BARRILES DE PAPEL No 207
MAKERS, by CHRIS ANDERSON
Académico, Ing. Diego J. González Cruz

Siguiendo con nuestra tarea de informar sobre la literatura en materias de Sociedad, Política, Economía y Gerencia, esta vez voy a conversar sobre el libro: *Makers*, de Chris Anderson. Anderson es el fundador de la revista *Wired (https://www.wired.com/author/chris-anderson/) y fundador del Movimiento Makers.* Resalta que su libro trata de lo que ocurrirá en los próximos 10 años, en el mundo de los Sistemas y los Negocios. Destaca en detalle lo que está ocurriendo hoy en el mundo de las computadoras. Es un libro que recomendamos sobremanera a los que le gustan los Sistemas, y las computadoras en general. También para aquellos que quieren comenzar un negocio. Algún día esta será materia de estudio en liceos y universidades.	**Crown Business, New York, 2012**

Este es un libro de solo 257 páginas, dividido en 13 Capítulos, un Epilogo, un Apéndice, Agradecimientos y Notas, que recomendamos leer exhaustivamente.

Contents

Part One THE REVOLUTION

Chapter 1 The Invention Revolution
Chapter 2 The New Industrial Revolution
Chapter 3 The History of the Future
Chapter 4 We Are All Designers Now
Chapter 5 The Long Tail of Things

Part Two THE FUTURE

Chapter 6 The Tools of Transformation
Four Desktop Factories
Chapter 7 Open Hardware
Chapter 8 Reinventing the Biggest Factories of All
Chapter 9 The Open Organization
Chapter 10 Financing the Maker Movement
Chapter 11 Maker Businesses

Chapter 12 The Factory in the Cloud
Chapter 13 DIY Biology

Epilogue
Appendix: The 21st Century Workshop

Acknowledgments

Notes

Index

Esta vez conservaremos los textos en ingles, y mis comentarios y observaciones estarán en español y en cursivas. Los textos los he reducido para facilitar su lectura, que por supuesto, los motivados, leerán completo en el libro (esta al final).

Comienza contando la historia de su abuelo Fred Hauser, un inventor natural, que patentó un regador de grama que funcionaba con un reloj. Era un inventor no un empresario. Esa diferencia es de lo que trata el libro. ¿Qué define exactamente el Movimiento Makers? Es una descripción extensa que abarca una amplia variedad de actividades, desde la artesanía tradicional hasta la electrónica de alta tecnología, muchas de las cuales existen desde hace siglos. Pero los Creadores, al menos los que aparecen en este libro, están haciendo algo nuevo. Una de las claves del éxito del movimiento Makers es el uso de las impresoras en 3-D, su funcionamiento lo pueden leer en la pagina 17 y siguientes. Esta es la idea fundamental de los Makers: convertir los ***bits*** *(el lenguaje de las computadoras) en* ***atoms*** *(lo físico y tangible), y viceversa.*

DIY manufacturing

That's because even commercial manufacturing has itself become digital, networked, and increasingly open-just like the Web. The biggest manufacturing lines speak the same language as a MakerBot, and anyone can move from one to the other.

As a result, global manufacturing can now work at any scale, from ones to millions. Customization and small batches are no longer impossible-in fact, they're the future. The same ability has come to desktop CAD tools, where you can design 3-D objects onscreen. Once you've created something in a CAD program, you can choose whether to "print local" (prototype one copy on your 3-D printer or other desktop fabricator) or "print global" (send it off to a service bureau to be manufactured in volume).

The distinction between amateur and entrepreneur has been reduced to a software option. The step from making one to making thousands is simply a matter of what menu options you click and how much you want to pay (or put on your credit card). My assumption was that the best way to reinvent a mature industry would be to open it up to the ideas of others. So I asked a few basic questions, which you could call a toolkit for transformation (it can apply to practically any product):

1. How would these products be improved if they were connected to the Internet?
2. How would they be improved if the designs were open, so anyone could modify or improve them?
3. How much cheaper would they be if their manufacturers didn't charge for their intellectual property?

Of course the New Industrial Revolution is not limited to open innovation.

Conventional proprietary product development benefits from the same desktop prototyping tools, from 3-D printers to CNC (computer numerical control) routers. These new capabilities are accelerating innovation in the biggest companies in the world, from Ford's automobile interiors to IKEA's new kitchenware.

Todo el Capítulo *3 lo dedica a explicar las revoluciones que ocurrieron en Inglaterra comenzando con la invención de la "spinning jenny":* a pedal-powered device that could allow a single operator to spin eight threads at the same time (jenny was Lancashire slang for "machine").

Y explica que definen las revoluciones industriales y que las causan:

The term "*industrial revolution*" itself was first coined in 1799 by Louis-Guilluame Otto, a French diplomat, in a letter reporting that such a thing was under way in France (revolutions were much in vogue). "Revolution" was also, perhaps unsurprisingly, the term used to describe the industrial changes by Friedrich Engels, whose capitalist critiques in the mid-1800s helped lead to Marxism. And it was popularized in the late 1800s by Arnold Toynbee, a British economic historian who gave a series of famous lectures on why this industrial movement had had such a profound impact on the world economy. But at its core, "*industrial revolution*" refers to a set of technologies that dramatically amplify the productivity of people, changing everything from longevity and quality of life to where people live and how many there are of them.

There are those who argue that the Information Age is a Third Industrial Revolution. Computing and communications are also "force multipliers," doing for services what automation did for manufacturing. Rather than amplifying human muscle power, they amplify brain power. They can also drive productivity gains in existing industries and create new ones. And by allowing us to do existing jobs faster, they free us up to do new ones. In short, the dawn of the Information Age, starting around 1950 and going through the Personal Computer in the late 1970s and early 1980s and then the Internet and the Web in the 1990s, was certainly a revolution. But it was not an industrial revolution until it had a similar democratizing and amplifying effect on manufacturing, something that's only happening now. Thus, the Third Industrial Revolution is best seen as the combination of digital manufacturing and personal manufacturing: the industrialization of the Maker Movement.

The Second Industrial Revolution

Chapter 4
We Are All Designers Now

So we might as well get good at it.

Aqui explica como la enseñanza primaria va cambiar, para enseñar a los niños a diseñar con CAD y 3-D.

Just as shop class disappeared with school budget cuts, better opportunities in the workplace for women and gender equality killed Home Economics. Kids grew up with computers and video games, not wrenches and band saws. The best minds of a generation were seduced by software and the infinite worlds to be created online. And they made the digital age we all live in today. That is how the world shifted from atoms to bits. The transformation has gone on for thirty years, a generation, and it's hard to argue with any of it.

But now, thirty years after "Industrial Arts" left the curriculum and large chunks of our manufacturing sectors have shifted overseas, there's finally a reason to get your hands dirty again. As desktop fabrication tools go mainstream, it's time to return "making things" to the high school curriculum, not as the shop class of old, but in the form of teaching design. Today, schoolchildren learn how to use PowerPoint and Excel as part of their computer class, and they still learn to draw and sculpt in art class. But think how much better it would be if they could choose a third option: design class.

Imagine a course where kids would learn to use free 3-D CAD tools such as Sketchup or Autodesk 123D. Some would design buildings and fantastic structures, much as they sketch in their notebooks already. Others would create elaborate videogame levels with landscapes and vehicles. And yet others would invent machines. Even better, imagine if each design classroom had a few 3-D printers or a laser cutter. All those desktop design tools have a "Make" menu item. Kids could actually fabricate what they have drawn onscreen. Just consider what it would mean to them to hold something they dreamed up. This is how a generation of Makers will be created. This is how the next wave of manufacturing entrepreneurs will be born.

"Desktop" changes everything

Aqui explica como se podrá hacer todo desde el escritorio con una laptop.

Two decades after "desktop publishing" became a mainstream reality, the word "desktop" is being added to industrial machinery, with equally mind-blowing effect. Desktop 3-D printing. Desktop computer-controlled routing, milling, and machining. Desktop laser cutting. Desktop computer-controlled embroidering, weaving, and quilting. Even desktop 3-D scanning, or "reality capture," digitizing the physical world. Desktop fabrication is leading to full-on desktop manufacturing. What's so important about the word "desktop"? Just consider the history of the computer itself. Until the late 1970s, "computing" meant room-

sized mainframes and refrigerator-sized minicomputers, which were the sole domain of governments, big companies, and universities.

Technologists had long predicted that computing would find a place in the average home-the Moore's Law trend of declining price and increasing power practically guaranteed that day would eventually come. This was not because the wise minds of the big computer companies had finally figured out why people would want one, but because people found new uses all by themselves. Then, in 1985, Apple released the LaserWriter, the first real desktop laser printer, which, along with the Mac, started the desktop publishing phenomenon. It was a jaw-dropping moment, combining in the public imagination words that had never gone together before: "desktop" and "publishing"!

Famously, Apple's printer had more processing power than the Mac itself, which was necessary to interpret the Postscript page description language that was originally designed for commercial printers costing ten times as much. But Steve Jobs wanted the Mac desktop publishing suite not just match to the quality of commercial printers, but to exceed them. Desktop tools could be better than traditional industrial tools, he believed, and he started by cutting no corners. But with desktop publishing, a smaller version of this was in reach of anyone. In a sense, you could "prototype" a publication at home by printing a few copies, and then, when it looked right, you could take a floppy disk with the file to a copy shop to be printed in volume.

Taking publishing out of factories liberated it. But the real impact of this was not in paper, but in the idea of "publishing" online. Once people were given the power of the press, they wanted to do more than print out newsletters. So, when the Web arrived, "publishing" became "posting" and they could reach the world. Even the simple act of posting online is a way of occupying what were once factories. Today your PC is seamlessly connected to warehouse-sized server farms (the "cloud") that allow you to access massive-scale computing in an instant. So there you have it: the industrial machinery of the biggest twentieth-century media empires transformed into the sort of thing that you can command from your laptop. Yesterday the biggest computing facilities in the world were working for the government, huge companies, and research labs. Today they're working for you. That is what the "desktop" wrought.

DIY design (Do It Yourself)

So now the 3-D printer is where Jobs's Macintosh and LaserWriter were twenty-five years ago. As with the first laser printers, 3-D printing is still a bit expensive and hard to use; it's not yet for everyone. We haven't really figured out what the killer app will be. But what we do know is that it will get better and cheaper even faster than the laser printer did, thanks to all the basic mechanical and electronic technology 3-D printing shares with its dimensionally deprived ancestor, the inkjet printer you've already got. The only real difference is that it squirts a different liquid (molten plastic, not ink) and has one more motor to control height. Like then, the first users are a little lost. When desktop publishing was first introduced, tens of thousands of people discovered that they knew nothing about

fonts, kerning, text flow, anchors, and all that; they had to learn a couple of centuries' worth of publishing terms and techniques overnight.

Today, with the spread of desktop fabrication tools, a generation of amateurs is also being suddenly confronted with the baffling language and techniques of professional industrial design, just as they were in the desktop publishing era. Remember, the early days of the personal computer revolution were equally arcane- "pixels," "bytes," "RAM"- and now we hardly give the details of computing a thought, in part because maturing technology hides most of that plumbing from us. So, too, for the Maker Movement. Today it is full of people who are dazzled by the potential of the industrial-quality tools now appearing on their desktops.

The alien language and techniques of physical creation are intoxicating for the geeks; they're rushing to explore this strange new world. But that is just the first wave of what is quickly becoming a mainstream phenomenon. Soon these early tools will become as ubiquitous and as easy to use as inkjet printers. And if history is any guide, it will change the world even faster than the microprocessor did a generation ago. We are all designers now. It's just time to get good at it.

Chapter 5
The Long Tail of Things

Mass production works for the masses. But what works for you?

Aqui el cuenta como enseño a sus nietas a amoblar sus casas de muñecas con todo tipo de muebles hechos en 3D.

But now we have a 3-D printer, a MakerBot Thing-O-Matic, and so this quest ended differently. We went to Thingiverse, an online repository of 3-D designs that people have uploaded. And there it was, just like The Sims. Every furniture type we could want, from French Renaissance to Star Trek, was available, ready for the downloading. We grabbed some exquisite Victorian chairs and couches, resized them with a click to perfectly fit our dollhouse scale, and clicked on "build." Twenty minutes later we had our furniture. It was free, fast, and there was so much more choice than the real world, or even Amazon. We may never buy dollhouse furniture again.

Of course, physical objects are more complex than 2-D images. Right now we can only print plastic in a few colors on our MakerBot. The finish is not as good as injection-molded plastic, and we can't print color details with nearly as fine precision as the painting machines or stencils of Chinese factories. But today, just a generation later, we have cheap and silent ink-jets that print in full color with resolution almost indistinguishable from professional printing. Now fast-forward the clock a decades or two from today's early 3-D printers. They will be fast, silent, and able to print a wide range of materials, from plastics to wood pulp and even food. They will have multiple color cartridges, just like your inkjet, and be able to print in as many color combinations. They will be able to print images on the surface of an object even finer than the best toy factories today.

Disruptive by design

That's the power of democratization: it puts tools in the hands of those who know best how to use them. We all have our own needs, our own expertise, our own ideas. If we are all empowered to use tools to meet those needs, or modify them with our own ideas, we will collectively find the full range of what a tool can do. The Internet democratized publishing, broadcasting, and communications, and the consequence was a massive increase in the range of both participation and participants in everything digital-the Long Tail of Bits. Now the same is happening to manufacturing-the Long Tail of Things. My first book, *The Long Tail*, *(Este libro fue un bestseller)* was about exactly this-the shift in culture toward niche goods-but mostly in the digital world.

But once these products (music, movies, and books) were available online in digital marketplaces with unlimited "shelf space," for lack of a better phrase, demand followed: the monopoly of the blockbuster was over. That was not exclusively digital, of course. The Internet also lengthened the tails of physical product markets for consumers. But it did so by revolutionizing distribution, not production. For physical goods, the twentieth-century limits to choice were based on three distribution bottlenecks-you could only buy things that passed all of the three tests:

1. The products were popular enough for manufacturers to make.
2. The products were popular enough for retailers to carry.
3. The products were popular enough for you to find (via advertising or prominent placement in stores near you).

