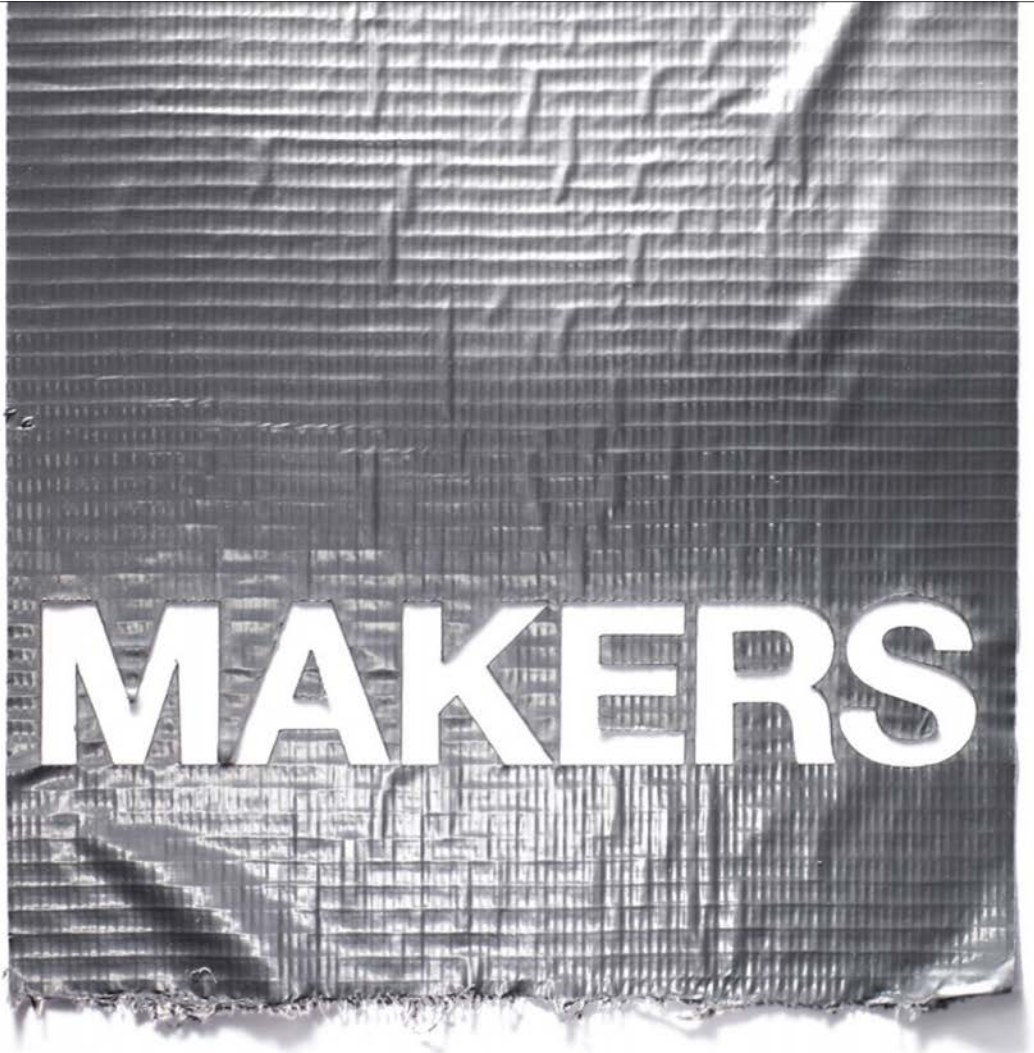

THE NEW INDUSTRIAL REVOLUTION

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Part One

The Revolution

Chapter 1

The Invention Revolution

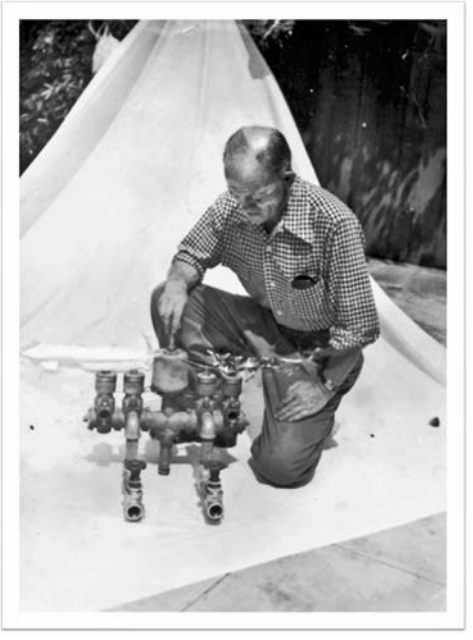
Fred Hauser, my maternal grandfather, emigrated to Los Angeles from Bern, Switzerland, in 1926. He was trained as a machinist, and perhaps inevitably for Swiss mechanical types, there was a bit of the watchmaker in him, too. Fortunately, at that time the young Hollywood was something of a clockwork industry, too, with its mechanical cameras, projection systems, and the new technology of magnetic audio strips. Hauser got a job at MGM Studios working on recording technology, got married, had a daughter (my mom), and settled in a Mediterranean bungalow on a side street in Westwood where every house had a lush front lawn and a garage in the back.

But Hauser was more than a company engineer. By night, he was also an inventor. He dreamed of machines, drew sketches and then mechanical drawings of them, and built prototypes. He converted his garage to a workshop, and gradually equipped it with the tools of creation: a drill press, a band saw, a jig saw, grinders, and, most important, a full-size metal lathe, which is a miraculous device that can, in the hands of an expert operator, turn blocks of steel or aluminum into precision-machined mechanical sculpture ranging from camshafts to valves.

