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THE MAKER REVOLUTION

BUILDING A FUTURE ON CREATIVITY AND INNOVATION IN AN EXPONENTIAL WORLD

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Introduction: The Maker Revolution

BOOM! The greatest explosion of innovation and creativity in all human history is upon us. Radical advances in 3D printing, biosciences, artificial intelligence, robotics, computer science, pharmacology, physics, material science, network and communications, education, tool use and access to knowledge, markets, financing, and communities are driving the fastest and largest leap forward we have ever experienced. And best of all, this revolution is open to almost everyone. That's right, this revolution is one that the average person will be able to participate in and reap the rewards of participating. This is a unique time in human history that offers a fundamentally positive transformative potential. I hope by the end of the book you will not only agree with me, but join the revolution. BOOM!

> Author note: I use "BOOM!" in my presentations to keep the audience engaged and because some of the success stories are so amazing that they deserve a "BOOM!" It has become something of signature. Yes, you will see it here. And yes, you should read that word out loud. Shall we practice?

Everything around us is changing. Everything. The past is no longer a reliable guide to the future. Yes, there are some terrifying trends and scary new technologies, and some technologies can be misused. But after being immersed in the technology and trends of the future for more than thirty years, I've become more optimistic about the future, not less. And while it is human nature to see and anticipate negative outcomes, or to focus on

worst-case scenarios, we can (re)train ourselves to see opportunities and look for potentially positive outcomes.

These trends are so broad and deep that they will touch every aspect of our lives. I see direct impacts on work, play, home, sleep, sports, language, personal identity, spirituality—on everything . . . and that is just with progress we have seen with artificial intelligence in the last couple of years. There is no corner of human existence that will not change over the next twenty years. Not one.

For much of the last decade, I have been a leader in one of the most remarkable revolutions, the Maker Movement. I've had an opportunity to be at or near the forefront of many of the revolutions in the recent past. During the personal computer revolution, in the early 1980s, I ran an interactive multimedia software/hardware company before multimedia was a thing. I launched one of the first fifty Fortune 500 corporate websites in the mid-1990s, democratized access to printing technology as a product management director at Kinko's just prior to the first dot-com boom and bust, and drove both an online health benefits website and a software-as-services back-office platform in the 2000s during and after Web 1.0. After 2007 I became a leader in the Maker Movement, and from that perch and through personal interest I've become embedded in a far-ranging group of activities, people, organizations, companies, and "crazies" (in the best sense of the word) who are creating the future. I'm not trying to brag (I don't think), just trying to build context for where I'm coming from. I'm far from the success I seek, but I'm grateful for the opportunity to live and work in what I am convinced is the most remarkable time to be alive in human history.

A major theme of this book will be rooted in the Maker Movement and what it means for you and society. But the Maker Movement is operating within the context of exponential technological innovation, and it is riding the wave of change being driven by these exponential technologies. As such, I will

also cover the exponential technology that is the impetus for much of the change within the movement. It is impossible to grasp the coming impact of the Maker Movement without this background. I will leverage my experience as an adjunct faculty member at Singularity University for this section, with shout-outs to Ray Kurzweil, Peter Diamantes, Salem Ismael, Peter Van Geest, Rob Nail, Jonathan Knowells, David Kraft, Vivek Wadhwa, and others involved there.

THE MAKER MOVEMENT—A QUICK SURVEY

The Maker Movement started in 2004 with the initial publication of *Make:* magazine by O'Reilly Publishing. Dale Daugherty is recognized as the founder of the movement, with the support of Tim O'Reilly, founder and CEO of O'Reilly Media and the chronicler, instigator, and founder of not a few movements himself. Maker Media has spun out of O'Reilly and remains the go-to resource for all things maker-ish. In 2006, Dale and Dan Woods (now CEO of TechShop in my old role) launched the first Maker Faire at the San Mateo, California, fairgrounds and started the practice of bringing participants of the nascent industry together at an annual festival of maker celebration, networking, and conversation. It has exploded.

These annual celebrations are kind of like a state fair, but they trade out the animals for robots, geeks, steampunk outfits, and propane-driven fire spectacles. At the first Faire, about 25,000 people showed up. Since then it's grown like crazy. More than 150,000 people attended the Bay Area Maker Faire in 2016, and there are now also major Maker Faires in New York City and Chicago as well as over thirty featured Faires and hundreds of Mini Maker Faires held around the globe each year.