As Amazon showed, the Web could help with the latter two, right out of the gate. First, the shift to search as a discovery mechanism meant that people could find products that were not necessarily popular enough to promote the usual way in bricks-and-mortar retail. Second, Amazon and others who used centralized distribution warehouses and, later, distributed warehousing in the form of listings for third-party merchants who handle all the fulfillment, meant that they could list many more products than any physical retailer could carry. (Like the original catalog retailers, but without the limited pages of a paper catalog sent through the mail.)

Meanwhile, eBay did the same thing for used goods, countless specialist Web retailers emerged, and eventually Google aggregated them all into the ultimate way to find anything. Today the Web has already surfaced a Long Tail of products to rival the tail of digital ones. Bottlenecks 2 and 3 above are largely removed. But that was just the start. Remember that the real Web revolution was not that we could just buy more stuff with greater choice, but make our own stuff that others could consume. In the Web case, the "stuff" was and is mostly creativity and expression in digital form: words, pictures, videos, and the like. It doesn't compete with commercial goods for money, but does compete for time.

A blog may not be a book, but at the end of the day, it's just another way to entertain and inform. Now the same is happening with physical goods. The 3-D printers and other desktop prototyping tools are the equivalent of the cameras and music editing tools. They

allow anyone to create one-offs for their own use. Manufacturing has now become just another “cloud service” that you can access from Web browsers, using a tiny amount of vast industrial infrastructure as and when you need it.

Somebody else runs these factories; we just access them when we need them, much as we can access the huge server farms of Google or Apple to store our photos or process our email. The non-academic way to say it is this: nothing is stopping you from making anything. The people now control the means of production. Or, as *The Lean Startup* author Eric Reis puts it, “It’s not about ownership of the means of production, anymore. It’s about rentership of the means of production.”

The industrial artisan

The Long Tail of Things is around you already and has been for years, just not on this scale. Take any domain where you have a deep interest and start searching online. Got a classic car, perhaps an old MG roadster? A few clicks in your browser and you’re in the domain of hyperspecialized suppliers who focus on making nothing but replacement bonnet release cables for car models that haven’t been made for a generation. Or perhaps you’re looking for a jewelry tree on which to dangle necklaces. You may start at Crate & Barrel, but five clicks later and you’re on Etsy, buying something much cooler and more interesting (and no more expensive) from a metal artist in Texas. The barriers to variety have disappeared.

This is what i.materialize, a design firm, calls “the power of the unique.” In a world dominated by one-size-fits-all commodity goods, the way to stand out is to create products that serve individual needs, not general ones. Custom-made bikes fit better. Right now this is mostly the privilege of the rich, as such products require hand-crafting. But what if they could be produced using digital manufacturing where there is no cost to complexity and no penalty for short production runs? Increasingly, when computers are running the production machines, it costs no more to make each product different.

If you’ve ever received a catalog or magazine in the mail that has a personalized message for you, that’s a formerly one-size-fits-all production machine-the printing press-turned into a digital one-size-fits-one machine, using little more than a big version of the desktop inkjet printer. In a sense, this is just the extreme of the specialization that Adam Smith originally recognized in *The Wealth of Nations* as the key to an efficient market. People should do only what they do best, he said, and trade with others who make other specialized goods.

What was good in the eighteenth century is even better in the twenty-first, now that specialists have access to global supply chains for their commodity input materials and global consumer markets for their niche output products. Nearly thirty years ago, two MIT professors, Michael Piore and Charles Sabel, predicted this transition in a book titled *The Second Industrial Divide*. They argued that the mass production model that defined twentieth-century manufacturing economies (the “first industrial divide” between people and production) was neither inevitable nor the end of innovation in making things.

Under somewhat different historical conditions, firms using a combination of craft skill and flexible equipment might have played a central role in modern economic life-instead of giving way, in almost all sectors of manufacturing, to corporations based on mass production. Had this line of mechanized craft production prevailed, we might today think of manufacturing firms as linked to particular communities rather than as the independent organizations that, through mass production, seem omnipresent.

Today, digital desktop fabrication has indeed introduced a sort of “mechanized craft production” that Piore and Sabel could only have dreamed of. Rather than returning to the sewing machines and local machine shops that big factories drove out of the market a hundred years ago, the modern Maker Movement is built on high-tech digital fabrication, and can let regular people harness big factories at will to make what they want. It’s the perfect combination of inventing locally and producing globally, serving niche markets defined by taste, not geography.

And what’s clear about these new producers is that they’re not going to be making the same one-size-fits-all products that de fined the mass production era. Instead, they’re going be starting with one-size-fits-one and building from there, finding out how many other consumers share their interests, passions, and unique needs.

Happiness economics

The hot field of happiness economics argues, rather persuasively, that once people reach some level of comfort, they are willing-even eager-to trade in potential earnings at a lucrative but uninspiring job for less (but comfortable) pay at more satisfying work. Some research by the Chicago economist Erik Hurst suggests that half of entrepreneurs start businesses as much to pursue happiness as to make money. What’s more, consumers tend to value more highly products of which they feel they have had a hand in their creation, whether assembling a kit or just encouraging the creators themselves online.

Researchers call this “the IKEA Effect,” and it dates all the way back to the Home Economics movement. As Duke University behavioral economist Dan Ariely and his colleagues write in a paper on this. Today, in experiments with IKEA furniture, when the paper’s study participants were given the opportunity to buy IKEA furniture they built themselves versus identical units built by others, they bid 67 percent more for their own creations. They did the same with Lego kits and paper origami. In all cases, people would pay more for things where their own sweat was one of the ingredients. This is the Maker’s Premium. It’s the ultimate antidote to commodification.

Take any niche and check out the new producers. Mountain bike parts, classic car accessories, cool vinyl “skins” for phones and other gadgets-they’re all seeing a wave of new micro-entrepreneurs selling online. Although each market is different, what’s common about this new creative class is that they were once consumers who wanted something that didn’t exist before. So, rather than settle for what was on the market, they made something better themselves. Writes Carpo, “This is, at the basis, the golden formula that has made Google a very rich company. Variability, which could be an obstacle in a

traditional mechanical environment, has been turned into an asset in the new digital environment-indeed, into one of its most profitable assets."

Information inside

Walk into an Apple Store and look around you. All those shiny objects-all those beautifully designed and manufactured slabs of titanium, high-end plastics, and circuitry-started life on a screen somewhere. So, too, for a Nike store. Or a car dealership. Physical products are increasingly just digital information put in physical form by robotic devices such as CNC mills and pick-and-place machines making printed circuit boards. That information is a design, translated into instructions to automated production equipment. In a sense, hardware is mostly software these days, with products becoming little more than intellectual property embodied in commodity materials, whether it's the code that drives the off- the-shelf chips in gadgets or the 3-D design files that drive manufacturing.

Remixing the physical world

The answer comes down to the unique qualities of digital information. It seems like such a small distinction: products shared as physical things or products shared as digital descriptions of physical things. After all, if you've got to fabricate them to make them real, one way or another, who cares what form the instructions take? But as we've learned over the past few decades, digital is different. Sure, digital files can be shared and copied limitlessly at virtually no cost and with no loss of quality. But what's more important is that they can be modified just as easily. We live in a "remix" culture: everything is inspired by something that came before, and creativity is shown as much in the reinterpretation of existing works as in original ones.

That ability to easily "remix" digital files is the engine that drives community. What it offers is an invitation to participate. You don't need to invent something from scratch or have an original idea. Instead, you can participate in a collaborative improvement of existing ideas or designs. The barrier to entry of participation is lower because it's so easy to modify digital files rather than create them entirely yourself. Think of a digital product design not as picture of what it should be, but instead as a mathematical equation of how to make it. That is not a metaphor-it's actually the way CAD programs work.

When you draw a 3-D object on the screen, what the computer really does is write a series of geometrical equations that can instruct machines to reproduce the object at any size in any medium, be it pixels on a monitor or plastic in a printer. But it didn't happen, at least not at the scale that everyone expected. Cars, for example, are chosen primarily for their reliability. The more variability there is in the manufacturing process, the harder it is to keep the defect rate down. Without perfect 3-D models of the customer (and telepathic understanding of their wearing preferences), clothes are hard to tailor predictably, which is why men still have their inseams measured in shops.

Small batches

Part Two

The Future

Chapter 6

The Tools of Transformation

3-D printers are heading for the alchemist's dream: making anything.

Just as we now use radio waves to excite atoms and generate heat in our own kitchens (which would have been mind-blowing in the 1950s), *(aqui esta hablando de los hornos microonda)* his replicator uses some fancy energy technology that is never quite specified in Star Trek: The Next Generation to get atoms to self-assemble into food and drink. Okay, poetic license revoked-we're still a long way from molecular self-assembly, or at least in any useful way. A 3-D printer can only work with one material at a time, and if you want to combine materials you need to have multiple print heads or switch from one to another, like the different color cartridges in your desktop inkjet printer.

And there's nothing self-assembling about the way a 3-D printer works: it does all the assembling itself, with the brute force of a laser solidifying a powder or liquid resin, or melting plastic and spreading it down in a fine line. But you get the point. We can imagine something, draw it on a computer, and a machine can make it real. We can push a button and an object will appear (eventually). As Arthur C. Clarke put it, "anysufficiently advanced technology is indistinguishable from magic." This is getting close.

Four Desktop Factories

1) 3-D printer.

A 3-D printer and the paper printer you've probably already got on your desktop play similar roles. The traditional laser (or inkjet) printer is a 2-D printer: it takes pixels on a screen and turns them into dots of ink or toner on a 2-D medium, usually paper. A 3-D printer, however, takes "geometries" onscreen (3-D objects that are created with the same sort of tools that Hollywood uses to make CG movies (computer generated) and turns them into objects that you can pick up and use. (*aqui va una fotografia*). Some 3-D printers extrude molten plastic in layers to make these objects, while others use a laser to harden layers of liquid or powder resin so the product emerges from a bath of the raw material. Yet others can make objects out of any material from glass, steel, and bronze to gold, titanium, or even cake frosting. You can print a flute or you can print a meal. You can even print human organs out of living cells, by squirting a fluid with suspended stem cells onto a support matrix, much as your inkjet printer squirts ink onto paper.

2) CNC machine:

While a 3-D printer uses an "additive" technology to make things (it builds them up layer by layer) a CNC ("computer numerical control") router or mill can take the same file and make similar products with a "subtractive" technology, which is a fancy way of

saying that it uses a drill bit to cut a product out of a block of plastic, wood or metal. There are countless other specialty CNC machines: CNC quilters and embroidery machines, CNC sign and vinyl cutters (for silk-screening), and CNC paper and fabric cutters for crafters, to name a few. Some CNC machines are the size of a large table and are designed to make furniture out of wood (industrial CNC machines can be as big as a warehouse and can carve out objects as big as an airplane fuselage). (*aqui va una fotografia*)

3) Laser Cutter:

One of the most popular of the new desktop tools is the laser cutter, which is mostly a 2-D device. It uses a powerful laser to cut a precise pattern of any complexity into sheets of whatever material you feed it, from plastics and woods to thin MyDIYC Epilog Zing laser cutter metal. Many CAD programs can break a 3-D object into 2-D parts so they can be fabricated with a laser cutter, and then neatly slotted together like one of those plywood dinosaur kits.

4) 3-D Scanner:

This device, which can be as small as a breadbox, allows you to do “reality capture.” Rather than having to draw an object from scratch, you can put an existing object in the scanner. It then uses lasers or other light sources and a camera to image the object from all sides, and then turns it into a 3-D image made up of tens or hundreds of thousands of polygons, just like a videogame character or CG movie set. The software can simplify it and let you modify any part you want. A common first experiment is to scan your head, thenexaggerate your features and 3-D print a bobble- head of yourself.(*aqui va una fotografia*).

You may think of 3-D printing as bleeding-edge technology today, the stuff of high-end design workshops and geeks. But you may have encountered a 3-D printer already, in ways so prosaic you didn’t even notice. Take custom dental fittings, such as those that change the alignment of the teeth over months with a series of slightly different mouth guards, each of which shifts the teeth imperceptibly into a new position. In that case, a dental technician scans the current position of your teeth, then software mathematically models all the intermediate positions to the desired endpoint. *(esto lo estan utilizando mucho los odontologos)*

Finally, those positions are 3-D printed in plastic as a series of mouth guards that you wear, each for a two or three weeks, until your teeth are in the new position. Likewise for the prototypes of practically every gadget you’ve every bought, and the architectural models for the newer buildings around you. Custom prosthetics are 3-D printed, if you’re lucky enough to have a dentist who can replace a crown in a single sitting, that’s probably 3-D printed (then sprayed with enamel) in the office. (*Cada vez los odotologos lo usan mas).* Doctors have printed and replaced an entire human jaw from titanium. Today, you can buy a custom 3-D printed action figure of your World of Warcraft character or your Xbox Live avatar. And if you go to Tokyo, you can have your head scanned and you can

buy a photorealistic action figure of yourself (try not to get too creeped out). Commercial 3-D printing only works with a few dozen types of materials, mostly metals and plastics of various sorts, but more are in the works.

Researchers are experimenting with more-exotic materials, from wood pulp to carbon nanotubes, that give a sense of the scope of this technology. Some 3-D printers can print electrical circuits, making complex electronics from scratch. Yet others printicing onto cupcakes and extrude other liquid foods, including melted chocolate. At the huge scale, there are already 3-D printers that can make a multistory building by "printing" concrete. Right now that requires a 3-D printer the size of the building, but it may someday be built into the cement truck itself, with a concrete that uses positional awareness to decide where to put down concrete and how much, directly reading and following the architect's CAD plans.

Ya hay videos de casas construidas en sitio a partir de equipos 3-D gigantes.

