larger companies and build the manufacturing processes of the future. And to show you how that can get started neighborhood by neighborhood, I want to bring Mark Hatch of TechShop up. Please welcome Mark, guys.

MARK HATCH: Uh oh, there it goes. All right. So I'm going to talk about maker spaces and bringing manufacturing to city centers. First of all I want to mention the book. So this is a revolution. Every revolution needs a manifesto.

As a former green beret I am an actually professionally trained revolutionary. So I'll use appropriate terminology where it comes up. This book has got two basic objectives. The first objective is a call to action by you as an individual. Revolutions actually get their steam when individuals get engaged, when individuals change their behavior, when individuals work together to make the changes that they want.

So at the end of this I'm going to give you a challenge and ask you to participate, in revolutionary type of terms, into some kind of a collective action. Or at least an action at the local level that will help change your perception and your reality so that you'll understand how important this particular movement is. And I may sell one of these using a square device later in the deck here.

Briefly, for those of you who don't know what TechShop is, TechShop's a membership based, do-it-yourself open access fabrication studio. It's roughly 15,000 to 20,000 square feet. It has every tool you need to make anything on the planet.

We teach hundreds of classes. We do not assume you know anything about the tools. You can come in as a novice, start using the tools, taking the classes, and then you can start making some amazing things. In fact, we personally have seen people go through their own Industrial Revolution in 90 days.

They come in. They've never made anything since sixth grade. And 90 days later they own a company that will sustain themselves. How is that possible? You have to have a manufacturing facility at your fingertips. So we have everything.

We've got the machine tools. We've got the lathes. We've got the mills. We've got a computer numerically controlled machine.

We've got sheet metals. We've got stampers. We've got a big welding shop. This is our sexy beast. This thing will cut through five inches thick of anything on the planet. Computer numerically controlled, we can teach you how to use this in three hours. It's a remarkable tool.

We have a complete woodworking shop, including lots of safety types of machines like that saw stop. We have a plastics lab. We have an electronics lab. We have a textiles lab so that you can do clothing. Or you can do sails. Or you can put a seat on your motorcycle.

We have software and electronics. We have 3-D printers. And I want to come back to the software. Autodesk has been a huge partner of us. And one of the reasons that this Industrial Revolution is coming at us is because the tools are easy to use. And they're easy to use because it's now virtualized.

You can now download the first rendition. You can manipulate it. You can test it multiple times. And then you can go to print or then you can go to cut.

It's a critical piece. So this Industrial Revolution is being driven by ease of use, actually very cheap tools, and incredibly powerful. And when you combine these kinds of trends we end up in the space that we're in today.

We also have laser cutters. We call this our gateway drug. It's easy to use, very powerful, and extremely addictive, just like a good gateway drug should be. We have people launch businesses off this inside of weeks after learning how to use the tool. We have a large project bay.

And you might think that what I'm trying to sell is access to tools. But you would be wrong. What we're really trying to do is create a community of creative folks at each of the cities that we go at that can help one another use those tools effectively. It is in fact the community that we're reselling, not the tools. The community is by far the most powerful thing.

But it's not just individual. So one of the things I want to talk about is how do you get involved personally. But there is a corporate component to this. There's a big business component. There's an educational component to this.

So we're finding that partnerships are very important. Because our platform is opening up the research and development facilities in ways that large companies like Ford Motor Company here have never done.

This is me explaining to Alan Mulally what a sumo robot is. Sumo robots fight one another and they fall off. And they make for fabulous events. And this is in our facility that Ford funded in Dearborn.

So Autodesk is one of the key drivers. The software that they've got, we've got over $1 million in software in every single one of our locations. A membership comes with a free class on how to use Inventor and a six month license to Inventor.

Ford Motor Company fully funded and built a location in Dearborn. I want to unpack that just a little bit. Why in the world would Ford need a maker space near their campus? And the person who was driving this is Bill Coughlin. He's the head of the patent licensing division of Ford. It's called Ford Global Technologies.

And one of the stories he told me. He says, Mark, we have 10,000 mechanical engineers within a 30 mile radius of Dearborn. Do you know how many of them are actually in research and development working on the next iteration of a Ford platform? He says, I can't tell you but it's not very many.

He said, in fact, most of our engineers are in operations, building the products that people are going to drive. And in fact, a fair portion of our 10,000 engineers have moved outside of engineering. And they're actually in marketing, they're in finance, they're in field sales. They're not in engineering at all.

But the reason they became an engineer was when they were in fourth and fifth grade, they were playing with LEGO blocks and they decided they wanted to take all the hard classes. And they went to great universities around the world. And we attracted them. And they have 20 years of experience.

And we don't let them anywhere near our research and development facility. How insane is that? We have 10,000 trained engineers with 20 years of experience in the field and we don't let them play. My objective is to increase, and he said like 10x. I want 10 times as many engineers as we currently have in research and development working in an open facility.