Initially his inventions were inspired by his day job, and involved various kinds of tape-transport mechanisms. But over time his attention shifted to the front lawn. The hot California sun and the local

mania for perfect green-grass plots had led to a booming industry in sprinkler systems, and as the region grew prosperous, gardens were torn up to lay irrigation systems. Proud homeowners came home from work, turned on the valves, and admired the water-powered wizardry of pop-up rotors, variable-stream nozzles, and impact sprinkler heads spreading water beautifully around their plots. Impressive, aside from the fact that they all required manual intervention, if nothing more than just to turn on the valves in the first place. What if they could be driven by some kind of clockwork, too?

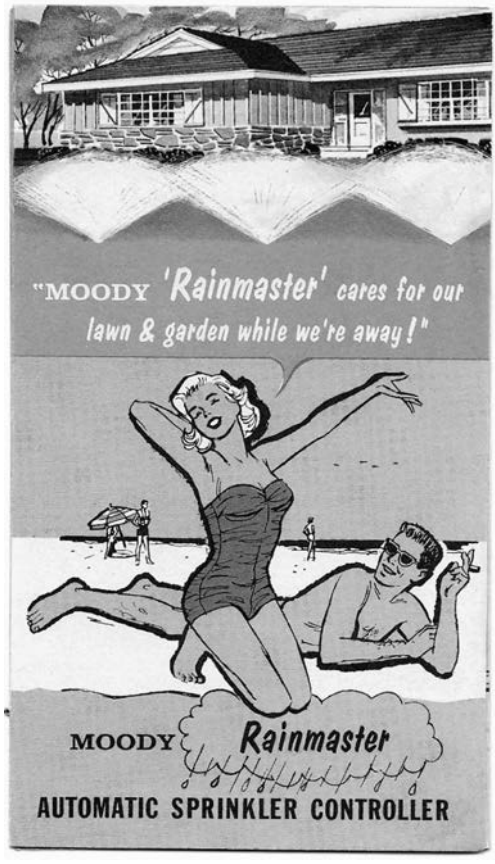
Patent number 2311108 for "Sequential Operation of Service Valves," filed in 1943, was Hauser's answer. The patent was for an automatic sprinkler system, which was basically an electric clock that turned water valves on and off. The clever part, which you can still find echoes of today in lamp timers and thermostats, is the method of programming: the "clock" face is perforated with rings of holes along the rim at each five-minute mark. A pin placed in any hole triggers an electrical actuator called a solenoid, which toggles a water valve on or off to control that part of the sprinkler system. Each ring rep-



resented a different branch of the irrigation network. Together they could manage an entire yard—front, back, patio, and driveway areas.