Meanwhile, researchers are working just as hard at moving in the other direction: 3-D printing at the molecular scale. Today there are "bio printers" that print a layer of a patient's own cells onto a 3-D-printed "scaffold" of inert material. Once the cells are in place, they can grow into an organ, with bladders and kidneys already demonstrated in the lab. Print with stem cells, and the tissue will form its own blood vessels and internal structure. Today's vision for 3-D printing is grand in ambition. Carl Bass, the CEO of Autodesk, one of the leading companies making 3-D authoring CAD software, sees the rise of computer- controlled fabrication as a transformative change on the order of the original mass production.

In an essay he published in the *Washington Post*, Bass explained what's so different about this way of making things:

The ability to produce a small number high quality items and sell them at reasonable prices is causing an enormous economic disruption. In it, you can see the future of American manufacturing. In a computerized manufacturing process like 3-D printing, complexity and quality come at no cost. A traditional paper printer can print a circle or a copy of the Mona Lisa with equal ease. The same rule applies to a 3-D printer.

The same design can be fabricated in metal, plastic, cardboard, or cake icing. (It might not be very useful in all those materials, but it would exist.) "We can separate the design of a product from its manufacture for the first time in history, because all of the information necessary to print that object is built into the design." Bass explained. Even better, as 3-D printers proliferate and become used for small-scale bespoke or custom-made manufacturing, they can provide a more sustainable way of making things.

There are little or no transportation costs, because the product is made locally. There is little or no waste, because you use no more raw material than you need. And because the product is custom-made just for you, you're more likely to value it and keep it longer. Personalized products are less disposable; you simply care about them more. Rich

Karlgaard, the publisher of *Forbes* magazine, thinks that 3-D printing "could be the transformative technology of the 2015–2025 period." He writes:

This has the potential to remake the economics of manufacturing from a large-scale industry back to an artisan model of small design shops with access to 3-D printers. In other words, making stuff, real stuff, could move from being a capital intensive industry into something that looks more like art and software. This should favor the American skill set of creativity.

It is the reverse of mass production, which favors repetition and standardization. Instead, 3-D printing favors individualization and customization. For small batches, digital fabrication now wins. For big batches, the old analog way is still best (see diagram). But just think about how many products actually make more sense in units of hundreds, not millions. For this "long tail of things," the only option a few decades ago was handcrafting.

Digital fabrication inverts the economics of traditional manufacturing. In mass production, most of the costs are in up-front tooling, and the more complicated the product is and the more changes you make, the more it costs. But with digital fabrication, it's the reverse: the things that are expensive in traditional manufacturing become free:

1. **Variety is free**: It costs no more to make every product different than to make them all the same.

2. **Complexity is free**: A minutely detailed product, with many fiddly little components, can be 3-D printed as cheaply as a plain block of plastic. The computer doesn't care how many calculations it has to do.

3. **Flexibility is free**: Changing a product after production has started just means changing the instruction code. The machines stay the same.

As easy as XYZ

Let's return to the 3-D printer, this miraculous machine that has so fired the imagination of futurists and machine-shop operators alike. How does it work? At its core, a 3-D printer is just a variety of three-axis CNC machine. Two computer- controlled motors move a head left and right and forward and back (the x and y axis), while another motor moves the printer tray or the platform holding the object being printed up or down (the z axis).

If you've ever looked into your desktop inkjet printer while changing a cartridge, you'll recognize many of the parts. An inkjet is a 2-D printer, which means that it only works on the x and y axis. The motor that moves the print head back and forth is just like the ones used in the 3-D printer; the inkjet just uses a roller to advance the paper along the other axis.

Overall, the concept is exactly the same: a computer translates a design into motor commands and deposits a material in exactly the right place, very quickly. The 3-D printer just does same thing with more motors and squirts more than just ink. Some 3-D printers,

such as the MakerBot, squeeze melted ABS plastic out a tiny hole to lay down materials in layers, a process called fused deposition modeling (FDM). Other, higher-end machines use lasers to harden liquid resin in a bath (known as stereolithograpy, or SLA) or harden layers of powdered plastic, metal, or ceramic, a process known as selective laser sintering (SLS).

3-D printers are an “additive” technology, which is to say that they build up objects, layer by layer, from the bottom up. By contrast, other computer-controlled machines, such as the CNC router and CNC mill, are “subtractive”; they use a spinning tool to cut or grind away material. So an additive process deposits material where the object “is”; a subtractive process takes away material where the object “isn’t.” With a 3-D printer, software first examines the CAD file for an object and figures out how to make it printable using the least amount of material and time. Take, for example, a bust of a human head.

In a sense, this is the same concept as the original Postscript printer language that started the desktop publishing movement nearly thirty years ago. It’s a way of translating from a visual language that people understand (words and typefaces in desktop publishing then, 3-D objects on a screen now) to a machine language that computers understand. Today the fabrication language is called “G-code.” Just as Postscript was originally intended to drive huge industrial printers but has now found its way to the desktop, G-code was designed for machine shops but is now used in basements.

Once the 3-D printer has finished one slice, the G-code commands the z motor to move the head up a tiny fraction of an inch, and the head traces the next slice, laying down another layer of material. And so it goes, layer by layer, all the way up the object until it is finished. In some 3-D printers, such as those that harden liquid resin, the object actually moves down into the bath as it is fabricated, so that a new layer of liquid can flow on top of the previous layer, to be hardened by the laser.

This can work on resolution as small as a few dozen nanometers, allowing the printing of structures as small as a human cell. Yet others use layers of very thin plastic sheet, with glue between each layer, and the printer head cuts out the shape in each layer. But the basic concept is always the same: build up an object in slices as thin as is physically possible. In a high- quality printer, these are practically invisible. One of the advantages of the 3-D printer that uses a laser to harden powder is that the unhardened powder, which is still densely packed in the tray, can serve as a structural support for overhanging parts of the object, which can be droopy until they cool.

When the project is done, operators take the part out and brush away the excess powder. It’s possible to do the same thing with a 3-D printer that extrudes molten plastic, but only with a second head, which deposits a layer of powder or other disposable material where a pillar must go to support some overhanging ledge at a higher layer. All these manufacturing calculations sound very fiddly, but it all happens automatically; indeed, it’s almost magical to watch. That’s the beauty of digital fabrication; you don’t need to know how the machines do their work, or how to optimize their toolpaths. Software figures all

that out. The CAD design of the object contains all the information the 3-D printer needs to figure out how to make it.

The Homebrew Printing Club

Anderson en esta seccion cuenta la historia de la fabrica MakerBots de equipos 3-D.

This all started in industrial tooling companies in the 1980s, but over the past decade the technology has spread to regular folk, just as the PC did. To see how, take the subway to an otherwise undistinguished part of Third Avenue in Brooklyn, and knock on the metal door with the big mobile-phone readable QR code on it. Wait for some stylishly disheveled young man to open it and let you in. Welcome to the Botcave. Where industrial 3-D printers tend to look like medical equipment, MakerBots tend to be personalized, decorated with dayglow letters and showered with parental love by their owners.

The one I made is black with orange lettering and blue LEDs. It looks really cool when it's running in a dark room. Out of the box, the MakerBot is a regular 3-D printer: it produces plastic parts from digital files. Want a certain gear right now? Download a design and print it out yourself. Want to modify an object you already have? Scan it, tweak the parts you want to change with the free SketchUp software from Google, and load it into the ReplicatorG app. Within minutes, you have a whole new physical object: a rip, mix, and burn of atoms.

The MakerBot is one of the simplest 3-D printers. It has just four motors: the x, y, and z, along with a fourth motor to drive the ABS plastic filment through a heater to melt it and then on the build platform to make the object. The frame of a MakerBot is laser-cut plywood, and some of its plastic pulleys are actually made by other MakerBots themselves. The electronics are based on the Arduino processor board. This is the difference between commercial industrial tools and the products of the DIY movement. The Maker gear is as much about its process of creation as it is about the product itself.

Buy one and you're not just buying a printer-you're buying a front-row seat to a cultural transformation. Open source is not just an efficient innovation method- it's a belief system as powerful as democracy or capitalism for its adherents. The philosophy in a MakerBot goes deep. It's built on several previous open source projects including the RepRap 3-D printer (a clever but more spindly design), the Arduino microprocessor board and a series of software packages that turn CAD files into instructions for the three motors that control a 3-D printer's motors.

In this case, open source means open everything: electronics, software, physical design, documentation, even the logo. Practically everything about the MakerBot was either developed by a community or given to one to do with as they please. It is a shining example of how abandoning intellectual property protection can actually grant even more protection in the form of community support and goodwill. *(Este es el delicado tema de las patentes).*

The creators were learning the realities of supply-chain management the hard way-those boxes couldn't go out until the last parts were in them, but some components hadn't arrived in time and others had arrived defective. A MakerBot has hundreds of parts, and if just one of them is missing, it can't ship. Meanwhile, the huge printer companies such as Hewlett-Packard are hovering in the wings. Right now they're just selling expensive 3-D printers to commercial customers.

But at some point, probably in the next few years, the market will be ready for a mainstream 3-D printer sold in the millions in Wal-mart and Costco. (*Yo vi uno funcionando en un Home Depot de Miami*). At that point, the incredible economies of scale that an HP or Epson can bring to bear will kick in. A 3-D printer will cost $99 and everyone will have one.

The gateway drug

3-D printers are appropriately mind-blowing, but while they evolve their way to eventually becoming proper matter compilers, the real workhorse of the Maker movement is the humble laser cutter. Go into any makerspace, and the row of laser cutters are the ones working all day, with a line waiting to use them. They're the digital tool everyone uses first, in part because they're so simple and foolproof.

Makers call them the "gateway drug" to digital fabrication. Like all the digital manufacturing tools, a laser cutter is another kind of CNC machine. In this case, the computer drives motors that move a high-powered laser around an xy plane. The laser can either burn a thin line though a sheet of material (anything from plywood and plastic to thin metal) or, by varying its intensity, burn partly through it, in a form of etching.

What makes laser cutters so popular is that they're easy to use. Rather than designing an object in 3-D, you can just create an image in a 2-D drawing program such as Adobe Illustrator. Anyone can draw in 2-D- it's what we do on paper. And if you can draw it, the laser cutter can cut it out for you. It's perfect for the kind of thing you might otherwise use a jigsaw for. They're fast, cheap and quiet-the ideal starter prototyping tool.

But just because a laser cutter works in two dimensions doesn't mean it can't make 3-D objects. Special software packages can take a 3-D object and break it out into 2-D planes, which can be cut separately, even adding little tab-and-slot elements so that they can fit together, making a strong and easy to assemble kit. If you've ever seen one of those wooden dinosaur skeleton kits, you've seen the work of a laser cutter.

More sophisticated "five-axis" industrial versions can twist and rotate the cutting head like a human hand to cut in from side angles and otherwise carve metal like the most skilled sculptor, but operating at superhuman speed. If you've bought flat-packed IKEA furniture, that was CNC'd at the factory. Your car was probably prototyped with a room-sized CNC machine, which carved the body shape out of foam. And even bigger, warehouse-sized CNC machines can carve an entire airplane fuselage out of foam, which will serve as a mold for a fiberglass body.

Reality capture

*Esta es la idea fundamental: convertir los **bits** (el lenguaje de las computadoras) en **atoms** (lo físico y tanjible), y viceversa.*

All these digital tools are ways to turn bits into atoms. But how about the reverse: turning atoms into bits? It's hard to draw 3-D objects from scratch on a screen; much easier is to just start with something that already exists and is similar to what you want, and then modify it. This process is called ***reality capture***. The idea is that you can take any object (for some reason, people always seem to start with their own heads) and scan it, creating a "point cloud" of dots that define its surface. Then other software turns that cloud of points into a mesh of polygons, just like the "wireframes" that make up the characters in computer-animated films, which can be manipulated and modified on screen.

You can buy a commercial 3-D scanner that can do this with lasers that trace over an object and cameras that capture the positions of points on its surface, but there are cheaper ways, too. Autodesk offers a free online service called 123D Catch that allows you to upload regular photographs of an object (taken from all angles) and cloud-based software will turn it into a 3-D object that you can modify and print on a 3-D printer. There's even a version that runs on the iPad.

Or you can make your own 3-D scanner with a pocket projector shining a grid pattern ("structured light") on an object, which is viewed with a high-definition webcam. Rotate the object and the webcam will capture all the sides and dimensions, extracting geometries from the way that a known light pattern is distorted when projected on the surface of the object.

Finally, there are research projects to do this with the webcam built right into your laptop or smartphone. Software running on your PC can guide you into rotating and showing different sides of the object, filling in the missing pieces in the software's internal model of it. This sort of "guided scanning" can mean that some day if you want to duplicate an object, you need only point your phone at it, following the phone's directions to move around the object and zoom in on sections, and press "print." A duplicate, perhaps even in color, will appear in your desktop 3-D printer. At that point the possibilities become clear. We can photocopy reality, or at least as closely as a Hollywood prop. And the resolution will only improve. Low-fidelity will become high-fidelity.

The next step will be to go more than skin deep, duplicating not just form but also function. We can already make the cup for the Earl Grey tea. How much longer until we can make the tea, too? The replicator awaits.

Chapter 7

Open Hardware

A market where customers help you develop your products and then pay you for them? Sure-just give away the bits and sell the atoms.

Anderson en este Capítulo explica en detalle como se forman las Comunidades de Makers.

We wanted to invent something new, but there was no way we could do that sort of thing, or anything even close to it. The kids lost interest after lunch. Okay, there was always the plane. On Sunday we took it to a park. I tossed it in the air and promptly flew it into a tree. The kids just looked at me, equally appalled by my lack of ability and the gap between my promise of how cool the plane would be (and the spectacular YouTube videos of aerobatics we'd watched) and how uncool it had actually turned out to be. I threw sticks at the plane in the tree to try to dislodge it, while my mortified children pretended not to be with me.

My geekdad weekend was a failure, and I was equally annoyed at myself for getting it so wrong and my kids for being so unappreciative. I went for a run to let off some steam. While on the run, I started thinking more about the sensors that were available for Lego Mindstorms. There were accelerometers ("tilt sensors"), electronic gyroscope sensors, a compass sensor, and a Bluetooth link that could connect to a wireless GPS sensor. They were actually pretty amazing, and it occurred to me that those were exactly the same sensors that you'd need to make an airplane autopilot.