What's happened? We've been open about two years now. He has seen a 55% increase in the number of high quality patentable ideas coming in to his office, 55%. 30%, more than half, was directly attributable to merely opening up the labs to the Ford employees so they could come in and play.

And there is in fact right now on track-- I can't tell you what it is-- a product idea that came up that they're probably going to put on the automobiles here in a couple of years. And it came from an engineer in marketing. There was no stage gated new product development process. It was just a bright guy with an interesting idea and the right experience and access to the tools to be able to make a change.

We have other members, we have other partners. Lowe's, obviously retail. Intel has recently jumped in. BMW is helping to fund the Munich location.

GE has been a fabulous partner. Beth Comstock rocks. She really is from the future. At least it appears to me that she is.

Let me talk about DARPA, because that's a little bit of a surprise. DARPA is working on advanced manufacturing. They're trying to figure out, what does a black box manufacturing process look like where you put something in at one end, and there's very little human intervention, and stuff comes out at the other end? And they're one of our partners,

DARPA is working on an open innovation platform. And I'll talk a little bit more about that in just a minute. So my argument is the future is already here. This was my experience. I came in and saw TechShop for the first time six years ago. Jim Newton had invented it, build the first one out.

I talked to three entrepreneurial groups back to back and each of them said, I saved 98% of my development cost by working here. I've got manufacturing background. I worked at Kinko's, ran the computer services section. And I realized that Bruce Sterling was right. The future's already here, it just isn't evenly distributed.

It became obvious to me that this open access, open platform where we can tap into the most creative minds in every community was clearly something that needed to happen and had to go global. And it couldn't have happened earlier because the tools weren't easy. The tools weren't as powerful as they needed to be. And they certainly weren't cheap enough. But that has completely changed.

So let me show you some cool projects. Do you remember Square, the peer-to-peer transaction processing play? Is everybody familiar with that one, I hope? That's James McKelvey. He's Jack Dorsey's partner.

And it was actually James's idea. He's a glassblower by training. Let me repeat that. He's a glassblower by training. He owns a studio in Saint Louis.

He lost a commission because he couldn't take American Express. He called Jack up, came up with this idea. They came into the valley, did their PowerPoint presentation, and got turned down. Top 10 smartest venture capitalist on the planet said no.

Makes sense. Jack is a programmer and James is a glassblower. What do you know about merchant banking? Nothing.

But they didn't give up. And so what happened was James came to TechShop Menlo Park. And what you see in the upper right hand corner are the original three prototypes. He didn't know electronics.

This isn't that sophisticated, so he taught himself some electronics. He took the soldering class. He took the milling class. All three of them, about six hours. He started learning how to use Inventor. He built his little three models using a Stratasys 3-D printing system. And then you know the rest of the story. Came back, took the money from the VCs. $3.2 billion valuation over a year ago. They have 600 employees. They're on track to do $16 billion in transactions this year.

When a glassblower can change the merchant banking industry in the United States, you know there's something new afoot. And he actually did most of the design and development work in a couple of months.

This is Ken Hawthorn. He's a co-inventor of Lightning Motors. Lightning Motors is the world's fastest electric motorcycle. This last year they won the Pike's Peak Race. It's like 14,000 feet. You go from the bottom to the top and back down again, 158 turns. I love this.

In most professional races the person who comes in second is like, what, 3/10 of a second behind. I mean, if you really blow them away they might be a second or two behind. This motorcycle beat every electric motorcycle and every naturally aspirated motorcycle. It beat Ducati by 20 seconds. They crushed the competition.

And they didn't have a multimillion dollar manufacturing product line to be able to do that. They launched out of Menlo Park. They did the carbon fiber faring themselves.

They did the aluminum frame. They did all the electronics themselves. It was like eight engineers able to take on Ducati. I don't understand why BMW doesn't buy them now.

Phil Hughes I've mentioned here before. He built the world's most efficient data cooling center system. He spent $20,000. The Department of Energy eventually held a head-to-head competition with IBM, Emerson Electronics, Siemens, and 12 other competitors. Phil and Bob beat everybody. Emerson Electronics has licensed the system and it's now being distributed globally.

And I love the mention of Boeing. They spent lots of time trying to figure out how to save 2% or 3% of the energy costs. This thing is 15% to 20% more efficient than the current data cooling centers.

The global spend in data cooling is $250 billion. Phil and Bob architected a system that should save the globe over $10 to $20 billion a year. And they did it out of a small lab in Menlo Park.

This is back to DARPA. So this was DARPA's first experiment in open innovation. It's a rally fighting vehicle. It was a pretty crazy idea. It's a six month campaign. Three months to do the design and development, three months to build, six months all in.

And they actually built, I think, five of them. The DOD didn't think it was going to work. And now they won't give the vehicles back.

But this is the next one. And this is why we got involved. We're actually doing some of the software prototyping process, as well as a little bit of the manufacturing. So the DOD came back to DARPA and said, that's cute. That's a little rally car. You can't really use open innovation to develop platforms.