These events are wonderful exhibitions of human creativity, ingenuity, and possibility.

Have you ever seen a rock band supported by 500,000-amp Tesla coils? The performers must wear metal mesh suits to

protect themselves from the bolts of lightning striking their bodies and instruments. They "play" the coils. High notes are hit by raising a hand up high and low notes played by holding the hands low. Dual notes from the pair of coils can be played at the same time. A few years ago we were able to get Mike Rowe, of *Dirty Jobs* fame, to step into the phone booth–sized box on stage between the coils and get (safely) zapped by massive bolts of deadly lightning. My favorite "art" piece a couple of years ago was a Burning Man performance art mobile, a flaming steampunk octopus. Imagine a fifteen-foot metal octopus outfitted with a massive sound system and huge propane tanks, shooting fifteen-foot streaming bursts of flaming propane out of each arm and its head. This is not your father's state fair. This is mixed up with kids ages eight to eighty bouncing around booths stuffed with crafts, robots, advanced manufacturing gear, fire, and homemade everything.

There are so many R2-D2 robots at Maker Faires, an entire corral is set aside for them. Yes, an R2-D2 corral. Kids can learn how to solder, make a "blinky light," and pick locks . . . all before lunch. Maker Faire is a celebration of all things "STEAM" (science, technology, engineering, art, mathematics). At a Maker Faire, you can listen to panels on how to open your own makerspace, become a citizen scientist, use your 3D printer for printing prosthetics, and see practical uses for drones. You can attend "power tool races" (not for the faint of heart) where they do a "fifty-yard dash" with over-powered belt sanders and circular saws. The racer places an amped-up, highly modified, circular saw on the ground between two rails, with a fifty-yard electric cord that spools out as the saw careens from one side of the track to the other. The blades cut into the ground and then launch down the track at terrifying speeds, bouncing off the walls . . . which usually but not always hold these spinning tools of instant death. I'm waiting for the chainsaw races. And not the kind where you cut down a tree.

After spending a day on-site and meeting various entrepreneurs who collectively told me that they had saved 97 percent of their startup costs by using the TechShop platform, I knew that makerspaces would one day be in every city on the planet. William Gibson's quote came to mind, "The future is already here—it's just not very evenly distributed."

Though we still have a long way to go, we are clearly on a trajectory to place makerspaces not just in every city, but also in every school. But I'm getting a little ahead of myself again.

I joined Jim and eventually became a cofounder of TechShop, and with a very talented group of fellow makers we grew it to forty times its size, attracted tens of millions dollars in investment, and brought the company to thirteen locations on four continents with partners including GE, Ford, Autodesk, Samsung, DARPA, the U.S. Department of Veterans Affairs (VA), Lowe's, Leroy Merlin, and many others. I had the privilege of meeting President Barack Obama, visiting the White House and the Roosevelt Room within the White House, and—most importantly—getting to know some of the most amazing and exciting makers, heroes, unsung heroes, and other amazing people from around the world who make up the Maker Movement.

These were the early days, though. Most of the amazing things that have happened were not clear or on the horizon yet.

At the time, TechShop charged $100 for a monthly membership, with discounts for annual memberships and unlimited access to tools you'd been cleared on. It was and is an amazing deal. (At Kinko's we charged $36 an hour just for access to a design computer.) We derived immense satisfaction from building a community of makers in every location we opened.

It was like building a beehive: We needed the physical infrastructure to house the hive, but it was the members that added the value. And once we reached three hundred members or so, magic happened. TechShop went from being a place where someone needed to be in order to get their work done to being the only place people wanted to be to work.

A catalytic action happens at around three to five hundred members. When you are in a major city and you have thirty to fifty people on-site at any given time, a person is two degrees of separation from success. If a TechShop dream consultant (DC) doesn't have the answer to your question, there is someone else on-site, at that moment, who does.

I've seen this play out so many times that it feels normal to me.

"Hi, I'm having some trouble with sourcing," said a TechShop member to a DC that I was having a conversation with. "I recently learned that some woods are treated with arsenic as a preservative, and I don't want arsenic in my final product. I'm not sure what to do."

The DC didn't have the background to answer the question. "I'm not really an expert in sourcing," he said, "But let's see who is here tonight." He eyed the room. Sure enough . . .