We could kill two birds with one stone: invent something cool with Lego that had never been done before and get the robot to fly the plane! It was sure to be a better pilot than me. The moment I got home, I prototyped a Lego autopilot on the dining room table, and my nine-year-old helped write the software. We took some pictures, posted them, and it was on the front page of Slashdot by that evening. We put it in a plane-the world's first Lego UAV, I think-and took it out a few weekends later.

It almost kind a worked-it was definitely staying a loft and steering on its own, albeit not exactly where we had intended. At that point I went down the rabbit hole, and resolved to improve it until it worked as I'd dreamed, a quest that I'm still on years later. (The kids, sadly, lost interest within days, and returned to their usual staple of videogames and YouTube, both of which offer more immediate gratification). I worked on some improved versions of the Lego autopilot, eventually developing one that had most of the mission-following functionality of a professional autopilot, if not the performance (it's now in the official Lego museum in Billund, Denmark).

But it was soon clear that Lego Mindstorms, for all its charms, was not the right way to make a real autopilot: it was too big and expensive, for starters, and didn't then have a good way to work with radio-control systems. What would be a better way? I decided to conduct my search for answers online in public, sharing what I'd done and found.

But because this was 2007 and Facebook was booming, I set up DIYDrones.com as a social network (on the Ning platform), not as a blog (so 2004!). That distinction-a site created as a community, not a one-man news and information site like a blog-turned out to make all the difference. Like all good social networks, every participant, not just the creator, has access to the full range of authoring tools: along with the usual commenting,

they can compose their own blog posts, start discussions, upload videos and pictures, and create profile pages and send messages to each other.

Community members can be made moderators, to encourage good behavior and discourage bad. What this meant was that the site wasn't just about me or my ideas. Instead, it was about anyone who chose to participate. And right from the start, that was almost everyone. The site was soon full of people trading ideas and reports of their own projects and research. Initially, members would just post code and design files, trading ideas back and forth in a form of nerd braggadocio.

But over time we set up more-organized systems of collaboration, including version control systems and file repositories, wikis, mail lists, and formal team assignments. I was blown away by what I was seeing people in our community doing with sensors from mobile phones and chips that cost less than a cup of coffee; feature-by-feature they were equaling aerospace electronics that had cost millions of dollars just a decade earlier.

It felt like the future of aviation: just as the PC emerged from the Homebrew Computer Club hobbyists and eventually overturned the industrial corporate computing world in the 1980s, I could imagine that the same sort of movement could be the way that robots were introduced to our skies. We were present at the creation. If there was going to be an Apple Computer of this industry, it should be us!

My first cottage industry

I started my first aerial robot business on the proverbial dining room table. Using a blimp controller design created with a community member, I started assembling the parts necessary for a kit. I sent the circuit board design files off to be fabricated, and began hunting around for good deals on other electronics parts that I could buy in volume. Weeks of sourcing followed, with the simple rule that manufacturers should never pay retail for their materials.

Motors from China, Mylar blimp "envelopes" from a warehouse in Canada, propellers from Taiwan, a big box of custom laser-cut plastic shapes for the base, and stacks of flat-packed cardboard pizza boxes to put them in. (I also got Lego to donate a big box of gears and shafts). The first few dozen boards I hand-soldered together, before vowing to Never Do That Again. Then I advertised on Craigslist for a local student to do another hundred or so, which turned out to be more trouble than it was worth.

Finally I just did what I should have done from the start and contracted with an assembly firm to do a few hundred more properly, with automated pick-and-place machines. A big box of the finished boards arrived at my doorstep, and I spend an evening testing them and loading their software.

Finally it was time to pack the kits. We had all the components, and I bribed the kids to be my packing team. Piles of parts with Post-it notes specifying how many should go in each box spread over the dining room table and floor. For a full morning, as they filled box after box with increasing tedium, the kids knew what it was like to work in a real factory. (A

painful lesson: don't put a five-year-old on quality assurance-we had to check all those boxes again). For the community's next product, an airplane autopilot board, we decided to put things in the hands of professionals.

The one that seemed culturally matched was Sparkfun, which designs, makes, and sells electronics for the growing open-source hardware community. But, over time, our community started designing products faster than Sparkfun could adopt them, and many were too niche for Sparkfun's store. It was time to start our own factory. I started a proper company, 3D Robotics, with a partner, Jordi Muñoz (of whom much more later). As demand picked up, we outgrew the garage. Muñoz moved the operation to commercial space in an industrial park in San Diego, which was nearer the low-cost labor center of Tijuana. The toaster oven gave way to a proper automated reflow oven with a nitrogen cooling system for perfect temperature control.

And for that we needed a nitrogen generator, of course. And so it went, with more and more professional tools, which Muñoz and his team learned to use by finding tutorials on the Web. Pick-and-place robots build circuit boards, which are baked in automated reflow ovens, temperature-regulated by a nitrogen generator. Laser cutters, 3-D printers, and CNC machines make quadcopter parts. It's a real factory now, just three years after Muñoz started hand-assembling boards on his kitchen table with a soldering iron.

From Maker to millions

Because we're online, we're global from the start and tend to grow more quickly than traditional manufacturing companies because of the network effects of online word of mouth. But because we're making hardware, which costs money and takes time to make, we don't show the hockey-stick exponential growth curve of the hottest Web companies. So, as a business, we're a hybrid: the simple business model and cash-flow advantages of traditional manufacturing, with the marketing and reach advantages of a Web company.

We're still a small business, but the difference between our kind of small business and the dry cleaners and corner shops that make up the majority of micro-enterprise in the country is that we're Web-centric and global. We're competing in the international market from day one. The usual trap of focusing on the local market first with hopes of expanding internationally later leaves companies unprepared for global competition. Selling to the whole world on day one makes a company stronger. Today, two-thirds of our sales come from outside the United States.

Make a profit. Really.

Profit is always a tricky question for Web companies, since they tend to put a priority on growing traffic, and charging money gets in the way of that. But for hardware, which has inherent costs and must be paid for, charging the right price is key to building a sustainable business. One of the first mistakes budding Makers make when they start to sell their product is not charging enough. It's easy to see why, for all sorts of reasons. They want the product to be popular, and they know the lower the price, the more it will sell.

Some may even feel that if the product was created with community volunteer help, it would be unseemly to charge more than it costs. What entrepreneurs quickly learn is that they need to price their product at at least 2.3 times its cost to allow for at least one 50-percent margin for them and another 50-percent margin for their retailer (1.5×1.5 = 2.25).

That first 50-percent margin for the entrepreneur is really mostly covering the hidden costs of doing business at scale that they hadn't thought of when they first started, from the employees that they didn't think they'd have to hire to the insurance they didn't think they'd need to take out and the customer support and returns they never expected. And the 50-percent margin for the third-party retailers is just the way the retail market works. (*Most companies actually base their model on a 60-percent margin, which would lead to a 2.6x multiplier, but I'm applying a bit of a discount to capture that initial Maker altruism and growth accelerant.*)

Open design's advantage

There are open-source rockets designed to reach space, as well as open-source submarines. We have open-source watches and alarm clocks, cappuccino makers, and toaster ovens. In a sense, all these companies give away the bits and sell the atoms. All the design files, software, and other elements that can be described in digital form-the bits-are given away freely online, under a license that usually offers almost unrestricted use as long as it continues to be open and shared.

But the physical products themselves-the atoms-are sold, because they have real costs that must be recouped. Every day, we see more and more examples of open-hardware business models working brilliantly. The MakerBot 3-D printer is open hardware, as is the RepRap on which it is built. So is Arduino, and the hundreds of products from companies such as Adafruit, Seeed Studio and Sparkfun.

Today, inventors increasingly share their innovations publicly without any patent protection at all. That is what open source, Creative Commons, and all the other alternatives to traditional intellectual property protection are. Why do they do so? Because the creators believe they get back more in return than they give away: free help in developing their invention. People tend to join promising open projects, and when those projects are shared, the contributions are automatically shared, too. Inventors also get feedback as well as help in promotion, marketing, and fixing bugs.

And they accrue "social capital," a combination of attention and reputation (goodwill) that can be used at a future date to advance the inventor's interests. Any product that can build a community before launch has already proven itself in a way that few patents can match. For the companies that are built on open innovation, the advantages go beyond simple access to market.

A well-constructed "architecture of participation," to use the term coined by Tim O'Reilly, whose company runs *Maker* magazine, means that hundreds of skilled people may contribute for free, for all the incentives that have been observed in everything from open-source software to Wikipedia, from being part of something they believe in to simply

making something that serves their own needs, but choosing to share it because of the community norms.

Product documentation, marketing, and support is often done the same way, by a community of volunteers within a community. Some of the most costly functions of traditional companies can be done for free, so long as the social incentives are tuned right. It's what we do for everything at 3D Robotics, and here's why: when you release your designs on the Web, licensed so that others can use them, you build trust, community, and potentially a source of free development advice and labor.

The simple act of going open-source has provided us with an essentially free R&D operation that would have cost hundreds of thousands of dollars if we'd been closed-source and had to hire our own engineers to do the work, to say nothing of the quality of that work. Once you seed your community with content and start attracting users, your job is to give them jobs. Elevate people who seem to be constructive participants to moderator status, and give especially friendly and helpful members a "noob ninja" badge.

Once you promote/reward enough of them for doing a good job of constructive community-building, you'll find that members typically help each other, saving you the work. Finally, the tricky matter of whether to pay volunteers. I'm in favor of offering key contributors to a product a royalty, but don't be surprised if they decline. The reasons can be many: they're not in it for the money; the absolute payment amounts are tiny compared to what they make in their day job; they feelicky taking payment when others who contributed don't; and finally, when they realize that any royalty you pay will lead to higher prices for consumers, they decline simply because this conflicts with the real reason they contributed, which is to create something that can reach the largest audience possible, and higher prices mean fewer users.

But there are rewards short of simple payment that can be even more motivating, especially for top contributors, who tend to be equally accomplished in their professional life and thus often already well compensated by their day job. Here, for example, is the reward hierarchy we came up with for the DIY Drones dev teams. It ranges from the silly but effective, such as a coffee mug for a "commit" (a commit is a code contribution of any size, which may have only taken an hour or two), to reward that could have signifi cant monetary value, such stock options in 3D Robotics for top contributors.

En el libro aqui sigue un grafico sobre la "Hierachy Reward"

How to build community

When you go open-source, you're giving away something in hopes of getting back more in return. Is it guaranteed? No. You also need to build a community, ensure that the initial product is needed, documented, and distinct enough for people to want to join in its development. And even then, managing an open-source community can be a full-time job in itself. But when it works, it can be magical: an R&D model that's faster, better, and cheaper than that one of the biggest companies in the world.

When you're creating a community from scratch, consider starting it as a social network rather than as a blog or discussion group. The best new social networking tools allow you to have it all: great blogging tools, great discussion groups, profiles, personal messaging, videos, photos, and more. One of the key elements of a successful community is content of broad appeal, not just discussion forums but blog posts, photo and video sharing, and news feeds.

The Makers communities all have this, from the fantastic stream of daily blog posts of MakerBot, Sparkfun, and Adafruit to the video profi les of members on Kickstarter and Etsy. In a sense, such rich, engaging content is marketing-marketing for the community itself, but also the products that the community has created. Whether they think of it this way or not, the most successful Makers are also the best marketers.

Seen this way, all making in public is marketing. Community management is marketing. Tutorial posts are marketing. Facebook updates are marketing. E-mailing other Makers in related fields is marketing. Of course, it's not just marketing: the reason why it's so effective is that it's also providing something of value that people appreciate and pay attention to. But at the end of the day, everything you do, from the naming of your product to whose coattail you decide to ride (like we chose Arduino), is at least partly a marketing decision.

Above all, your community is your best marketing channel. Not only is that the source for the word-of-mouth and viral marketing that you'll need, but it's also a safe place to talk about your own products, as enthusiastically as you want. If you've given people a reason to gather that serves their needs and interests, crowing about your cool new gizmo isn't advertising, it's content!

Castles without walls

But how can companies built on such open-innovation grounds protect themselves from competition and even piracy? After all, part of the social compact in open innovation is to return the gift, sharing everything with the community that created it. What is their defensible advantage? Is it the brands? Many open-hardware projects share the design files of their products, but reserve their names and logos as proprietary trademarks.

Others can make the same product, but they *can't call it the same product* (at least not legally in the countries where the trademarks are registered). Is it the communities? Yes, as long as they're serving early adopters and other Makers. A Chinese company can make a clone of our products and maybe sell it cheaper, but it won't have our community, and if our community can spot the clone, they will probably decline to help those who chose not to support the "home team."

But let's be honest: our communities exist because our products are *hard to use*. They are mostly support communities, where members help each other navigate confusing and uncharted territory. Ultimately, however, the goal of open-innovation projects is to make products that are as good as or better than traditional closedinnovation products. And that

means easy to use: well designed and documented. When you go to Target to buy a toaster, you don't care if it has a community. Great products don't need great communities.

Sometimes great products speak for themselves. In those cases, the only real defensible advantage is an ecosystem. Not a community of customers, but a community of other companies and innovators who are building products that are designed to work with and support your own. Think of the tens of thousands of apps that support and reinforce Android, an open (mostly) mobile operating system.

The fact that others could copy it didn't matter, because that all that goodwill had created a network effect that was far harder to copy than simply code. But what if someone wants to rip us off anyway? Well, it depends on what you mean by "rip us off." If someone else decides to use our files, make no significant modifications or improvements, and just manufacture them and compete with us, they'll have do so much more cheaply than we can to get traction in the marketplace.

If they can do so, at the same or better quality, then that's great: the consumer wins and we can stop making that product and focus on those that add more value (we don't want to be in the commodity manufacturing business). But the reality is that this is unlikely. Our products are already very cheap, and the robots we use for manufacturing are the same ones they use in China, at the same price. There is little labor arbitrage opportunity here. And even if the products can be made cheaper, at the same quality, there is the small matter of customer support.