Well, DARPA begs to differ. So this is an amphibious troop transport. It's a three year program, $3 million. And at the end of it they should have a fully functioning end design troop transport that will float across water.

If DARPA can use open innovation, anybody can. This is military. This is US military, Department of Defense. If they can use open innovation, anybody can.

If GE can use open innovation, anybody can. If Ford can use open innovation, anybody can. And then certainly individuals doing nanosatellites from NASA-- this is a cool one.

So the satellite there on the left hand side is the satellite that you see in the upper right hand corner that was built in Menlo Park with the help of some folks from NASA. They've done three so far. And that is a photograph from the space station looking down at the Earth as those satellites go across.

This is a self regulated tire inflater Brandon Richardson and his team were developing. And it looks like it'll save 3% to 4% of the fuel cost on large transportation vehicles. It inflates the tire in real time.

This one's a fun one. This goes back to the Kickstarter. It comes back to the personal stuff. So this is Max Gunawan. And this is the lamp he made. I may have broken it earlier. Let's see if it-- there we go.

So Max is a designer by training, but he's been working for Gap for the last few years. He designs fixtures, shelves. There's something that'll get you up on a Monday morning, designing shelves. So Max was hopeful that he would be able to use his design and development skills to launch a small company and graduate from the Gap.

And so he came into TechShop and he learned how to use a laser cutter. So this is actually a piece of wood. This is cherry and it's got some nice cuts in it. It's absolutely beautiful. This is actually just Tyvek. And then there's an LED in it. Actually, this is an early prototype.

So he actually learned Arduino because he wanted to have a little microcontroller in there, surprisingly enough. He'd never done that before. He learned how to solder. He'd never done that before.

He'd never used a laser cutter before. He'd never used cutting tools to be able to make a lamp. But he had this design idea, developed it, did his Kickstarter campaign. Any I had this conversation with him. I was a little concerned.

He says, I'm going to raise $60,000. I was like, Max, the average Kickstarter campaign's like $2,500. How are you going to motivate your social network to raise $60,000? And he says I don't know. I just figured out that's how much I need in order to do the right thing in dropping. The processing that's going on here needs to be on some Atmel processors, not on an Arduino board.

And I need to have the right kind of lithium ion. And so I've got to do some design work. And I just, I need 60 grand, so that's what I'm doing.

And he says, buy the way, 60 grand will sell 600 units. I'll do 50 of them a week, and I can actually do them here. So I've got me and two buddies. We're going to do 50 of them a week. 60 grand will get my company launched.

And then he raised $580,000. Yeah, it's one of those. If you're a big company you call that an elegant problem, right? Because you know you have the resources available to figure it out. This is Max, and he's got three months to deliver 5,000 of these. So he spent the next two months in China. And I'm not joking, he did.

That's how he got it done. He got it manufactured in China. I think once we've got the Cities thing figured out he will not have had to go to China. He could have just gone down the street somewhere here in Vegas, fired up a manufacturing facility, and gotten the same kind of quality and a faster turnaround.

This one I've talked about before. This is the DODOcase. This was the overachiever here. He was an electrical engineer but he'd never made anything physically. So this is an iPad case. It's called a DODOcase.

Do any of you carry it? I usually get a few. Patrick came in and asked, what classes do I need to take to learn how to use the tools I need in order to launch my little company?

And it was three classes. He learned how to use Inventor a little bit. We helped him out a lot. 90 days later from the time he came through the door he did $1 million in sales.

Not only did he go through his own personal Industrial Revolution, he did $1 million in sales. He did $4 million in the first full year, $10 million in the second, $35 million last year. He's on track to do $65 million in sales this year. And yes, that's a DODOcase on the President's desk.

And this is one of my favorites. This is a phase changing polymer blanket, came out of the D-school. I've talked about it before. General Electric is one of their partners.

It is on track to save 100,000 babies' lives. And the key technology piece in this was donated to Naganad and the team there by members in the community. Jane Chen, the CEO, was just given a top five social entrepreneur of the year award by the World Economic Forum.

But I'm going to come back to the challenge. I've shown you a bunch of really interesting things. Hopefully some of them are a little bit inspiring. But let's get personal.

I bought a 3-D printer recently. And took it home, got it set up. Because you've got to have a 3-D printer these days. And the very first thing I did was download a 3-D design for a flower.

Now the reason I did this is that I haven't given my wife a flower in five years because she developed an allergy to roses. So we now live in a flower free home. So I go online, I download the flower, I print it out, and I give it to my wife.

It was huge. I had no idea. She needed an ugly looking green flower. But it was from me, right? And I made it.

I mean technically I don't know that I made it. I downloaded it off Thingiverse and had the thing printed out. I clipped it.

But it changes the relationship when you make something yourself. And so the challenge is I would like you to make something for someone that you care about this Christmas. And then reevaluate the difference between making something as simple as downloading a piece of junk off the internet and giving it away versus buying a piece of junk off the internet and giving it away. So please join the revolution, both at the personal level and at the corporate level. Thank you very much.