Once he had constructed the prototype and tested it in his own garden, Hauser filed his patent. With the patent application pending, he sought to bring it to market. And there was where the limits of the twentieth-century industrial model were revealed.

It used to be hard to change the world with an idea alone. You can invent a better mousetrap, but if you can't make it in the millions, the world won't beat a path to your door. As Marx observed, power belongs to those who control the means of production. My grandfather could invent the automatic sprinkler system in his workshop, but he couldn't build a factory there. To get to market, he had to interest a manufacturer in licensing his invention. And that is not only hard,



but requires the inventor to lose control of his or her invention. The owners of the means of production get to decide what is produced.

In the end, my grandfather got lucky—to a point. Southern California was the center of the new home irrigation industry, and after much pitching, a company called Moody agreed to license his automatic sprinkler system. In 1950 it reached the market as the Moody Rainmaster, with a promise to liberate homeowners so they could go to the beach for the weekend while their gardens watered themselves. It sold well, and was followed by increasingly sophisticated designs, for which my grandfather was paid royalties until the last of his automatic sprinkler patents expired in the 1970s.

This was a one-in-a-thousand success story; most inventors toil in their workshops and never get to market. But despite at least twenty-six other patents on other devices, he never had another commercial hit. By the time he died in 1988, I estimate he had earned only a few hundred thousand dollars in total royalties. I remember visiting the company that later bought Moody, Hydro-Rain, with him as a child in the 1970s to see his final sprinkler system model being made. They called him "Mr. Hauser" and were respectful, but it was apparent they didn't know why he was there. Once they had licensed the patents, they then engineered their own sprinkler systems, designed to be manufacturable, economical, and attractive to the buyer's eye. They bore no more resemblance to his prototypes than his prototypes did to his earliest tabletop sketches.

This was as it must be; Hydro-Rain was a company making many tens of thousands of units of a product in a competitive market driven by price and marketing. Hauser, on the other hand, was a little old Swiss immigrant with an expiring invention claim who worked out of a converted garage. He didn't belong at the factory, and they didn't need him. I remember that some hippies in a Volkswagen yelled at him for driving too slowly on the highway back from the factory. I was twelve and mortified. If my grandfather was a hero of twentieth-century capitalism, it certainly didn't look that way. He just seemed like a tinkerer, lost in the real world.

Yet Hauser's story is no tragedy; indeed, it was a rare success story from that era. My grandfather was, as best I can remember (or was able to detect; he fit the caricature of a Swiss engineer, more comfortable with a drafting pencil than with conversation), happy, and he lived luxuriously by his standards. I suspect he was compensated relatively fairly for his patent, even if my stepgrandmother (my grandmother died early) complained about the royalty rates and his lack of aggressiveness in negotiating them. He was by any measure an accomplished inventor. But after his death, as I went through his scores of patent filings, including a clock timer for a stove and a Dictaphone-like recording machine, I couldn't help but observe that of his many ideas, only the sprinklers actually made it to market at all.

Why? Because he was an inventor, not an entrepreneur. And in that distinction lies the core of this book.

It used to be hard to be an entrepreneur. The great inventors/businessmen of the First Industrial Revolution, such as James Watt and Matthew Boulton of steam-engine fame, were not just smart but privileged. Most were either born into the ruling class or lucky enough to be apprenticed to one of the elite. For most of history since then, entrepreneurship has meant either setting up a corner grocery shop or some other sort of modest local business or, more rarely, a total pie-in-the-sky crapshoot around an idea that is more likely to bring ruination than riches.

Today we are spoiled by the easy pickings of the Web. Any kid with an idea and a laptop can create the seeds of a world-changing company—just look at Mark Zuckerberg and Facebook or any one of thousands of other Web startups hoping to follow his path. Sure, they may fail, but the cost is measured in overdue credit-card payments, not lifelong disgrace and a pauper's prison.

The beauty of the Web is that it democratized the tools both of invention *and* of production. Anyone with an idea for a service can turn it into a product with some software code (these days it hardly even requires much programming skill, and what you need you can

learn online)—no patent required. Then, with a keystroke, you can "ship it" to a global market of billions of people.