Our community is our competitive advantage: they provide most of the customer support, in the form of discussion forums and blog tutorials and our wiki. If you bought your board from a Chinese cloner on eBay and it's not working, the community is unlikely to help-it's seen as not supporting the team that created the product in the first place. How will people know the difference between our products and clones allowed by our open-source license? Because the clones can't use the same name. The only IP that we protect is our trademarks, so if people want to make the same boards, they'll have to call them something else.

It's a great way to maintain some commercial control while still being committed to the core principles of open source. Another core aspect of open source is that users can make the products themselves, if they want-no need to pay you for it. That's great for about 0.1 percent of the user base, and they're often the best source of new ideas and innovation around the product. But the reality is that the other 99.9 percent of users would rather pay someone to do it for them, guaranteeing that it will work. That's the core of your business.

How to get your "pirates" to work for you

Here's an example of how it works in practice: In late 2010, someone posted on the DIY Drones site that Chinese copies of our ArduPilot Mega design were for sale on Taobao, eBay, and other online marketplaces. And indeed they were: well-produced, fully functional clones. Not only that, but our English instruction manual had been translated into Chinese,

too, along with some of the software. Our community members were shocked by this blatant “piracy” and asked what we were going to do about it. Nothing, I said.

This is both expected and encouraged in open-source hardware. Software, which costs nothing to distribute, is free. Hardware, which is expensive to make, is priced at the minimum necessary to ensure the healthy growth of a sustainable business to ensure quality, support, and availability of the products, but the designs are given away free, too. All intellectual property is open, so the community can use it, improve it, make their own variants, etc.

The possibility that others would clone the products is built into the model. It’s specifically allowed by our open-source license. Ideally, people would change/improve the products (“derivative designs”) to address market needs that they perceive and we have not addressed. That’s the sort of innovation that open source is designed to promote. But if they only clone the products and sell them at lower prices, that’s okay, too. The marketplace will decide. By the way, the Arduino development boards have gone through exactly the same situation, with many Chinese cloners.

The clones were sometimes of lower quality, but even when they were good, most people continued to support the official Arduino products and the developers who created them. Today clones have a small share of the market, mostly in very price-sensitive markets such as China. And frankly, being able to reach a lower-price market is a form of innovation, too, and that is no bad thing. Personally, I’m delighted to see this development, for four reasons:

1. I think it’s great that people have translated the wiki into Chinese, which makes it accessible to more people.

2. It’s a sign of success-you only get cloned if you’re making something people want.

3. Competition is good.

4. What starts as clones may eventually become real innovation and improvements. Remember that our license requires that any derivative designs must also be open-source.

Think how great would it be if a Chinese team created a better design than ours. Then we could turn the tables and produce their design, translating the documentation into English and making them available to a market outside China. Everybody wins! (Hey, a guy can dream ;-)

When I gave community members such access, I usually asked them not to mess with the code by mistake (membership in the code development teams was more exclusive, because the danger of messing things up was higher), but in the case of Hazy I forgot. The first thing Hazy did was integrate the Chinese translation of the manual seamlessly, so users could simply click a link to switch easily between the two languages. Then it got

interesting: Hazy started fixing bugs in the code itself. The first time this happened, I assumed he'd made a mistake and pushed a wiki file into the wrong folder.

But I checked it out, and it was code and his fix was not only correct, but properly documented. Today he is one of our best dev team members. I've still never met him, but after a while I asked him a bit about himself. His real name is Xiaojiang Huang. He lives in Beijing, and by day he is a Ph.D. student in computer science at Peking University. He told me his story: When I was a kid, I was fascinated by all kinds of models, and I wished I could have an RC plane. Several years later, I was able to afford an RC helicopter when I graduated from college. I also got RC trucks and planes. Sometimes I am derided as naïve for playing with "toys," but I'm happy because it's my childhood dream.

I met ArduPilot by chance when I was surfing the Web, and was attracted by its powerful functions. Some friends of mine were also interested in it, but they felt a little inconvenient because of the English documents. So I tried to translate them into Chinese, hoping to reduce the difficulty of playing with ArduPilot for the Chinese fans. Thank you for the great work of DIY Drones, and I hope it will help more people make their dreams come true.

But when I reminded them that this was not a "pirated" version, but instead a "derivative design" fully permitted and even encouraged by our open-source license, the tenor changed. So now at least some of the "pirates" work for us. Instead of just using our technology, they're helping us to improve the technology for everyone. "Hazy" realized his dreams, and in doing so helped us realize ours, too.

Chapter 8

Reinventing the Biggest Factories of All

There's no manufacturing business like the car business. If that can be transformed

Este Capítulo se lo dedica al sector industrial mas importante, el sector automovilístico, y como los Makers han incursionado en el y como continuaran. Tambien destaca el éxito de TESLA.

The trials of a 20th- century inventor

Genius, reflashed

The Old Paradigm

With high capital intensity, current global auto manufacturers design a single model, make hundreds of thousands of copies a year, and push it through a network of dealerships. Mass Customization and the search for low- volume runs is elusive and expensive.

How We Do It Differently

We will license a lightweight, superior safety chassis that can be produced profitably at 2,000 units/year.

Not your father's DIY

How revolutionary is this? After all, DIY cars have been around for decades, and the humble dune buggy kit, with a fiberglass body on a VW bug frame modeled after the Meyers Manx design, was a fixture in the 1960s and 1970s.

Detroit West (again)

You don't have to imagine what an entire car industry built along these lines might look like-it's already here. At the former GM/Toyota NUMMI (New United Motor Manufacturing, Inc.) factory in Fremont, California, Tesla has built the most modern factory in the world. It happens to build cars, but it could build anything. It is not just automated, it's a veritable robot army. Hundreds of general-purpose KUKA robot arms do everything from metal-bending to assembly. Sometimes this comes from management techniques, but the really powerful changes come from new tools. And there is no tool more powerful than the computer itself. Rather than just driving the modern factory, the computer is becoming the model for it. Infinitely flexible and adaptable, general-purpose industrial robots can be combined to create the universal Making Machine. And like computers, they work at any scale, from the mile-long NUMMI plant to your desktop. That-not just the rise of advanced technology, but also its democratization is the real revolution.

Chapter 9

The Open Organization

To make things a new way, you need to make companies a new way, too.

Anderson en este Capítulo resalta como se emplean los trabajadores ahora, y sobre el exito del mexicano Jordis Muñoz, experto en robotica, el desarrollador de la tecnología de los drones. Y lo hizo a los 19 años. En 2012 ya era el CEO de esa empresa.

When people share a purpose and have established roles, responsibilities, and modes of communication, it's easy to make things happen. You simply turn to the person in the next cubicle and ask them to do their job. "No matter who you are, most of the smartest people work for someone else," he observed, stating what has now become to be known as "Joy's Law." His implication: for the sake of minimizing transaction costs, we don't work with the best people. Instead, we work with whomever our company was able to hire. Even for the best companies, that's a woefully inefficient process. Even though Sun thought it had the best engineers and the best technologies, there were more good people outside the company than within. The same is true today. Take even the best company you can think of, say Apple, and consider how it hires. First, it's based in the United States, and most of its employees are in Cupertino, California.

So there's a bias toward those who are already in the U.S., or can legally work in the country, as well as toward those who live in the San Francisco Bay Area or are willing to move there. (It's lovely in Cupertino, but if your spouse doesn't want to leave her family in Rome or Chang Mai, that may matter more). Like all companies, Apple favors people with

experience in the industry it's hiring for, and it likes to see degrees from good universities as an indication of intelligence and work ethic. Even though Steve Jobs was a genius teenage dropout, there aren't many others like him at Apple. The company may "think different," but these days it hires pretty much like every other good company: based on professional qualifications.

It also can only hire people who want to be hired. So that eliminates all those elsewhere who love the jobs they're already in and don't want to leave. It tends not to hire children, the elderly, and felons, regardless of how smart they may be. Nobody who can't keep a secret and doesn't want to be bound by the terms of an employment contract, and so on. Yet there are smart, even brilliant, people who fall into all those categories. By being a company, rather than an open-ended community, even Apple is subject to Joy's Law.

Communities tend to be more egalitarian, in part because they typically don't have the same legal obligations and risk as a company. They don't have to check references and get people to sign contracts before they participate, the way a company typically must. To be sure, communities can't do everything and the world's economy can't run entirely on volunteerism. But Joy's point was that labor markets are changing. With the Internet, you don't have to settle for whomever is sitting in the next cubicle. You find and tap the best person out there, even if you're in Detroit and they're in Dakar. Or, more to the point, they can find you. In open-innovation communities, participants self- select. They are drawn to cool projects and smart people, and when work is done in the open, they can find it. I learned this firsthand in my own robotics community.

A most unlikely CEO

A few months after I'd launched DIY Drones and had a few hundred members, a guy named Jordi Muñoz signed up and posted a link to a cool hack he'd done with a new open-source microprocessor board called Arduino: he'd figured out how to use it to fly a toy helicopter with a Nintendo game controller. His first forum post began this way: "English is not my first language, sorry if I made mistakes trying to describe this project. I made an autopilot for my RC helicopter with accelerometers extracted from the NunChuck of Nintendo Wii" He included some pictures of the helicopter, now augmented with circuit boards and a tangle of wires, and, shortly thereafter, a video of it actually in the air. People quickly took notice. Another poster responded with encouragement:

"Your English is very good; don't worry too much about translations; a picture is worth a thousand words, and we're excited to see [the] video. That's an excellent helicopter you put together. It's cool that people are coming up with complex ideas and getting them to work" I was impressed, too; I'd never used Arduino, but this prompted me to look more closely at it. I got in touch with him to ask some more questions about Arduino, and we started a friendly correspondence. I liked his energy and was impressed by his fearless experimentation and effortless grasp of software concepts that I had struggled to understand.

I had a feeling that he was on to something; his instincts kept leading him to more and more exciting technologies, from sensors he found and figured out how to use to algorithms he tracked down in obscure papers. Eventually, we started to do some projects together on DIY Drones-first an airplane autopilot and then an autonomous blimp controller board. We'd trade circuit-board designs back and forth and we both spent our evenings hunched over soldering irons on our respective worktables, attaching components and testing them.

He taught me how to program Arduino and the best places to buy components and get boards made. I wrote the blog posts describing our progress and documented the projects with online tutorials. Initially, we were just electronics hobbyists sharing hacks with other DIYers. That, in turn, meant starting a proper company. I asked Jordi to join me as cofounder. And when he agreed, I thought that might be a good time to ask him a bit about himself. Here's what I learned: At the time of his first posting, Jordi Muñoz Bardales (his full name), was nineteen years old. He was a native of Encinada, Mexico, and had gone to high school in Tijuana. He had just moved to Riverside, a suburb of Los Angeles. His high school girlfriend, who has dual citizenship, was pregnant, so they had recently got married.

(Aqui coloco una fotografia de Jordi, un típico latino)

He was playing with the helicopter in their Riverside apartment because he didn't have anything else to do while they waited for his green card. He had never been to college. Needless to say, none of that mattered. The only thing that mattered was what he could do, which he had already resoundingly proved. Today, Jordi is CEO of 3D Robotics Inc., a multimillion-dollar company with a state-of-the- art factory in San Diego. As I write this, he is twenty-four years old. How did this transformation happen? Three steps:

1. A smart kid who didn't happen to be born in the United States, didn't speak great English, and didn't do terribly well in school, did have access to the Internet. Because he was curious and driven, he used the greatest information resource in history to make himself one of the world's leading aerial robotics experts. He was just following his passions, but in the process he got what amounts to a "Google Ph.D."

2. When I decided, against all odds, to start a company to do aerial robotics, I did it with the smartest guy on the subject I knew. I didn't ask for a résumé. It wasn't necessary. That guy had already proven himself by making extraordinary things.

3. With a lot of support from the community, some fearlessness, and once again the power of Google research, Jordi learned the fundamentals of electronics manufacturing and manufacturing operations. He hired a smart team of mostly other twenty-somethings, a

mix of Americans and bicultural Mexican engineers from Tijuana. They did the same thing, quickly learning everything they needed to know online, both in research and asking people. Eighteen months later, they were running a world-class robotics factory.

Twenty years ago, what would have been the chances that when the editor of *Wired* magazine decided to start an aerial robotics company, he would end up partnering with a nineteen-year-old high school graduate from Tijuana? Yet today it seemed like the most natural thing. Why wouldn't you start a company with people who you were already working well with and who had already proven their mettle? As New York Times columnist Thomas Friedman puts it, "It used to be that only cheap foreign manual labor was easily available; now cheap foreign genius is easily available."

Not just cheap because they work for less money; cheap because they're often working for no money at all, as a global volunteer in a project that they believe in while some other job puts food on the table. Today our robotics company has about a hundred contributors whose work has made it into a product. About twenty of them are paid employees, mostly working on hardware engineering and manufacturing in the factory. The other eighty are volunteers working on software. The volunteers all have other jobs, ranging from an Apple engineer to a cake maker, but some of them put in what in some weeks amounts to full-time work on the robotics projects.

Some of them are professional software programmers just looking for a new challenge; others are amateurs who have made this their hobby and taught themselves what they needed to know. But we certainly would have missed the cake maker, the graphics artist working for the Brazilian ad agency, the guy who runs the Italian ambulance radio company, the retired car-dealership owner, the Spaniard working for an energy company in the Canary Islands, and all the others who followed their passions into the project, even through their careers had taken them elsewhere. In short, because we don't operate the company in a Coaseian model, we've got more and smarter people working for us. We minimize transaction costs with technology, not proximity. A social network is our common roof. Skype is the "next cubicle." Our shared purpose is really shared, not dictated.

Joy wins: The open-manufacturing model

Why turn to the person who happens to be in the next office when it's just as easy to turn to an online community member from a global marketplace of talent? Companies are full of bureaucracy, procedures, and approval processes, a structure designed to defend the integrity of the organization. Communities form around shared interests and needs, and have no more process than they require. The community exists for the project, not to support the company in which the project resides. Yet communities can't make physical good by themselves. Somebody has to do the manufacturing, handle the inventory, get the liability insurance, and run the customer support, and that takes money, a legal structure, and real day-to-day responsibilities. Thus, a company. So, in the new manufacturing model, you need a new kind of manufacturing company, too. At its core, it has to incorporate all the skills and learning of traditional manufacturing companies-tight quality

control, efficient inventory management, and supply-chain management- so that it can compete with them on basic price and quality.