JEN MCCABE: Thank you so much. Let's give Mark another round of applause, guys. That's amazing. Thank you so much.

I promise, Mark, to be really impressed if you print me a green flower also. That would be great. So next up we're going to hear from a gentleman named David Benjamin who's doing a company called The Living and also lectures at Columbia University.

We're going to move from how having machine tools in your backyard can actually enable you to build a big business to examining biological machines for inspiration and designing new software in computational workflows. Come on up, David. He's going to blow your mind.

DAVID BENJAMIN: Great, thanks Jen. So in the context of innovation and manufacturing, one of the things that I'm interested in is how biology computes and manufactures. And as you probably all know, architects and designers have been fascinated by biology for centuries. Biologists like Darcy Thompson in 1917 have carefully observed and documented biological systems and biological forms. And designers and architects have made use of these as inspiration for their projects.

Yet recent advances in biological technologies and also in our understanding of biology make it possible to use and harness biology in completely new ways. We're now able to capture moving images at very high resolution. We're able to understand living organisms as complex parametric models. And we're able to manipulate biological systems from the DNA up.

So here are a few things we can learn from these biological systems. One, biological systems grow efficient structures. What I'm showing here is a kind of algae that produces spanning structures that are both efficient and dynamic. Biological systems also build adaptive networks.

So shown here is slime mold, which grows out from the center to reach these white dots which are sources of food. And it creates networks that are both robust, redundant, and efficient. Designers are using these networks as inspiration for transportation networks at a human scale.

Biological systems also generate complex dynamic forms. Here is the embryo of a tadpole growing from one cell to 40 million cells in 48 hours. First maintaining a spherical shape and then exhibiting dynamic shape change.

Biological systems can also process information in complex ways. It's now possible to observe how the brain and neural pathways work in real time in living organisms. And here you can see a tadpole's heart beating, it's eye lighting up all in real time. And finally, biological systems can sense and communicate. What I'm showing here is stem cells, which are sending and receiving signals which allow them to work together, communicate with one another, and determine whether they should grow into heart tissue, bone tissue, muscle or skin.

And one of the things that we're doing in our design practice is harnessing these incredible biological systems and making computer models of them that we can apply at different scales. Here we start with the growth of a bacterial colony. And we create algorithms that can explain what's happening. But also that can make useful what's happening for us to apply at a different scale.

So in other words, biological systems are already computers and factories. And at this point through new computational tools we're able to open up whole new worlds of design and manufacturing if we can understand these systems. And so what we've developed is a new method, a new design approach, a new workflow.

This is an ongoing collaboration with the Autodesk programmable matter group and the office of the CTO. And its powered by Autodesk Cyborg now in restricted beta release. It involves five basic steps, generate, evaluate, evolve, select, and produce.

So let me give you an example. This is the old way you might design a chair. You use your creativity to design the chair and then you figure out how to produce it. But shown in this red line is maybe a new way of using this new design method.

You basically create half of the design yourself and allow the other half to be filled in by this new design approach. And the way it works is we use a generative algorithm. We define this space underneath the seat of a chair a space of possibilities. We generate a point cloud that's driven by a few different input parameters. And this point cloud can be denser in some areas, coarser and other areas. And then we link up the points through a very fine lattice.

If you change the density of point clouds through changing the input parameters you get a different lattice. And with just a few different input parameters, in this case maybe 15 different input parameters, you can get a system where you can generate literally billions of billions of different design options. Second, for each of those design options that you can generate, you evaluate it or you simulate it. So this probably looks familiar to you. It's using finite element analysis to analyze both the weight and the stress or the displacement in a series of different chairs. For every chair you can generate you can also evaluate it.

Then you can link up these different components, these different behaviors, in a software workflow. Shown here is Cyborg which I mentioned earlier. And this allows you in a visual interface to connect up all of the different components of the workflow, generating, evaluating, and optimizing.

Three, evolve. So here you see how this is just a small subset of possible designs also shown on the back wall there. And in this case we've generated literally tens of thousands of designs automatically through the computer using cloud computing. And then we can use the fourth approach which is select. So here, once we have this huge data set, we need new tools of advanced data visualization in order to filter and sort these designs. And hone in on a small set of different designs that we like.

So we can use algorithms to cluster the designs shown in different colors here. We can identify the set of designs which are mathematically best at achieving low weight and best structure.

And then we can navigate through these designs, including we can look at the different design approaches shown by different colors and the different virtual DNA, the set of input parameters that created them, and hone in on a design that we like.

So we can use the software workflow to go all the way through all of these different steps. And we can basically then finish this off with manufacturing. It's a natural step.

Every model that we create we can easily 3-D, especially with some new 3-D printing technologies. Not only at the prototype scale shown here, but also at relatively full scale. And this is a lightweight strong structure produced through an aluminum polymer composite that's a chair that's lighter weight than a typical design and that we can sit on and use printed in one run in a 3-D printer.