"Ha, you see that member over there?" Pointing to someone across the room. "Let me introduce you to him; he does all the sustainable sourcing for Restoration Hardware—you know, the large furniture retailer and manufacturer. I'll bet he can help you sort it out. And if he can't, Autodesk has a sustainable manufacturing expert on staff, and as a partner of theirs, we can hook you up with them." BOOM!

Problem solved.

Another time, similar situation . . .

"I'm having trouble with my manufacturing design," announced a member. "Specifically, the size of the screws I'm using for my water-resistant watch. My Chinese manufacturer keeps messing up."

The DC on duty responded, "Well, let's see who's here tonight . . . Um, there's someone from Frog (a global hardware design and strategy firm), and someone from Ideo (another top design firm) is over there. Oh, and there's one of my friends from Apple—let's go talk to him. But if that doesn't work, we just announced a partnership with Flex, the second-largest

contract manufacturing company in the world, and they have a service offering called 'sketch to scale.' They have thousands of engineers who specialize in exactly the kind of this you are trying to do." BOOM!

Now, when I started at TechShop, none of these things were in place . . . but they are now. Chris Anderson, former editor of *Wired* and current founder and CEO of 3D Drones, likes to say, "If you can imagine it, you can build it." Indeed, one can. You and I currently operate in a world where just about anything can be crowdsourced—knowledge, money, manufacturing, markets . . . you name it. But we were in the early days.

As we were slowly growing TechShop, a steady stream of interesting people kept coming through the doors. Venture capitalists, most of whom don't, won't, and refuse to invest in hardware companies. Writers like Ashlee Vance, then with the *New York Times*, now with Bloomberg and the author of the *New York Times* bestseller on tech billionaire/entrepreneur/inventor Elon Musk, came through and immediately saw the power of a makerspace. Mike Rowe of *Dirty Jobs* and *Deadliest Catch* attended an early Maker Faire and eventually featured TechShop in an episode of CNN's *Somebody's Gotta Do It*. Many, many others visited the shop. Importantly, so did many early makerspace innovators that I will highlight in later chapters.

Here is the most important idea, though:

The tools of this new industrial revolution are cheaper, more powerful, and easier to use than any other tools in human history, by at least one or maybe even two orders of magnitude. And when someone drops the cost of producing a product by 97 to 99 percent, they have fundamentally changed the world.

In her original work on the Internet, Mary Meeker likened the World Wide Web to the construction of nineteenth- and early-twentieth-century canals (think of the Erie Canal and the Illinois and Michigan Canal) that reduced the cost of commodities transportation from Chicago to the East Coast by 97 percent.

We are living through a similar discontinuity now as the cost to create a sophisticated prototype of an idea has dropped in many cases by over 97 percent. Better, the speed with which one can get to that prototype has also accelerated exponentially. If you have access to the tools, you can produce it today. BOOM!

This new reality, where tools are cheap and easy to use, attracted a group of early adopters, writers, producers, futurists, evangelists, and dreamers.

Inc. magazine did the first piece on TechShop, but it was the US-based nonprofit think tank The Institute for the Future (IFTF), and Bob Johansen specifically, that really began to understand the makerspace's transformational impact on making, fabrication, mass manufacturing, and culture. Bob pulled a steady stream of Fortune 100 companies and international conglomerates into the Menlo Park facility to expose them to this new way of doing things. Eventually, Ashlee Vance's piece in the *New York Times* led to a collaboration between TechShop and Ford Motor Company that would expand TechShop's reach outside the Bay Area and propel Ford on a five-year odyssey to become the largest patent creator of its peers. In 2008, IFTF published a forecast on The Future of Making that included TechShop in it. We became the daily instantiation of the Maker Movement for their clients to experience.

When you drop the cost to build a prototype by 97 percent, what was once a $100,000 cost becomes a $3,000 one. A $100,000 invention is only available to the most dedicated, wealthy, risk embracers or to the insane. But at $3,000? Almost anyone can pursue their dream for $3,000. In roughly ten years, we have moved from a place where only the wealthiest and most well-connected people and corporations could afford to invent to an era in which almost anyone can. I will expand on this reality over the coming chapters, but this is truly miraculous.

War, insurrections, revolutions, and massive displacements of people took place as a result of the Industrial Revolution moving the center of production and innovation out of homes

and small businesses into large, well-funded enterprises. (Even Communists moved production to centralized facilities.) Now, in a very short period of time during the early stages of the twenty-first century, we have begun reversing important unassailable truths (not all, or even most, but enough to tangibly change an innovator's calculus) and realities of the previous centuries' assumptions about innovation.