Maybe lots of people will notice and like it, or maybe they won't. Maybe there will be a business model attached, or maybe there won't. Maybe riches lie at the end of this rainbow, or maybe they don't. But the point is that the path from "inventor" to "entrepreneur" is so foreshortened it hardly exists at all anymore.

Indeed, startup factories such as Y Combinator now coin entrepreneurs first and ideas later. Their "startup schools" admit smart young people on the basis of little more than a PowerPoint presentation. Once admitted, the would-be entrepreneurs are given spending money, whiteboards, and desk space and told to dream up something worth funding in three weeks.

Most do, which says as much about the Web's ankle-high barriers to entry as it does about the genius of the participants. Over the past six years, Y Combinator has funded three hundred such companies, with such names as Loopt, Wufoo, Xobni, Heroku, Heyzap, and Bump. Incredibly, some of them (such as DropBox and Airbnb) are now worth billions of dollars. Indeed, the company I work for, Condé Nast, even bought one of them, Reddit, which now gets more than 2 billion page views a month. It's on its third team of twentysomething genius managers; for some of them, this is their first job and they've never known anything but stratospheric professional success.

But that is the world of bits, those elemental units of the digital world. The Web Age has liberated bits; they are cheaply created and travel cheaply, too. This is fantastic; the weightless economics of bits has reshaped everything from culture to economics. It is perhaps the defining characteristic of the twenty-first century (I've written a couple of books on that, too). Bits have changed the world.

We, however, live mostly in the world of atoms, also known as the Real World of Places and Stuff. Huge as information industries have become, they're still a sideshow in the world economy. To put a ballpark figure on it, the digital economy, broadly defined, represents $20 trillion of revenues, according to Citibank and Oxford Economics.[1] The economy

beyond the Web, by the same estimate, is about $130 trillion. In short, the world of atoms is at least five times larger than the world of bits.

We've seen what the Web's model of democratized innovation has done to spur entrepreneurship and economic growth. Just imagine what a similar model could do in the larger economy of Real Stuff. More to the point, there's no need to imagine—it's already starting to happen. That's what this book is about. There are thousands of entrepreneurs emerging today from the Maker Movement who are industrializing the do-it-yourself (DIY) spirit. I think my grandfather, as bemused as he might be by today's open-source and online "co-creation," would resonate with the Maker Movement. Indeed, I think he might be proud.

The making of a Maker

In the 1970s, I spent some of my happiest childhood summers with my grandfather in Los Angeles, visiting from my home on the East

Coast and learning to work with my hands in his workshop. One spring, he announced that we would be making a four-stroke gasoline engine and that he had ordered a kit we could build together. When I arrived in Los Angeles that summer, the box was waiting. I had built my share of models, and opened the box expecting the usual numbered parts and assembly instructions. Instead, there were three big blocks of metal and a crudely cast engine casing. And a large blueprint, a single sheet folded many times.

"Where are the parts?" I asked. "They're in there," my grandfather replied, pointing to the metal blocks. "It's our job to get them out." And that's exactly what we did that summer. Using the blueprint as a guide, we cut, drilled, ground, and turned those blocks of metal, extracting a crankshaft, piston and rod, bearings, and valves out of solid brass and steel, much as an artist extracts a sculpture from a block of marble. As the pile of metal curlicues from the steel turning on the lathe grew around my feet, I marveled at the power of tools

and skilled hands (my grandfather's, not mine). We had conjured a precision machine from a lump of metal. We were a mini-factory, and we could make anything.

But as I got older, I stopped returning to my grandfather's workshop and forgot about my fascination with making things. Blame screens. My generation was the first to get personal computers, and I was more enthralled with them than with anything my grandfather could make. I learned to program, and my creations were in code, not steel. Tinkering in a workshop seemed trivial compared to unlocking the power of a microprocessor.

Zines, Sex Pistols, and the birth of Indie

When I reached my twenties, I had my second DIY moment. I was living in Washington, D.C., in the early 1980s, when it was one of the hotspots of the American punk rock movement. Bands such as Minor Threat and the Teen Idles were being formed by white suburban teenagers and playing in church basements. Despite not knowing how to play an instrument and having limited talent, I got caught up in the excitement of the moment and played in some of the lesser bands in the scene.[2] It was eye-opening.