So to summarize, here are three models. The first approach summarizes the traditional approach. The second approach maybe a human thinking approach. But the third approach we can only design through this workflow. A human alone could not create that. And we achieve better bottom line results. But also derive results that we might not be able to think of that might not occur to us in our human imagination otherwise.

The last thing we can do is we can continue running this approach. We can continue to optimize, but we can also optimize at different scales. So shown here is how we can use the macro micro approach. We can optimize the arrangement of these gray bars, but we can also consider every gray bar to be made up of a bunch of smaller red bars.

But really the power of this approach most fundamentally is that we can apply it to other design problems. So I'm going to show you a second example very quickly which shows how we take the same steps, generate, evaluate, evolve, select, and produce. But we swap some of the modules.

So first, generate. Instead of using a lattice structure here we're using bacteria to generate novel forms for us. So what we have is red and green bacteria, two different types of bacteria, growing in a Petri dish. They create complex spatial patterns. It's a kind of biological algorithm.

And these bacteria generate materials. They grow materials that are soft and hard. Red shows hard materials, green shows soft materials. They create a composite sheet, and we can then start using the other steps of the workflow.

Simulate, in this case using a multi material structural simulation, we see how you can take this sheet of material, fold it up, some rigid areas some flexible areas, and we see the structural performance. We're in a territory where it would be difficult for a human to predict the behavior of these things. But we can use the power of computation, the power of this workflow, to do it very efficiently.

Then we can use some of the same techniques of evaluation, evolution, selection, and also production. This is a flexible workflow. We can apply it to many things. And this is kind of the second example here.

In the end what this gets us is the ability to not only achieve very high performance results. And I'm showing here a multi material sheet that's 3-D printed with hard material and soft material. So this is kind of compatible with what we're able to produce here and now.

So this basically gets us the ability to use a new workflow that's drawing on both the power of biology and the power of computation. We have a new way to design, a new way to build. It opens up new possible design spaces.

It's important for me to note that this is beyond biomimicry, an approach that's probably familiar to most of you. It's not simply imitating biology. It's drawing on the logic of biology. And it's kind of collaborating with biology.

And most essentially, shown here on this matrix, is that we can apply this in many different scales to many different design problems. From things like car parts, to airplanes, to architectural structures. All in the same workflow, including probably some of your design problems you may have. So I encourage you to check out Cyborg and also to come talk to us if you'd like to think about how you may use this design approach in your own way. Thank you.

JEN MCCABE: Can I sit on this? Thank you. Well David, that is mind blowing. Bio inspired engineering is going to allow us to catalog and create completely new forms in furniture and in architecture.

Our final speaker today, Skyler, is from MIT where he's running an absolutely amazing lab. They're also working on dynamic shape change but it's self powered. Wait until you see these machines that build themselves. Come on up, Skylar.

SKYLAR TIBBITS: Thanks so much. I want to apologize a first, because I'm losing my voice. So hopefully it sticks with me. But I run a research lab at MIT. The research lab is called the Self-Assembly Lab, and we focus on self-assembly and programmable materials. And something more recently called 4-D printing that I'll get into. I want to start and tell you how I got here. Most of that is powered by what software and what computation has done to the design and making space. Powered by Autodesk and others, we've been able to generate things that we could have never generated before. Massive iterations, possible design solutions, and evolved that design space like we just heard from David.

We can also produce massive geometric complexity. So there's this unbelievable ability to produce and design things that we couldn't have done before. But then we can go a step further and we can simulate those. And we can optimize those structurally, mechanically, thermally, et cetera. And take that design space even further and evolve it.

But then what I think is powerful is that code can communicate with machines. So we can actually physically make things that we couldn't have made before. This is a multi-material 3D printer. It could be a laser cutter, CNC water jet CNC router, et cetera.

So code is a new language to design. And code is a new language to make. But what my research lab focuses on is what happens after the machine. How can we use code as a way to construct? How can we use computational thinking as an assembly process?

As a new way of putting things together. This is me assembling a prototype for six hours straight. And I would argue, it's not that much different from what's happening in many spaces either in manufacturing or kind of DIY maker spaces. That we have all this ability to design and make.

But when the parts come off we lose all of that. We throw the computational thinking out the window. And we slam these things together with materials that we assume are cold, dead, dumb, and stupid. And if we look at our industrial space, if we look at construction, manufacturing, product assembly, I would argue it's probably not that much different.

There's lots and lots of energy. Lots and lots of brute force techniques. People spending lots of time, fighting tolerances, et cetera. I think there's a huge opportunity here to rethink the way we assemble things in the industrial scale using our models of what's happened in computation for design and competition for digital fabrication.

If we look at another scale, if we look at what's happening right now to nano the micro scale in synthetic biology, DNA nanotechnology, and material science, it's unprecedented. I would argue that there's a revolution happening here. And that's the ability to program physical and biological materials to change shape, change property, compute, store information, et cetera.