More on this later.

MY INTRODUCTION TO EXPONENTIAL TECHNOLOGY

Early on at TechShop, we had visitors from Singularity University (SU). Founded in 2008 by Peter Diamandis and Ray Kurzweil at the NASA Research Park in California, SU is founded on Ray's book, *The Singularity Is Near,* which I read as soon as it came out in 2006. At SU they study and proselytize the view that we are experiencing rapid, exponential, technological acceleration across a number of domains. They (and I as an adjunct faculty member) espouse that it is difficult to fathom exponential change. There is little in our day-to-day experience that prepares us for this pace of change. The people at SU began taking tours of TechShop and eventually settled on a combination of a presentation and a robot-building group experience for their students.

Sometime earlier, a TechShop staff member had approached me to tell me that our "Lasers and Beer" and "Welding and Wine" experience events were getting boring. Initially, I wasn't convinced—how could power tools and alcohol be boring? I mean, what is NASCAR other than powerful machines, alcohol, and potential promise of a mishap? But I had to hand it to the staff—they not only wanted to create a robot-building group experience, but they wanted *combat* robots that would fight it out to the death in an MMA-style double-elimination competition. This quickly became one of TechShop's signature group events. And it fit the SU crowd perfectly. What better

the only technology to experience exponential change. Ray and the rest of the SU folks are tracking several technologies that are experiencing similar growth curves, including artificial intelligence and robotics, energy and the environment, nano and digital manufacturing (3D printing), medicine and neuroscience, and biotech and bioinformatics. These are large swaths of human endeavor that are accelerating at a pace that is nearly impossible for our linear minds to comprehend. Let me explain.

With some notable exceptions, there have been few historical opportunities to experience exponential phenomena. Most of human history and our personal experience is rooted in gradual change, not a rapid doubling of change every couple of years. As such, we have little or no frame of reference for things or phenomena that consistently increase at an exponential rate over an extended period of time. This makes these kinds of radically changing things effectively impossible to intuitively grasp and we therefore often substantially underestimate or totally fail to understand their potential impact.

A fine example of exponential growth is illustrated in the Legend of the Ambalappuzha Paal Payasam. Here it is from Wikipedia:

> Legend of the Ambalappuzha Paal Payasam
>
> According to the legend, God Krishna once appeared in the form of a sage in the court of the king who ruled the region and challenged him for a game of chess (or *chaturanga*). The king, being a chess enthusiast himself, gladly accepted the invitation. The prize had to be decided before the game, and the king asked the sage to choose his prize in case he won. The sage told the king that he had a very modest claim and that being a man of few material needs, all he wished was a few grains of rice. The amount of rice itself shall be determined using the chessboard in the following manner, said the sage. One grain of rice shall be placed

in the first square, two grains in the second square, four in the third square, eight in the fourth square, sixteen in fifth square and so on. Every square will have double of its predecessor. Upon hearing the demand, the king was unhappy since the sage requested only a few grains of rice instead of other riches from the kingdom which the king would have been happy to donate. He requested the sage to add other items to his prize but the sage declined.

So, the game of chess started and, needless to say, the king lost the game. It was time to pay the sage his agreed-upon prize. As he started adding grains of rice to the chessboard, the king soon realized the true nature of the sage's demands. By the 20th square, the number had reached one million grains of rice, and by the 40th square, it became one-million million. The royal granary soon ran out of grains of rice. The king realized that even if he provided all the rice in his kingdom and his adjacent kingdoms, he would never be able to fulfill the promised reward. The number of grains was increasing as a geometric progression and the total amount of rice required to fill a 64-squared chessboard was ([2^64] – 1), which is equal to the number 18,446,744,073,709,551,615, translating to trillions of tons of rice.

Upon seeing the dilemma, the sage appeared to the king in his true form, that of god Krishna. He told the king that he did not have to pay the debt immediately but could pay him over time. The king would serve *paal-payasam* (a dish made of rice) in the temple freely to the pilgrims every day until the debt was paid off.[1]

[1]"Ambalappuzha Sri Krishna Temple," *Wikipedia*, 2017, https://en.wikipedia.org/wiki/Ambalappuzha_Sri_Krishna_Temple#Legend_of_the_Ambalappuzha_Paal_Payasam.