But it also needs to incorporate many of the skills of Web companies in creating and harnessing a community around its products that allow it to design new goods faster, better, cheaper. In short, it must be like the best hardware companies and the best software companies. *Atoms and bits*. Thus the new industrial organizational model. It's built around "small pieces, loosely joined." Companies are smaller, virtual, and informal. Most participants are not employees. They form and re-form on the fly, driven by ability and need rather than affiliation and obligation. It doesn't matter who the best people work for; if the project is interesting enough, the best people will find it.

The open supply chain

How would an American manufacturing economy built on such principles look? On the face of it, that's a pointless question: read the daily headlines, and you'd hardly be blamed for thinking that there's no future for American manufacturing at all. After all, it's more than just that labor costs are lower elsewhere. Even more important, the ecosystem of suppliers and skills has moved abroad, too. As Garry Pisano and Willy Shih point out in a telling 2009 *Harvard Business Review* article on American competitiveness, Amazon can't make a Kindle 2 in the United States because:

1. The flex circuit connectors are made in China because the U.S. supplier base migrated to Asia.

2. The electrophoretic display is made in Taiwan because the expertise developed from producting flat-panel LCDs migrated to Asia with semiconductor manufacturing.

3. The highly polished injection-molded case is made in China because the U.S. supplier base eroded as the manufacture of toys, consumer electronics, and computers migrated to China.

4. The wireless card is made in South Korea because that country became a center for making mobile phone components and handsets.

5. The controller board is made in China because U.S. companies long ago transferred manufacture of printed circuit boards to Asia.

6. The lithium polymer battery is made in China because battery development and manufacturing migrated to China along with the development and manufacture of consumer electronics and notebook computers.

According to Pisano and Shih, only Apple "has been able to preserve a first-rate design capability in the States so far by remaining deeply involved in the selection of components, in industrial design, in software development, and in the articulation of the concept of its products and how they address users' needs." And even it still manufactures in China.That's depressing. But let's remember that the American manufacturing industry,

despite the gloom of the past few decades, is still the largest in the world (although it will soon be passed by China).

What's still being made in the United States? A combination of big things that will be sold in the country (such as cars), high-value items where the cost of labor is small compared to the price (such as airplanes), and specialty goods, where there is little commodity competition (such as medical equipment). Companies such as General Electric, Procter & Gamble, 3M, Boeing, and Lockheed Martin, and even stalwarts such as US Steel, remain among the biggest manufacturers in the world. U.S. automakers, such as Ford and GM, are staging a remarkable turnaround (thanks in part to government intervention and tough reforms). So Factory U.S.A. is still working in some industries, despite the rise of China.

What that tells us is that there's more to the geography of manufacturing than simply a race to the cheapest labor rates. Being closer to the consumer means a company's design can fit their needs better, as Apple proved. Although an iPhone says DESIGNED IN CALIFORNIA. MADE IN CHINA on the back, 2011 research by Kenneth Kraemer of the University of California, Irvine, and two other American economists found that more than half of the price of the phone stays in the United States. They write:

While these products, including most of their components, are manufactured in China, the primary benefits go to the U.S. economy as Apple continues to keep most of its product design, software development, product management, marketing and other high-wage functions in the U.S. China's role is much smaller than most casual observers would think. Add to that the increasing cost of transportation across the seas, the political risk of trade wars and tariffs and the hidden costs of delays and disruption in shipping along with the excess inventory needed to buffer that, and you can see why the Eastward migration of manufacturing may have peaked.

Can Makers make jobs?

But one thing we have not been making more of in recent years is manufacturing jobs. Even as output doubled over the past four decades, manufacturing employment fell by about 30 percent over that period. Meanwhile, the biggest creators of jobs in the American economy are small and medium-sized business-exactly what manufacturing moved away from over the previous decades as companies searched for economies of scale to compete with low-cost labor overseas. Actually, my statement above about small businesses creating jobs is not quite true. It's actually more correct to say that small businesses destroy a lot of the jobs that they create, since most small businesses fail before their third year.

What really creates jobs is small businesses that grow into larger businesses. But unlike in the first Industrial Revolution, these don't have to be industrial giants with armies of workers. And companies build on the Web-driven Maker model can do that. Why? For three reasons:

First, because most start with an open community, they have the powerful growth potential of network effects built in. The communities can not only provide a faster, better, cheaper

product-development process, but they also often offer a better, less expensive form of marketing.

Second, because these companies are built along Web lines, they're good at using the Web for everything, from finding low-cost suppliers to virtual manufacturing using service bureaus. Web-centric companies are simply better at using the best tools out there to save money and speed product development.

Finally, because they were born online, these companies are also born global. They typically serve a niche that cuts across national boarders.

As such, they are designed to be exporters from the start. They typically sell online, so they're not constrained by traditional distribution and geography. That means that they can not only grow faster, but can also fend off competition more easily-they're already competing on a global stage, so it's hard for imports to undermine them. Meanwhile, the traditional threat of competition from low-cost labor countries may not be as daunting as it once seemed.

China, for starters, is getting more expensive. Wages in the industrial provinces such as Guangdong are rising at 17 percent per year, and the creeping revaluing of the yuan only makes that worse in real terms. American workers are also up to three times more productive (not because they're necessarily more skilled or harder-working, but because they tend to be matched with more automation, which amplifies individual productivity). The Boston Consulting Group estimates that the net cost of manufacturing in China will be the same as that in the United States by 2015.

And as factory automation becomes more powerful, the labor component of the average product drops. And that means that the traditional "labor arbitrage" arguments for moving manufacturing jobs overseas will diminish. Right now, in the automotive industry, labor represents less than 15 percent of the cost of the vehicle (the United Auto Workers Union claims that's just 10 percent, but they only include assembly- line workers, not office, management, and R&D). Robots are only going to become better and more numerous: a factory job increasingly looks like a fewer number of workers making sure the robots get the components they need on time, and a shipping department. American firms can buy robots for the same price the Chinese pay. The labor-arbitrage view of global trade, a model that goes back to the dawn of the Industrial Revolution, assumes that manufacturing will always flow to low-cost countries.

But the new automation view suggests that the advantages of cheap labor are shrinking while other factors-closeness to the ultimate consumer, transportation costs (including possible carbon taxes), flexibility, quality, and reliability-are rising.

And even toymaker Wham-O is bringing back half of its Frisbee production from China, thanks to increasingly automated and efficient U.S. factories. Meanwhile, niche manufacturing companies focus on being close to their customers, offering custom or quick-turnaround goods to customers who are willing to pay for that. One of the concepts

that's taking off among regional development experts, whose job it is to attract businesses to their towns and cities, is the idea of "economic gardening"

In New York City, smaller companies still manufacture everything from envelopes (customers can easily visit the factory to inspect designs before they go on the line) to hand-crafted BMX bikes at Brooklyn Machine Works (at as much as $2,800 a frame, cheap labor is not the priority). The sorts of businesses that capitalize on being close to their market range from custom furniture, which needs close contact with customers, to high-end mattresses (build-on- demand lowers cost), to niche couture (my own office building in the hot high-tech district South of Market houses some textile factories, with immigrant Chinese workers working on locally designed clothes). That's always been the case, but now these companies aren't just local. If they're sufficiently innovative, they can sell globally, too, online.

The calculus of geography

I don't want to suggest that companies won't continue to outsource manufacturing to China or other low-cost countries. For many industries, the combination of relatively cheap labor and the concentration of suppliers that you can find in Guangdong is unbeatable. That is why no mobile phones are made in America, and why China is the toy capital of the world. And with more automation, the economic gap between manufacturing in China versus manufacturing in the United States is shrinking.

Here's a rough sense of how that "make it here" versus "make it there" calculus can look. But let's say sales continue to rise into the tens of thousands. At that point China starts to look more attractive again as a manufacturer. The 30-percent price difference between making it locally and making it in Guangdong, which was not as critical as time and flexibility at smaller scale-now is impossible to resist. This is a world where America can compete. And so can China. And Germany and Mexico and Poland. Digital manufacturing levels the global playing field. Any country can make things. The question is only what can they make better than anyone else.

A very modern factory

What they all have in common is that they're located where the entrepreneurs who started these companies wanted to live. They didn't need to locate near railway tracks or highways, the way factories once did, nor did they need lots of land and cheap labor. Nathan Siedle was an undergraduate engineering student at the University of Colorado, in Boulder, an upscale college town an hour from Denver. He was finding it difficult to locate electronic components that he needed for his projects

At that point he might have declared victory and simply finished his studies. But like many of the Makers in this book, he decided to share his discoveries instead. He set up a small Web storefront to sell the hard-to-find parts, maxing out his credit cards on inventory in the process. He called it Sparkfun, a winking reference to the frequent experience of touching the wrong parts together and watching them fry in a shower of sparks. By the time Siedle graduated, Sparkfun had grown into a real company. Rather than getting a job elsewhere,

Siedle decided to make a go of it. And since he liked Boulder, he just rented some space on the ground floor of a building in a local office park and set up shop.

Today, Sparkfun has more than 120 employees and annual revenues of around $30 million, and is growing by 50 percent a year. Daily blog posts and tutorials have turned its retail website into a high-traffic community, with more than fifty thousand visitors a day. How does Sparkfun compete with such low-cost production? With automation (the pick-and-place machines do much of the work, so its prices stay low), close ties to their customers and their needs (its hobbyist roots give it great geek cred), and a community built around its website's daily tutorials, posts by its employees (now mini-celebrities in the Maker world).

Sparkfun is proof that manufacturing success is not just about finding the cheapest labor. When you ask people about the state of American manufacturing, they often quote the same depressing statistic: despite the U.S. clout in mobile phones, including Apple's iPhone, Google's Android phones, Motorola, and others, none of those phones are made in America. We may be technology leaders, but we can only make the bits (the product concept and software), not the atoms (the physical phones themselves). "Designed in California. Made in China" indeed.

But visit the Sparkfun factory and you'll get a different view. Unlike most of its bigger electronics part supplier competitors, Sparkfun makes most of what it sells-right in Boulder. In short, electronics can be made in America, as long as they're specialty electronics, selling in the thousands, not millions. But most other electronic devices don't need the very latest, smallest, lightest, and fastest parts. Instead, they get their value from the software that runs on their commodity parts. That's the sort of thing you can do anywhere.

Economists estimate that it gets only $6.50 for the work of assembling a phone that sells for $300.40 Likewise for most of the Asian suppliers that make the components that go into an iPhone. The lion's share of the profit goes to Apple, the designer. Which business would you rather be in? Sparkfun, on the other hand, both designs and makes most of its products. And it does so in exactly the model I've described above: an open-innovation process built around a community of its customers.

At Maker festivals around the country, Sparkfun engineers teach people how to solder, which is actually a lot more fun than it may sound. Sparkfun's employees are young, passionate, and appear to totally love their jobs. Dogs and hobbies are indulged at work (although not on the production floor); tattoos and indie punk rock reflect its culture. This is a twenty-first-century American Maker manufacturing success story. It thrives in the face of Asian competition. It's growing fast and creating jobs. It is very profitable.

Equally important, it's got a great "multiplier effect." Each conventional manufacturing job is typically credited with creating four other jobs in the community. But Sparkfun, because it sells technology that helps others build their own companies, no doubt has a far higher multiplier. How high? It's hard to say, but here is one example: Facebook has about 2,500 employees as of this writing. Not just the ability to make stuff, but also the ability to invent

it, the ability to make the parts that go into it, and the ability to train the generation who will do all that.

Successful technological companies can do this. Their trickle-down effects are not measured in dry cleaners and local pizza franchises serving their workers' families, but rather in the tools they sell that make other companies around them more powerful. In other words, they are not just creating new jobs, but creating new companies that create more jobs. Sparkfun, a very modern factory, is the hub on one such new industrial commons.The question is only how far this Maker movement commons can spread. But the potential is limitless.

Chapter 10

Financing the Maker Movement

Where does Making end and Selling begin? In the new Maker Markets, it's often the same thing.

Comienza contando la historia de como un Makers comenzo una empresa relacionada con los pecesitos dorados (jellyfish), sus peceras, adornos, comidas, etc… Y como financiar los proyectos (Banks & Crowdfunding).

This meant getting into the manufacturing business at scale, which would not be cheap. Normally, at that point, an entrepreneur would seek funding. A bank loan is one method; venture capital is another. But neither is easy to get, and both come with risks and loss of control. A bank loan would probably be collateralized with whatever property Andon had, and would have to be paid back with interest, while a venture capitalist would want a sizable portion of the company.

There was, however, another way. Over the past few years, a new phenomenon of "crowdfunding" has taken off, by which supporters and potential customers collectively contribute the money necessary to get the product made. Crowdfunding may take many forms, from glorified tip jars to formal loans backed by people, not banks. The one Andon chose was Kickstarter, a website where people post descriptions of their projects and anyone can chip in to help. He set a target of $3,000. The Desktop Jellyfish Tank hit that figure in less than twenty-four hours. And then it kept going. More and more donors poured in, thanks to word of mouth and pent-up jellyfish demand. By the time the thirty days expired, Andon had raised more than $130,000 and 330 people had preordered a tank.

Underground VC

One of the reasons startups traditionally have to raise money at the start is to pay for product development, tooling, purchasing components, and manufacturing, all of which they'll presumably get back later when they sell the products. But if they can get those sales into presales, which is essentially what Kickstarter does, they'll have the money when they need it and won't have to raise venture capital or take out a loan.Second, Kickstarter turns customers into a community. By backing a project, you're doing more

than pre-buying a product. You're also betting on a team, and in turn they update you with progress reports and respond to suggestions in comments and discussion forums during the product's genesis.