But the other fascinating thing is that there's a design space and a design boom happening. Cadnano is example of that. And we'll see some other examples later. And this is developed in order to allow people to design two dimensional, three dimensional functional systems, just like we design at other scales.

But then you can extract the ACTG strands of that design. Get them synthesized. They come back in test tubes. You heat them up and cool them down. And the final functional object is self-assembled.

So what that argues is that there's this design opportunity. DNA and biological materials can become the building blocks. But they go further in that the materials are actually the blueprints. The materials are the assembly process. They contain the information in order to build the structure.

So I would argue that we need to have this same type of mindset and bring it to the industrial sector in the way we produce things at much larger scales. And a lot of people will say, well automation is the solution. If we can just make better machines that replace humans and that fight those tolerances, then we have it solved.

And that might be the solution. And yes we need smart machines just like we need smart people. But I would also argue that we need smarter materials. And that there's a huge opportunity for materials to contain information, materials to make decisions, and to collaborate with people and machines, responding physically to their local and external environment.

So that's something called self-assembly. And that's what my lab focuses on. It's a process by which disordered parts build an ordered structure through only local interaction. So that means a bunch of separate parts should be able to find one another, get excited, and build precise structures through only local interaction. Not me picking and placing parts, and forcing them into place.

So what do we need? If we want to use self-assembly at a much larger scale, what are the key ingredients that we can use to translate this into production into functional systems? I think there's three main categories.

The one on the top left is materials and geometry. This is your physical components. This is the shape and the material properties. If you change the material properties the dynamics of the system will change. If you change the shape what's possible in that design space will change.

The next is interactions. You have a bunch of physical components. How do they hit one another? How do they find one another? How do they go from one state to another state? How do they error correct? This is all the physical interactions that are happening.

And the last, probably the most important, is energy. How do we get enough energy to get these things excited and go from one physical state to another physical state? And what I think is most exciting here is that you can use passive energy. That you don't necessarily have to use current and fuel, but you can use heat. You can use gravity, agitation. Can we use sound as a construction technique, et cetera?

And they're all highly linked. If you lock in energy, if you say I'm going to use heat, well then maybe you should use metal or find a material the responds to that energy. If you lock in the material, maybe you're going to use wood, you should probably use moisture or something that responds and excites wood, et cetera, et cetera.

So I'm going to show you a number of projects that we've done in the lab with a number of collaborators. And the vision here is to look at a number of those key principles and try to extract this process across different scales and applications. This is a project that we did at TED Global with Autodesk and molecular biologist Arthur Olson. And we we're looking at biomolecular self-assembly.

We made 500 of these glass beakers. In each beaker was a different molecular structure. We had the polio virus, a tobacco plant virus, an enzyme. They had different numbers of components, 12 components, 8 components, 4 components. We had different colors, et cetera.

And the idea is that you would get one of these beakers. This is the polio virus, for example. You shake it hard and the parts break apart. And then you shake it a little bit softer but still randomly and the parts come back together. And they assemble a precise structure.

So what that shows is that through random energy and random non-intelligent interaction by me I can produce a precise structure. Not just random structures, but precise structures. We went a step further.

At Autodesk University last year we did an exhibit in the gallery. And we looked at chirality, the idea that if you throw a bunch of random parts in there black and yellow parts, and you shake it randomly, you always will produce a yellow structure and a black structure. You'll never produce a half yellow half black.

And the way we do that is through error correction. That locally these parts are connecting lots of times, popping in and popping out. And they're very weak.

But if you get two, and then three, then four successful parts it gets stronger, and stronger, and stronger. And so you're guiding the correct structures into place. And the weak local ones break off. So they error correct into the final positions.

At TED in 2012 we did a project called the Self-Assembly Line. The goal was to produce furniture scale objects that populated the plaza. So we were producing an installation that produced installations. The reason that we called it the self-assembly line was because we wanted to flip the assembly line.

We wanted to say, instead of the people having all the information, and the decision making, and the parts just being dumb, why don't we flip that? And the people are the energy and the parts are the information. So we built a large rotating chamber. And people would come up and spin the chamber. They would spin it faster or they would spin it slower.

They would start to build an intuition. How much energy do I need to input into the system for them to start to assemble? How much energy is too much so that they start to break apart? They don't know anything about what's going on. They don't even know what they're building. They're just giving energy and the parts have the information to assemble these structures.

But what I think is fascinating is that it became a tool to collaborate and to communicate across disciplines. That this phenomenon called self-assembly is something that's not intuitive. It happens in every discipline, physics, chemistry, biology, material science, et cetera. But we can't intuit what's going to happen. It's not something that we use at the human scale.

So this became a demonstration that we could start to collaborate and talk about things like drug delivery mechanisms for the polio virus. Or what are the key ingredients for these biomolecular structures? And how could we use it for furniture scale objects?