Another example of exponential phenomena that is used at SU is simpler but just as surprising. Imagine taking thirty steps. How far did you get? You probably have a pretty good idea it's about thirty meters. Now take thirty exponential steps, so each one is double the size of the previous one. Did you imagine one billion meters or twenty-six trips around the world? Not likely.

This exponential increase across multiple domains, often driven by computer chip capabilities, is radically and in some cases fundamentally changing the human experience. Economist Joseph Schumpeter referred to his theory of dynamic economic growth as the "gale force winds of creative destruction." "The same process of industrial mutation," he wrote in *Capitalism, Socialism, and Democracy* in 1942, "that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (83). Schumpeter observed that economic progress is not gradual and peaceful but rather disjointed and sometimes unpleasant. Whenever an entrepreneur disrupts an existing industry, it is likely that existing workers, businesses, or even entire sectors can be temporarily thrown into loss. These cycles are tolerated, he explained, because they allow resources to be freed up for other, more productive uses. Imagine if those gales begin to be exponential.

Let me give you a few examples of exponential growth in the following section.

NEW INFORMATION

In a UC Berkeley School of Information study, researchers looked at the rate that new information is created worldwide each year. In 2003 (at the beginning of the digital explosion), the amount of new data created and stored on print, film, magnetic, and optical media had almost doubled over the previous three years, coming to about 5 exabytes. This is roughly equivalent to 37,000 libraries the size of the Library of Congress.

This is new information created in just one year. In 2007, about 295 exabytes (an amount equal to 2 *million* Libraries of Congress) of new information was created and stored in one form or another. In 2013, the amount of new information created that year alone could fill 10 million Libraries of Congress (1,200 exabytes).

ELECTRIC CARS

In late 2015, the Energy Information Alliance made a prediction that the annual sales of electric vehicles with a range of two hundred miles per charge would be no more than a thousand vehicles total. Yet, just a few months later, Tesla announced its upcoming Model 3 all-electric compact sedan with a range of 215 miles per charge took over three hundred thousand preorders in the first week. This is an example of experts and pundits fundamentally misunderstanding the environment in which they are operating. Often, massive change comes from the fringe and areas that the experts are not watching, because they weren't material to the industry . . . yet.

DRONES

A drone in 2007 cost $100,000 or more. Outside of the military, there were no drone pilot jobs. Where would one even go to school to become a drone pilot? These days, I can have a drone delivered on Tuesday for under $50, and I can get a mini-drone for $20. And although, until recently, the FAA wouldn't even allow commercial uses for drones, now training programs are popping up around the country for a rush of new jobs.

3D PRINTERS

3D printers have followed a similar pattern. Ten years ago, there wasn't even a home segment. Now you can order one online for

under $300. The price of performance high-end printers is also changing via new manufacturing techniques, material performance characteristics, and even just plain old price reductions due to volume and competition.

SNAPCHAT FILTERS

My daughter-in-law is a Snapchat geofilter entrepreneur. She designs geofilters (creative overlays that show the "where and when" of a Snapchat image/video, or Snap) for weddings, birthdays, and other special events. Two years ago, this wasn't even a thing. Now she has competition. If you use the photosharing app Snapchat on your smartphone and swipe left, options for appending your photo with graphics, text, brands, and more are available. It's definitely a thing. Ask your kid. Yet, until recently, there was no such thing as "swipe left." There was really no Snapchat either, yet in less than five years they had a $24 billion initial public offering. My daughter-in-law uses Etsy, the online marketplace where artists and entrepreneurs make and sell things to one another. She "makes" geofilters. They are handmade—she paints them and then scans them digitally for uploading to Snapchat's geofilter system. Check out Poppies of Eden and geofilters on Etsy (yes, that was a blatant plug for my daughter-in-law).

IMPLICATIONS

My point here is that new industries are popping up between the interstitial spaces of giants, creating new opportunities and industries that we had not even imagined previously. And the pace at which this is happening is accelerating. (In fact, the pace of technology is exceeding our ability to have rational laws for dealing with it. One of the reasons tech unicorns [firms with values in excess of $1 billion] skirt and sometimes break laws is that

around privacy to keep our AI from blackmailing or perhaps worse, blackballing us, or there simply will be no privacy. Don't get me wrong, it will generally be great, but it comes with important policy ramifications. I visited a website last night looking into renters insurance for my son, and I just got off a call with a telemarketer who called me about renters insurance. The call was generated by my surfing habits. In the not-too-distant future the text that my son wrote that kicked off this line of interest will be ingested as it is delivered and my personal AI will handle the bulk of the transaction with recommendations.