Like all garage rock and roll, all you needed to be in a band was an electric guitar and an amp. But what was new about the 1980s punk phenomenon was that the bands did more than just play; they also started to publish. Photocopiers were becoming common, and from them arose a "zine" culture of DIY magazines that were distributed at stores and shows and by mail. Cheap four-track tape recorders allowed bands to record and mix their own music, without a professional studio. And a growing industry of small vinyl-pressing plants let them make small-batch singles and EPs, which they sold via mail order and local shops.

This was the start of the DIY music industry. The tools of the major labels—recording, manufacturing, and marketing music—were

now in the hands of individuals. Eventually some of these bands, led by Minor Threat and then Fugazi, started their own indie label, Dischord, which eventually produced hundreds of records and is still running today. They didn't need to compromise their music to get published, and they didn't need to sell in big numbers or get radio play. They could find their own fans; indeed, the fans found them via word of mouth, and postcards poured into such micro-labels to order music that couldn't be found in most stores. The relative obscurity conferred authenticity and contributed to the rise of the global underground that defines Web culture today.

My bands did all of this: from the photocopied flyers to the zines to the four-track tapes to the indie-label albums. We never got very big, but that wasn't the point. We still had day jobs, but we were doing what we thought was genuinely innovative and getting people at our shows, even touring to New York and to other cities with their own indie music scenes. Out of this came the roots of what would become today's alternative rock world.

By the time I was in my mid-twenties, it was clear that my talents lay elsewhere and I left music. I went back to college and, in part to make up for lost time, decided to major in the hardest subject I could find, physics. Although I wasn't terribly good at that, either, it did expose me to the beginnings of the Internet, which you'll recall started as a way for academic labs, especially big physics facilities with expensive equipment used by researchers from around the world, to connect to each other.

After graduating and working summers at some physics labs, I started working as a writer for the science journals *Nature* and *Science*, which were still part of the academic world and users of the early Internet. That in turn brought me to my third DIY chapter, the Web, which was created in 1990 at CERN, a physics laboratory in Switzerland. Once I saw that, just months after the first websites went live, I realized that I had been incredibly lucky to be in the right place at the right time. I was witnessing the birth of a new medium, one that I not only could be a part of, but could help promote.

From my start in the science world to my job today editing *Wired*, the digital revolution became my career. In the Web Age, the DIY punk movement's co-opting of the means of production turned into regular people using desktop publishing, then websites, then blogs, and now social media. Indie-pressed vinyl became YouTube music videos. Four-track tape recorders became ProTools and iPad music apps. Garage bands became Apple's GarageBand.

Now, three decades later, I find my thoughts returning to my grandfather's garage. It's not nostalgia, nor have I changed my mind about the digital revolution. It's just that the digital revolution has now reached the workshop, the lair of Real Stuff, and there it may have its greatest impact yet. Not just the workshops themselves (although they're getting pretty cool these days), but more what can be done in the physical world by regular people with extraordinary tools.

We are all Makers. We are born Makers (just watch a child's fascination with drawing, blocks, Lego, or crafts), and many of us retain that love in our hobbies and passions. It's not just about workshops, garages, and man caves. If you love to cook, you're a kitchen Maker and your stove is your workbench (homemade food is best, right?). If you love to plant, you're a garden Maker. Knitting and sewing, scrapbooking, beading, and cross-stitching—all Making.

These projects represent the ideas, dreams, and passions of millions of people. Most never leave the home, and that's probably no bad thing. But one of the most profound shifts of the Web Age is that there is a new default of sharing online. If you do something, video it. If you video something, post it. If you post something, promote it to your friends. Projects shared online become inspiration for others and opportunities for collaboration. Individual Makers, globally connected this way, become a movement. Millions of DIYers, once working alone, suddenly start working together.

Thus ideas, shared, turn into bigger ideas. Projects, shared, become group projects and more ambitious than any one person would attempt alone. And those projects can become the seeds of products, movements, even industries. The simple act of "making in public" can

become the engine of innovation, even if that was not the intent. It is simply what ideas do: spread when shared.