We did a project recently in New York that was exploring something called self organization rather than self-assembly. And just as David showed us before, maybe instead of the manufacturing perspective-- which is what you could argue from the self-assembly standpoint-- meaning that I want to build something that's precise and I want to have the parts build it for you. Maybe we could use these as a design tool. Maybe we could deposit materials and produce possible solutions based on their local and global interaction with the environment.

So what we did is we built one physical unit. It was based on carbon, so a tetrahedral structure with two positive and two negative magnets. And that one fundamental unit can produce many, many outputs. If they start to assemble in sheets you could get something like graphite. Or if they assemble in three dimensional structures like diamond. So we can get linear chains, we can get hexagons, we can get pentagons, squares, 2-D, 3-D structures from one single unit.

So the goal was to maximize the possible options of what we can do. We made 350 of these neutrally buoyant spheres. You can see here that they move freely in all three dimensions, which is this really fascinating phenomenon that you don't often see other than space or fish let's say.

But we can also program the amount of energy in the system. Those two black things in the back are pumps. And we can dial those pumps up. We can blast it so that they all break apart. We can calm it down so that they assemble. But we can also do chaotic oscillations, or standard oscillations, or even natural waves.

And the idea here is that if we start blasting the amount of energy, if we change the energy in the system, different dynamics happen. And we might be able to see things like solid, liquid, gas phases. Where the materials assemble themselves into rigid structures, or more fluid, or more separate components. You'll see throughout the video a number of recognizable shapes show up locally like the hexagons, pentagons, linear chains.

But I think there's another scale as well, this global structure that's really fascinating. And the dynamics of the global behavior. And you could take this project in two ways. The one way is that maybe we can use systems like this as an educational tool. That we can study chemistry, biology, and material science through intuitive physical domains.

And we can see the dynamics. And maybe we could discover things in those domains. And the alternative is that maybe we could deposit materials in the future and link those up with simulation and optimization so that they're communicating. So that we can design efficient structures, like a heat sink or like a bracket, where the materials reconfigure themselves into optimal structures. So the material is computing and the software is communicating and computing with it.

I want to shift now into a second track of research that we focus on in the lab. And that's called programmable materials. Specifically with this project called 4-D printing. It's a collaboration with Stratasys, who is a major player in the 3-D printing space, and Autodesk.

The idea is that we wanted to combine smart materials with 3-D printing. And the reason we called it 4-D is because we wanted to add time. That we wanted to be able to print things that transform and reconfigure over time.

So we use the Connex multi material printer by Stratysis. That allows us to deposit multiple materials at the same time. One of those materials is a black rigid plastic. And that gives us the precision, it gives us the angles, the joints, the structure. For me that's the information.

And then the other material is this white material that you'll see in a second. And that expands 150% in water. And we worked with Stratasys' material science group on that. And that's the energy. That gives it to be able to transform from one shape to another while the information gets to fold into precise ways and time when they're folding in where they're folding into.

Here's a first demonstration of the simulation that we started working on with Autodesk. Because the challenge is, if I want to design this staircase to turn into that chair, or this clicker to turn into a cup, or whatever it is, that's a huge challenge. And we can't figure out how to go from one state to another. So we need simulation tools, but we also need optimization tools that figure out where the materials are going to be deposited.

And this is very similar to the design boom that's happening in the life sciences. Why we're looking at working with Autodesk on Project Cyborg as this new cross platform tool to design programmable materials. Here's a physical demonstration. It's a single strand with the black and white materials. It's dipped in water and it folds into the letters MIT.

And then another single strand dipped in water. And this one folds into a three dimensional cube. So there's no human interaction here. It's just dipped in water and all of the information and energy is coming from the material and the environment. So all of those steps to get from the single strand to MIT.

We then started looking at sheets. So instead of a single strand, what if we can print quick, cheap, easy, two dimensional sheets that fold into more complex structures? So this one is a truncated octahedron. So a two dimensional sheet dipped in water. And then starts to fold into this three dimensional structure with all the precision of the geometry and custom angles.

In this example we started to demonstrate double curvature by using something called curve crease origami. So we print this super, super thin disk. And we dipped it in there. And we started waiting, thinking oh crap, it's not working, it's not working, it's not working.

And then it jumps into place. And it pops and then folds very quickly after that. And it folds into this complex saddle structure. So you'll see in a second when I pull it out.

It has all of the mountain and valley folds of origami that builds this complex double curvature. And we're just scratching the surface. There's a lot of stuff that we can work on in this space using origami and curvature to make complex structures.

But I think one of the best examples is a very recent example we just did this past weekend. We're exhibiting all of these models in the gallery in the exhibit space here. So if everyone wants to go see that afterwards, please feel free. This is a large scale protein based on the Crambin protein.

So we go to the protein data bank. We download the 3-D model of the protein. And we can propagate a custom joint across that. We then print it with the Connex multi material printer, and we dip it in water. This is a 200 gallon tank we have in the lab.