Finally, Kickstarter provides perhaps the most important service a new company needs: market research. If your project doesn't hit its funding target, it probably would have failed in the marketplace anyway. All this makes perfect sense, but it just wasn't possible before the Web. What this sort of crowdfunding offers is simple: a way for the people who most want a product to help make it happen. The means of transmission themselves are prosaic: e-mail, Twitter, Facebook, other social media.

But the degrees of separation they connect are the real magic, reflecting latent knowledge about people's desires that can only be identified by the combination of the people they know and ideas that are compelling enough to pass along (what social scientists call memetic). But such investment is heavily regulated by the Securities and Exchange Commission (nationally to protect small investors) and is typically limited to accredited professional investors.

However, as Paul Spinrad pointed out in an O'Reilly analysis of the issue:

These laws were enacted to protect unsophisticated investors from fraud, but they also prevent people from investing in small businesses in their own neighborhoods, or garage ventures launched out of communities of interest that they belong to-despite the likelihood that their personal ties to such investments gives them a better basis for evaluating risk (and contributing to success) than some mass of SEC filings cooked up in an office somewhere.

And so, in the name of investor protection, the investments industry currently has a monopoly on all the invested assets of the non-millionaire public. People can't invest in the people they know from their own communities; they can only entrust their money to the choices contained in a managed menu of exclusively non-local, large-scale investment products. Although some are concerned that such equity-based funding (as opposed to the simple pre-ordering and charitable backing of Kickstarter) could lead to fraud, the hope is by having the SEC regulating the websites, rather than the companies; they can help self- regulate the industry.

And because the total amounts are small, the capacity for damage is limited. The point is to unlock an economic engine that can drive innovation, even as the traditional financial industry pulls back.As Dominic Basulto put it in a Washington Post essay, "There is a unique, underground venture capital economy happening right now in America that is, in many ways, off the radar screens of economists. When we tally up the economic indicators, the conventional wisdom seems to be that economic growth in this country has stalled.

Social capital

Let's return to the jellyfish example to see what makes this model so powerful. Consider the advantages Andon had by going the Kickstart route with his project, rather than to a bank or traditional investor:

1. He raised the money without having to pay interest or give up a portion of the company.

2. The process of raising the money also served as free market testing. If he hadn't been able to hit his target, he probably also wouldn't have been able to sell the tank.

   Raising money directly from your future customers improves the chances that you'll be successful once the product hits the market.

3. The public fund-raising effort got attention from everything from popular blogs to NBC television, serving as free marketing. Grassroots funding leads to word-of-mouth support.

Crowdfunding is venture capital for the Makers Movement. Just as the tools of production have been democratized, creating a new class of producer, so have the tools of capital-raising, creating a new class of investor. Not investors in a company but in a product, or, to be precise, the idea of a product. The act of "making in public," which is what Kickstarter project leaders do, turns product development into marketing. The creator posts an idea, then updates frequently on the progress to completion.

The backers are not only rooting for the product because they've put some money into it, but also because they feel a sense of co-ownership in its creation. Making in public is an incredibly effective form of advertising, but rather than having to pay for the promotion. What's more, it's fun. As Sarah Dopp explains at Culture Conductor, a Web community blog: Most of Kickstarter's magic mojo is simply that they made a game out of raising money. Here are the rules to that game:

1. Set a deadline. Let people know there is a limited time to this campaign.

2. Set a minimum funding goal. "If we don't reach this number, the project won't have enough funding to happen."

3. Enforce the deadline and the funding goal. The campaign STOPS at the deadline, and if you didn't meet the goal, the project Doesn't happen. (This is where Kickstarter is most valuable: they play bad cop about the rules of the game, while you get to play good cop and try to get people excited.)

4. Set up tiered levels of giving, and promise people different thank-you gifts for each level.

5. Let the fundraisers keep full ownership of their projects. (It's not investment; it's sponsorship. It's pre-selling. It's generosity.)

This is not without risk, of course. There is no guarantee that the entrepreneur will actually make the product or that it will be as good as was promised. Nor is there a promise of how long it will take. And if the entrepreneur drops the ball or simply disappears, there is no

easy mechanism for the donors to get their money back. Technically, you are making a donation to a cause. Although you have been promised that you will get a product in return, there is no binding legal agreement to ensure that.

Kickstarter, as with many of the sites like it (IndeGoGo, RocketHub, and Funded By Me, to name just a few), counts on transparency and the sophistication of Web users to access risk themselves to protect against fraud or incompetence. It advises backers to use their own judgment, but offers no protections of its own. Its advice to prospective backers:

Each project is crafted solely by its creator, and it's up to them to make the case that they can successfully bring their project to life. The Web is an excellent resource for learning about someone's prior experience. If someone has no demonstrable prior history of doing something like their project or is unwilling to share information, backers should consider that when weighing a pledge. If something sounds too good to be true, it very well may be.

But it is not. It is simply giving people an opportunity to contribute to a cause, and in this case the cause is the creation of a product they want. You're not even backing a company; you're just backing a specific project. No single person puts up more money than he or she can afford, and typically people only back products that they personally want and understand. No doubt there will be some disasters ahead. Most likely are the naïve inventors with a good idea but absolutely no competence in manufacturing who discover that they have badly underpriced their product and are unable to make it for the promised cost.

Teams may fall apart, personal issues may arise, and some people will just flake out. As of May 2012, three years after its founding, more than 47,000 projects have been launched on Kickstarter, of which more than 40 percent were successful, raising a total of $175 million. More than ten thousand of those projects were successful in meeting their pledge totals, so $60 million went to the project creators. Most were just a few thousand dollars for music, film, and other arts projects (for which Kickstarter was originally intended), but there were also hundreds of successful physical products.

Two dozen such projects, like the Jellyfish Tank, raised more than $100,000 each. Sixty days after his Kickstarter fund-raising period closed in December 2010, Wilson had shipped more than twenty thousand of the watch cases. As Carlye Adler put it in *Wired*: Build a better mousetrap and the world is supposed to beat a path to your door. It's a lovely thought, one that has inspired generations of American inventors. Reality, though, has fallen somewhat short of this promise:

Build a better mousetrap and, if you're extremely lucky, some corporation will take a look at it, send it through dozens of committees, tweak the design to make it cheaper to manufacture, and let the marketing team decide whether it can be priced to return a profit. By the time your mousetrap makes it to store shelves, it is likely to have been fine-tuned and compromised beyond recognition. Take Peter Dering, a civil engineer and an expectant father with an idea for a device called Capture that would allow you to easily clip a camera to your clothes or backpack. He, too, could have pitched his idea to a camera

accessory company. Instead, he decided to go it alone. His Kickstarter project raised $365,000 from more than five thousand backers.

This, he wrote, “transformed my life. On May 2, 2011, I launched Capture as a guy with a dream, out on a limb. Seventy-five incredible days later, I am a father with a business” Kickstarter has become the favored funding route for inventors everywhere, or at least for those who can put together a video and story that describes their vision in a way that compels people to buy into it.

The accidental bank

Kickstarter’s origins go back long before its founding in 2009. One of its cofounders, Perry Chen, was living in the French Quarter of New Orleans in 2002, working on his own electronic music and dreaming of hosting a great DJ show with the Austrian DJs Kruder and Dorfmeister. A few years later, Chen had moved to Brooklyn and was waiting tables at a hipster diner called, predictably, “Diner.” There he struck up a conversation with Yancey Strickler, a brunch regular, and started to tell him about his idea. Today, Kickstarter is multimillion-dollar Web company that’s trying as hard as it can to stick to its indie roots. Its building at 155 Rivington Street on Manhattan’s Lower East Side is nothing to look at. The biggest projects on Kickstarter, like it or not, are consumer goods. It simply fills a market need that was there all along, waiting for someone to tap it.

Voting capital

For all Kickstarter’s egalitarian charms, once a project is funded, the creator is pretty much on their own to get it actually made. As they’ll quickly discover, the idea is the easy part. That, in a nutshell, is the model of Quirky, which launched around the same time as Kickstarter in 2009 and is growing just as fast. Ben Kauffman, its founder (age twenty-four at the time of this writing), got his start in his senior year of high school, when he somehow persuaded his parents to take out a second mortgage on their house to fund the creation of mophie, a company to design and make iPod accessories.

He sold that company in 2007 and his next project was to create a website where people could vote on ideas and give suggestions on how to improve them. Although that never took off as a stand-alone site, it became the technological foundations of Quirky, which sought to combine the two ideas: using the crowd to develop better products like, well, iPod accessories. Today, to be fair, Quirky does a lot more than that. Every week it puts into production two new products invented by its community. They tend to be handy “solution” household accessories, like expanding towel racks and closet organizers, mostly under fifty dollars.

Quirky has a display rack in Bed Bath & Beyond, a big American home-products retailer.

None of this is world-changing stuff, but the products tend to be well designed, attractive, and actually useful. It’s hard to peruse the list and not find something you wouldn’t mind having. As I write this, the hot product at the moment at Quirky is the “Pivot Power” flexible power strip. It’s like a regular power strip, but each outlet can pivot so that bulky power

adapters don't block neighboring outlets. Designed by Jake Zein, a software programmer from Milwaukee, Wisconsin, it's classic Quirky: clever, clearly solving a problem, stylishly designed, and slightly inessential. It's the kind of thing you'd see in the store and think, "Yeah, I hate it when I can't fit power adapters in all the power strip outlets," admire its design, and maybe buy one. You don't need it, but once you've seen it you might want it.

This is not an accident. Quirky's products are the result of a remarkable series of public review steps, each of which weeds out bad ideas and improves good ones. Hundreds of people have had a hand in every Quirky product, either originating the idea, suggesting some change, or voting on which variation they prefer. For most of them it's just pennies, but the original inventor can earn thousands of dollars. Not millions, but not nothing. And they don't have to do much work-just describing the idea and submitting some sketches. In all, 30 percent of the sales from Quirky.com and 10 percent from retail partners goes to the community. Of that, 35 percent goes to the inventor; the rest goes to others who helped improve or select the winning design.

The way it works is this:

- Anybody can submit an idea, but it costs ten dollars to do so. This is just to keep out spammers and cranks.
- Community members vote for ideas they like, and offer comments.
- The most popular ideas go to the next phase, design. Both the inventor and Quirky's own professionals submit designs. The most popular wins.
- More voting ("influencing") happens for the product name, tagline, feature set, and other branding.
- Quirky's engineers make the winning design manufacturable and work with a factory to make it.

As at Kickstarter, there are countdown clocks and competitions everywhere-the whole thing feels like a game. You don't need to have any ideas of your own to participate and feel as though you're helping create things, or at least improve them. Partly it's the act of improving ideas, but equally it's the gamble that the product you vote for will ultimately be made and become a big hit. At the core, what the Quirky community represents is crowdsourced market research. Like Kickstarter, Quirky also uses a presale process, where products are only made if they reach a certain number of purchase commitments. (Your credit card is only charged if the product goes into production). The initial physical work is all done in Quirky's offices, which are outfitted with a high-end 3-D printer and a full suite of other digital prototyping tools, and the manufacturing is done by Quirky's factory partners, mostly in China.

The community can influence the final product, but they can't completely control it. At the end, they're just helping a professional design team work faster and better. And in turn, the design team cuts them in on a piece of the action, both in money and glory.

Industrialized crafting

Finally, at the other end of the spectrum is Etsy. This is the by far the biggest of the three Maker markets I've profiled here. Launched in 2005, it now has more than 15 million members, and did a half billion dollars' worth of sales in 2011. As of April 2012, it had 300 employees and was selling $65 million in goods per month from 875,000 sellers to 40 million visitors from around the world. Indeed, at an estimated value of $688 million after six years, its growth is spookily similar to eBay in the early 1990s-a fast-growing marketplace for the Long Tail of Things. What is being sold? Handmade goods.

That's right. So far, Etsy has just been arts and crafts on an epic scale. The range is incredible, from fine art to needlepoint, with a lot of jewelry and hipster ephemera in between. Each is made by someone (the rules of Etsy is that everything must be handmade in some way, although that doesn't mean production equipment can't be used as well). I've bought everything from cool panda stickers for my daughters' Macbook to some awesome silkscreened prints of scientists' names and symbolic images done in the style of rock-band posters that are now on the wall of my workshop. (Tesla and Bohr are my favorites.)

All around my office people have Etsy purchases: jewelry, bookends, furniture, clothes. It plays into the generational quest for individuality and authenticity-real stuff from real people, not packaged culture from companies. Etsy stuff is sometimes gorgeous and sometimes just odd (there is a whole site, called Regretsy, focused on the most comic of the head-scratchers available there), but it is always unique. If what you want is something created by a person and not just by a machine, Etsy is a gold mine. Unlike Kickstarter and Quirky, Etsy doesn't try to help Makers fund or create their products.

Instead, it's simply a way to sell them, with a strong social component that comes from its focus on handmade goods and the crafting and arts communities that make them. Like eBay, Etsy offers simple ways for sellers to create their own listings and handles the payment processing. It charges twenty cents for each listing for four months, and 3.5 percent of the sale. There is some debate as to whether Etsy really is a viable marketplace for small businesses. Its emphasis on handcrafting means that sellers are generally prohibited from scaling up with more-efficient automated production techniques or outsourcing some of the work.

It's hard to get noticed in such a huge marketplace, and the listing fees necessary to show up in search can add up. And all that competition can drive down prices. For most, this is a hobby or their art, and much of the incentive lies in finding an audience for that, even if not much money follows. But for the others, who do want to make a go of it as a business, Etsy may be a place to start, but it's not the platform for growth. For that, they need to build their own company and learn how to do real manufacturing, the twenty-first-century way.

However, with the rise of small businesses around the world, we feel hope and see real opportunities: Opportunities for us to measure success in new ways, to build local, living

economies, and most importantly, to help create a more permanent future. Right now, he noted, Etsy is still small compared to the global economy-hundreds of millions of dollars versus tens of trillions. But as Etsy expands around the world, it is bringing its model with it, from France to Germany. With its expansion comes a greater focus on growing small businesses, not just selling arts and crafts. Yet its roots remain at the human scale, with a person and face behind each product. “Don’t think of it as Etsy becoming more like the rest of the world,” Dickerson said. “Rather the rest of the world becoming more like Etsy.”