We've seen this play out on the Web many times. The first generation of Silicon Valley giants got their start in a garage, but they took decades to get big. Now companies start in dorm rooms and get big before their founders can graduate. You know why. Computers amplify human potential: they not only give people the power to create but can also spread their ideas quickly, creating communities, markets, even movements.

Now the same is happening with physical stuff. Despite our fascination with screens, we still live in the real world. It's the food we eat, our homes, the clothes we wear, and the cars we drive. Our cities and gardens; our offices and our backyards. That's all atoms, not bits.

This construction—"atoms" versus "bits"—originated with the work of a number of thinkers from the MIT Media Lab, starting with its founder, Nicholas Negroponte, and today most prominently exemplified by Neal Gershenfeld and the MIT Center for Bits and Atoms. It is shorthand for the distinction between software and hardware, or information technology and Everything Else. Today the two are increasingly blurring as more everyday objects contain electronics and are connected to other objects, the so-called Internet of Things. That's part of what we'll be talking about here. But even more, we'll look at how it's changing manufacturing, otherwise known as the flippin' Engine of the World Economy.

The idea of a "factory" is, in a word, changing. Just as the Web democratized innovation in bits, a new class of "rapid prototyping" technologies, from 3-D printers to laser cutters, is democratizing innovation in atoms. You think the last two decades were amazing? Just wait.

If Fred Hauser were born in 1998, not 1898, he'd still have his workshop, tinkering with nature and bountiful ideas. The only thing that would have changed in his converted garage is the addition of a computer and an Internet connection. But what a change!

Rather than a solo obsession, he likely would have been part of a community of equally obsessed people from around the world. Rather than inventing everything from scratch, he would have built on the work of others, compressing decades of work into months. Rather than patenting, he might have published his designs online, like other members of his community.

When it came time to make more than a handful of his designs, Hauser wouldn't have begged some manufacturer to license his ideas, he would have done it himself. He would have uploaded his design files to companies that could make anything from tens to tens of thousands of units for him, even drop-shipping them directly to customers. Because his design files were digital, robotic machine tools could make them, saving 90 percent or more in tooling costs. Rather than searching for distributors, he would have set up his own e-commerce website, and customers would have come to him via Google searches, not salesmen.

In short, he would have been an entrepreneur, not just an inventor. That, in a nutshell, is the theme of this book. The history of the past two decades online is one of an extraordinary explosion of innovation and entrepreneurship. It's now time to apply that to the real world, with far greater consequences.

We need this. America and most of the rest of the West is in the midst of a job crisis. Much of what economic growth the developed world can summon these days comes from improving productivity, which is driven by getting more output per worker. That's great, but the economic consequence is that if you can do the same or more work with fewer employees, you should. Companies tend to rebound after recessions, but this time job creation is not recovering apace. Productivity is climbing, but millions remain unemployed.

Much of the reason for this is that manufacturing, the big employer of the twentieth century (and the path to the middle class for entire generations), is no longer creating net new jobs in the West. Although factory output is still rising in such countries as the United

States and Germany, factory jobs as a percentage of the overall workforce are at all-time lows. This is due partly to automation, and partly to global competition driving out smaller factories.

Automation is here to stay—it's the only way large-scale manufacturing can work in rich countries (see chapter 9). But what can change is the role of the smaller companies. Just as startups are the driver of innovation in the technology world, and the underground is the driver of new culture, so, too, can the energy and creativity of entrepreneurs and individual innovators reinvent manufacturing, and create jobs along the way.

Small business has always been the biggest source of new jobs in America. But too few of them are innovative and too many are strictly local—dry cleaners, pizza franchises, corner groceries, and the like, all of which are hard to grow. The great opportunity in the new Maker Movement is the ability to be both small *and* global. Both artisanal and innovative. Both high-tech and low-cost. Starting small but getting big. And, most of all, creating the sort of products that the world wants but doesn't know it yet, because those products don't fit neatly into the mass economics of the old model.

As Cory Doctorow imagined it a few years ago in a great sci-fi book also called *Makers*,[3] which was an inspiration for me and countless others in the movement, "The days of companies with names like 'General Electric' and 'General Mills' and 'General Motors' are over. The money on the table is like krill: a billion little entrepreneurial opportunities that can be discovered and exploited by smart, creative people."

Welcome to the New Industrial Revolution.