"Mr. Hatch, your son wants to know whether he should get renters insurance, and whether there might be a discount associated with it. Given the likelihood of crime in his neighborhood, and the value of the goods and equipment he has, I recommend that you . . .," and it will provide me with options and ideas before I've finished the text. Yes, your car will drive itself, and it will have extended conversations with your appliances and your AI. Will your AI hide things from you? About yourself? Will it take your job? Can it do your job better than you? Maybe. But in the meantime, make it work for you.

ROBOTICS

The biggest short-to-medium-term impact of robots continues to be in industrial situations. The biggest threats that most robots create are regarding mundane and difficult jobs that are drudgery. Jobs that we will look back on and say they were ill suited for humans. As an optimist, I believe robotics will help create better jobs that are more interesting. Design, engineering, and art will be needed and enabled by robots. I've met with several startups launching out of makerspaces that are building a variety of robots. There is the sandwich-maker robot. It makes just about any sandwich you can imagine. It is a crazy-looking contraption. You want ham and cheese

and sour cream, with lettuce, onions, tomatoes, Dijon mustard, hold the mayo? No problem. You want roast beef au jus? No problem. This thing looks crazy. Another group is working on a six-hundred-burger-per-hour hamburger machine. Combined, these two machines are putting nine hundred thousand jobs at risk. Not the best jobs, but jobs. And they work almost 24/7, don't complain, and are never late. They do break, though, and someone must fix them. Have you ever heard of a hamburger machine technician? It might become the new entry-level job.

A cleaning robot I'm familiar with is a hotel version of the Roomba® vacuum cleaning robot. You just let it loose in a hotel room and it deep cleans the rug (all the way under the bed) automatically. This reduces the time needed by the staff to do that job. It does it better, more quickly, and more cheaply than staff.

Of course, the combination of AI and robots gets us to the self-driving car and the self-driving truck. These innovations will change much of our assumptions around logistics.

Warfighting has and will continue to change. More robots, more AI, more drones, sometimes more precision. Today's warfighter looks very different from the ones just twenty years ago. It's hard to imagine what they will look like in another twenty. Likely warfighters will be commanding a cloud of devices designed to extend, enhance, and enable abilities, resilience, and lethality.

MANUFACTURING, 3D PRINTERS, AND NANOTECHNOLOGY

3D printers have gone through the traditional hype cycle where the short-term expectations of a technology far exceeded its capabilities. It wasn't long ago that everyone was asking if there would be a printer in every home. Eventually you might have one in your home, but doing what? That is always the question: "Why do I need this in the home?" If there is not a clear and compelling answer, then no, you don't need one. Tech for tech's

sake ends up in the shed. But the hype cycle suggests we are seriously underestimating 3D printing's long-term impact.

Most of the impact of 3D printing, or additive manufacturing, is likely to be seen in the industrial sector. GE spent $1.2 billion on two acquisitions last year alone. The benefits, though, will come out of its unique properties, not in the wholesale replacement of existing processes. Examples: GE uses its high-end printers to reduce weight in aircraft engines. What many people and even engineers don't understand is that solid metal pieces are often ridiculously over-engineered because they are solid through and through. What if you could put the metal just where it is needed, that is, make it hollow, or ribbed, or with an internal structure like a spider web? You might be able to design something with exactly the amount of strength needed with no excess material, potentially saving lots of weight. 3D printing enables this kind of design. SpaceX used it to create an engine that could not be produced in any other way. Optimal internal geometries that enable the most efficient engine can't always be milled or cast. Form may follow function, but function follows tool capability. 3D printing is a tool capability new to the world.

Our entire built environment, buildings, desks, chairs, homes, and so on, are still designed with very basic shapes and materials in their standard produced form. Imagine buildings with more organic shapes and structures, more like a bird's nest, or buttressed with framing that on the inside looks more like bone, and not solid. Even mundane things like a tablespoon or knife look and feel over-engineered when we contemplate what a fork might look like were it a highly engineered, 3D printed version optimized for the material it is made from.

For almost thirty years, 3D printing was relegated to high-end prototyping labs with large budgets, was done on large machines behind locked doors, and was considered only the purview of engineers. Then a couple of key patents expired and the "home" 3D printer was born.