And it starts to fold itself into the complex structure of this Crambin protein, with all of the alpha helixes in this structure. This is a single backbone so there's no cross linking. And what we're trying to do now is figure out ways that with Project Cyborg and the programmable matter group at Autodesk, how do we simulate this folding so that we could take any complex biological structure-- like the ribosomes let's say, or RNA replicase-- and figure out how to simulate the folding so that it doesn't get tangled?

So that it goes under, or which fold first. The left side or the right side, or the middle out. So that we can study these structures at human tangible scales.

So the last project I'm going to show is something called DNA Display. I'm going to show a video about this. It's a project where we two dimensionally printed DNA a as a sort of smart ink.

[VIDEO PLAYBACK]

[MUSIC PLAYING]

-A vision has been propelled to empower individuals to design, synthesize, and utilize DNA as a new design medium. For not only science, engineering, and medical, but creative applications as well. However, the path one takes from idea to synthesized DNA, to imaging and ultimately functionality has many roadblocks. And expert domain knowledge is required that severely limits the usability and scalability of DNA design.

One major hurdle is that you can't see or feel DNA. And the equipment to image DNA a extremely expensive, difficult to use, and hard to get access to for most non experts. Our project, DNA Display, attempt to take on this challenge and make DNA both physical and visual as a creative new design medium. Our project has four main steps.

First, the design process. Through Project Cyborg one can design high level attributes and custom patterns with expert knowledge of DNA and proteins markers embedded in the tool. Next, custom sequences of DNA that will interact with protein markers can be ordered directly. CNC and desktop printing solutions were developed to deposit proteins on a variety of substrates. Finally, one washes with DNA and reveals a custom design pattern on paper.

Here The Game of Life, one of the early demonstrations of visual computing, points towards a first step in the future of DNA based paper computing. To go further, we imagine that the patterns could act in ways similar to microfluidics or electronics, where the structures of the drawing becomes a computational medium. This project eliminates the expensive and difficult process of imaging and opens up a new opportunity to draw a custom patterns with DNA, making it physical and visual.

[END VIDEO PLAYBACK]

SKYLAR TIBBITS: Thanks so much. So what we're trying to do is use DNA as a smart ink and deposit DNA on a variety of substrates from transparency to paper based mediums. And we can tap into that ability to program with DNA. To make it compute, store, recognize local and environmental information. And therefore it becomes a sensor that we can draw with. And we can use custom graphics.

So we print, with a protein on paper in this case, and we wash with this pink medium which is the DNA and gold nanoparticles. And what happens is it reveals a pattern only when the DNA binds with the protein. And so you get these custom patterns. We printed a number of different drawings just to demonstrate that you can get the patterns to emerge with this local interaction.

But I think it points to a future of architectural surfaces, graphics, signage, textiles where we could use DNA as a smart ink that respond to, let's say, air pollution, pollen levels, acidity, number of people in the environment, et cetera. And the patterns and the graphics change.

So where do I think we are and where is this going? For me this is an image of today. That we have complex things, that come together in complex ways, with complex people and instructions. And we want to move to a model which is much smarter. This is one example that's just the product life cycle. And I think there's many other sectors.

On the left hand side we want smarter products that are adapting to our environment and adapting to my performance. They're not just static and going with me. But rather, they're helping me perform better. You can imagine walking shoes that when I start running become running shoes. Or I go on grass and they grow cleats.

If it starts raining they close up. If it gets too hot they open up. There's many products outside of that that can respond to us and perform better. Which means we need new materials that can store information, make decisions, compute, et cetera.

Which means we have an opportunity for manufacturing where the materials can communicate with us. They can error correct. They can assemble themselves.

Shipping. We can send things flat and have them assemble or reconfigure on different conditions. And most importantly, I think disassembly.

Where you could say products, if they fail they should be able to repair themselves. If they're outdated they should be able to reconfigure themselves. And if we want to recycle them, let them self disassemble.

So I'll leave you with a quote, which I think is a challenge for everyone here. And a challenge for our lab. "Can we design material parts with enough information and decision making that they can assemble themselves and adapt independently to internal and external forces?" Thanks so much.

JEN MCCABE: Wow. OK, so Skyler said, if you change the energy in a system the dynamics change. David, Ben, Mark, Skyler, myself, Tony, we're all working on changing the dynamics of the system. We're working on changing what's possible.

And their work shows me today that the most important job each of us have is to figure out how we can change the dynamics. The New Industrial Revolution is already here. The only question that you have to answer is how are you, personally and professionally, going to redefine the space of what's possible? Thank you for joining us today.

[VIDEO PLAYBACK]

-One doesn't need to look back in order to see the remnants of our history. The work and tools of the craftsman hold true today. The cornerstones of the Industrial Revolution are holding firm.

As we evolve our craft and look to the future of innovation and manufacturing, there is a new era upon us. The creation of a new profession. A combination of industrial designer, modeler, and taste maker who will need to help us navigate this new manufacturing world.

Once again, we will take pride in saying, I can make it myself. The New Industrial Revolution is here. Are you a part of it?

[END VIDEO PLAYBACK]