Chapter 11

Maker Businesses

What starts as a hobby can become a mini-empire.

En este Capítulo se muestran tres ejemplos de los éxitos de los Makers en los EE.UU.

All Makers who aspire to become entrepreneurs have heroes. These are people we read about who started with little more than a passion and access to tools, and then just didn’t stop. They just kept making, building, and taking chances until they had a real business. You can still see the path from the basement workbench to the marketplace, and the consequences of having been built by hand. This chapter is about three of my own Maker heroes. One, Burt Rutan and Scaled Composites, starts in the 1970s, at the beginnings of the modern DIY movement, and goes all the way to space today.

Another, BrickArms, a Lego accessory company, is a classic Long Tail business driven by passion, some cool tools, and the Web. Finally, there is Square, one of the hottest companies in Silicon Valley, which was born when a Maker craftsman and a Web visionary got together to create the ultimate hardware/software combination, one that could someday transform the financial industry.

The ambitious hobbyist

The desert town of Mojave, California, is one of those crossroads outposts you need a good reason to visit. The wind blows hard year-round, and snakes warm themselves on the roads in the morning. A few small hotels mostly house sun-baked construction workers erecting hundreds of massive wind turbines on the nearby rocky hills. There’s one bar, Mike’s, where the jukebox plays heavy metal loud, and hard men with tattoos drink beer with few words. Up there, in the thin desert air, can be found some of the most fantastic machines ever imagined. Mojave’s airport is the civilian counterpart to the nearby Edwards Air Force Base, where experimental aircraft have been punching holes in the sky since World War II and the test pilots who broke the sound barrier and reached the limits of the atmosphere became the first astronauts. Today Mojave is the home of many of America’s commercial space companies. One of them is Scaled Composites, the aviation company founded by the legendary Burt Rutan.

Past it, a mile-long row of hangars hold even more ambitious vehicles designed to rekindle an adventure with the heavens that was somehow lost between Apollo and the grinding

bureaucracy and cost of the Space Shuttle. Scaled's spinoff, The Rocket Company, is now building a fleet of launch vehicles for Virgin Galactic, Richard Branson's space tourism venture that is scheduled to begin operations in late 2012. Like everything else Scaled makes, the spacecraft are constructed almost entirely of fiberglass and carbon fiber.

It's a matter of some irritation to Burt Rutan, who retired in 2011, that the landing gear is still steel and aluminum; they are one of the last vestiges of the metal-aircraft era that Scaled was created to end (thus the Composites in its name). And, perhaps most importantly in the context of this book, they can be made by almost anyone. All you need to craft a fiberglass aircraft is a foam shape on which to lay the sheets of material, a brush to spread on the resin, and a plastic sheet to hold it down while it cures, creating a smooth surface.

What makes Scaled's story so relevant to the Maker movement is that it shows just how complex and sophisticated Maker companies and manufacturing can be. Composites, for example, are a classic Maker technology: they have democratized much of advanced aircraft manufacturing. You can lay up a wing as easily in your garage as Boeing can its its biggest factories. No special tools are required-if you've made a papier-mâché bowl, you'll understand the concept. In fact, Scaled and Rutan got their start making composite kit planes for homebuilding hobbyists, much as kit cars also use fiberglass bodies.

The same techniques that will takeFoam working and aluminum bending. The list seems endless. Although the festival is about flight, it's clear that the community is about creating things. Few of the aircraft they build will spend more time in the air than they did in the workshop. Indeed, many of them will never fly at all. The creation of a beautiful machine is the real appeal for many. This tinkerer DNA remains at the core of Scaled Composites. Many of the engineers rent space in the smaller hangars that line the runway in Mojave for their "projects," which are usually gorgeous small aircraft, from single-pilot pylon racers that can fly 500 miles per hour to half-size replicas of military aircraft from World War II.

The Long Tail of Lego

Lego, as a family-oriented company, has some rules about guns. With few exceptions, it doesn't make twentieth-century weapons. You can go farther back into history and have Lego swords and Lego catapults, but not Lego M-16 automatic rifles or rocket-propelled grenade launchers from today. That would have been the end of the story, but Chapman is a Maker. In his Redmond, Washington, basement he has a small CNC mill and he knows how to use 3-D CAD software.

So he started designing some Lego-sized modern guns. And because he could, he actually fabricated them.To do so, he first sent the files to his desktop CNC machine, a Taig 2018 mill that costs less than $1,000, to grind the mold halves out of aircraft-grade aluminum blocks. Then he put the molds in his hand-pressed injection molding machine, which uses regular propane like that for a backyard barbecue to melt plastic, and a lever like a water pump to force it into the mold. For the plastic he just used spare Lego blocks, to use the same ABS plastic as the real thing.

The ultimate combination of atoms and bits

And in that moment, he realized what the company heand Dorsey should do: revolutionize payments. And that's how he found himself at TechShop, trying to put together a little plastic block. That block held a credit card reader (which was nothing more than the magnetic head of a cassette player) that plugged into the audio jack of an iPhone. When someone swiped a card through the device, it generated an audio signal that the software in the phone could read, translate into meaningful data, and send to a website to initiate a credit card payment.

That allowed the phone to replace a bulky and expensive point-of-sale terminal. Anybody could take a credit card payment, anywhere-they just needed a phone and this little plastic reader. The company McKelvey and Dorsey started would be called Square, in part because of the shape of the little device. Unlike McKelvey and Dorsey's previous companies, Square was a combination of both hardware and software: the little phone dongle was the atoms and the phone app and Web services that worked with it were the bits.

That meant that they were in the electronics business, like it or not. This was not the way Dorsey had wanted it. He was a programmer and felt sure the problem could be solved with software alone, by using the phone's camera to read the numbers on the credit card. Easier said than done. "That actually turns out to be really hard," says McKelvey. "If you don't have the card tilted just right, it's impossible to read the characters" The two fought about it, making increasingly technical arguments about why their approach was better. There was only one way for McKelvey to settle it: "I had to build a hardware prototype to convince him that hardware was a better way."

So McKelvey went to TechShop to build a series of test credit card readers. He'd actually started a few months earlier in the student machine shop of Washington University in St. Louis, where McKelvey teaches glassblowing. But Dorsey and Square were based in San Francisco, so to win the day he had to come to Silicon Valley and finish it there. The first few Square devices were hand-cut. Then the next were made on TechShop's CNC machines, with McKelvey writing raw G-code script (rather than designing in a CAD program).

Each version got smaller, more stylish. Dorsey was convinced-hardware it would be. The plan was to give away hundreds of thousands of the Square readers and make the money back on a cut of the transaction fees, much like a credit card company. But that meant being able to make a huge number of the Square readers at a cost of less than a dollar each. They had to be practically unbreakable and foolproof. On the scale at which Square needed to operate, a mechanical or electrical problem with the readers would bankrupt the company.

The reason McKelvey was prototyping the devices himself atTechShop, even though he knew little about this kind of hardware engineering, was to get first hand experience. If the company was going to hand out millions of these gadgets, they'd better work just right.

This was going to be the consumers' gateway to their service, and the physical embodiment of the company. Today, Square has a valuation in the billions of dollars and millions of customers. It has expanded from person-to-person transactions with phones to full iPad-based point-of-sale terminals, competing with such cash-register giants as NCR.

Visa, the credit card company, is an investor, in part because it sees in Square the same sort of ambition to become a global payments platform, one as tuned for themobile age as Visa was for the plastic age. In the mornings Dorsey runs Twitter, where he has returned as CEO, and in the afternoons and very late into the evening, he runs Square. Count the hours and you can see his priorities. His wealth may be more tied up in Twitter, which is worth even more billions of dollars than Square, but his heart is in reinventing payments.

McKelvey, meanwhile, remains Square's chairman, but he spends most of his time in St. Louis. There he continues to teach and practice glassblowing. Which, as it happens, is not unrelated to his Maker moment in TechShop. Making glass this way has traditionally required industrial-sized operations, such as those that make Tiffany lamps today. But as is always the case with industrial-sized operations, you get only the sort of mainstream products that can support the economics of a factory.

Creativity was constrained by the need to sell in large numbers. But in the early 1960s, two glass artisans, Harvey Littleton and Dominick Labino, invented a formulation for low-temperature glass and a small propane-powered furnace that could properly melt it. Now it was possible for an individual to work glass with equipment that a small studio or community arts center could afford. That was the equivalent of the laser printer in the PC era, or the laser cutter and 3-D printer today. Cheaper, smaller, more powerful tools means that ever more complex activities become accessible to regular people.

Those 1960s innovations democratized the tools of production and a thriving glass art movement began, which McKelvey leads today. He was the chairman of the world's largest gathering of glass artists, has written a textbook on the craft, and runs a studio, the Third Degree Glass Factory in St Louis. McKelvey is a classic Maker who has built a business from what was once a hobby. So when he and Dorsey decided to start Square twenty years later, those same instincts drove him to DIY the hardware. That allowed Square to get to market sooner, with a better product-they were able to refine their design and understand its strengths and weaknesses faster because they had made it themselves.

Today, Square is so successful that some of the biggest financial payment companies in the world have started running attack ads trying to encourage their customers not to switch. Verisign, which makes point-of-sale credit card readers, thinks the Square method is less secure than its own. Its ads say "The glassblower stole your credit card" McKelvey loves it. It reminds him of where he came from-and the perils of big companies underestimating Makers.

Chapter 12
The Factory in the Cloud

Once manufacturing went online, nothing would be the same again.

Anderson aqui cuenta la historia de la exitosa Alibaba en China.

Mitch Free was destined to be a worker, and probably not much more. He grew up in Tyrone, Georgia, then a town of 160. His father ran a small construction business; Mitch helped out when he felt like it. He went to college for six weeks before he decided that remedial English wasn't for him, and quit. He then enrolled in a technical school for a one-year course and selected machining on a whim (electronics, which he was more interested in, was full). Once finished with that, without honors, he started work in a machine shop called Dixie Tool and Die, pressing a button on a stamping machine that made window linings for Ford vans. Sometimes he hand-polished metal.

It was 1982, he was twenty years old and married to his high-school girlfriend, and this looked like a preview of the rest of his life. Then, one day, his boss asked whether anyone on the shop floor knew anything about CAD/CAM design. The Ford Motor Company had given the shop a big contract and it required digital files. Free, who knew nothing about digital stuff, put up his hand anyway. Why? "I was getting really depressed about my career choices," he says. Also, nobody else wanted to do it.

He crammed with some technical manuals and went to Ford's operations in Dearborn to learn what the car company wanted. Then he started digitizing the machine shop's designs to comply. He got better at it. First he manually edited the machine-code files, then he learned how to program software to do it. As sometimes happens, learning to program flipped a switch in his head. He loved it. He had finally found his calling. In 1988, Northwest Airlines, which had a maintenance facility in Atlanta, recruited him to create digital copies of replacement airplane parts that the manufacturer couldn't supply, so the airline could fabricate them itself if needed.

Over time, he became the "innovation guy" at Northwest and grew more expert at digital tools, including a CNC machine he built that could automatically examine turbine blades, looking for flaws. He was taking old DC-10s out of mothball storage and fixing them up enough for a crew to take them to Israel, where they could be overhauled and resold to a leasing company for a profit of more than $10 million each. By the late 1990s he had become the airline's director of technical operations at a time when it was becoming clear that the difference between successful and unsuccessful airlines was all supply-chain management-using global suppliers to get the right part to the right place at the right time. That, in turn, made him realize that there was something bigger afoot than simply running an airline efficiently-the entire process of manufacturing was being reinvented by digital technologies.

He took an offer to run regional sales for a CNC machine company, and in the course of doing so, he started talking to more manufacturers. He discovered that what they needed more than anything else, even more than a new CNC machine, was the ability to talk to each other. So he started hosting lunches. Then, one day in 1999, driving back from a

lunch, he heard a LendingTree.com ad on the radio: “Request your mortgage. Let lenders compete for it.” He realized he should be doing the same for manufacturing. Free bought the domain “MFG.com” for $2,000 and in 2000 started an online marketplace for manufacturing.

The idea was simple: companies that wanted something made would upload their CAD files to the site, wrapped with a description of how many they wanted and any other instructions, and machine shops and other manufacturers would bid on the job, just as lenders compete for mortgages on LendingTree. Around that time, all sorts of other “business-to-business” marketplaces, with names such as Ariba, VerticalNet and CommerceOne (and lots of “e” prefixes from eMetals to eTextiles), were starting up in industries from cars to plastics. Driven by the dream of “frictionless digital capitalism,” as Bill Gates’s book, *The Road Ahead*, put it at the time, they were all going to revolutionize supply-chain management.

In February 2000, when MFG.com was starting, there were more than 2,500 such online B2B markets. Then the market crashed, and by 2004 fewer than two hundred were left. Billions of dollars of stock market value evaporated. By starting small, without the distortions of too much money and pressure, it had time to find its path. That path was simplicity. No auctions, reverse or otherwise. No group buying or order pooling. No “frictionless capitalism.” Just a place to upload files and get quotes.

Rocket science

It worked. After the dot-com crash, business started to grow nicely, and by the mid-2000s there were thousands of requests and offers placed every day. A few of them were from a small, somewhat secret group in Kent, Washington, called Blue Origin, which wanted high-tolerance parts for what appeared to be a rocket. It was, in fact, a rocket, and Blue Origin turned out to be the stealth space company started by Amazon founder Jeff Bezos. The Blue Origin engineers were so impressed by MFG.com that they brought it to Bezos’s attention, who started using the site under an assumed name to check it out.

While Bezos was secretly browsing the site, Free was negotiating to sell it to Dasault Systems, a French manufacturing technology company. Just two weeks before the deal was to close, Bezos pounced and put in a counteroffer to invest in the site and keep it in Free’s hands. Today it is the world’s largest custom manufacturing marketplace. It has more than 200,000 members in fifty countries and has brokered more than $115 billion in deals so far, with an average of $3-4 billion a month today. Forget the rhetoric-this is the raw deal flow of what companies are actually doing every day. What’s even more interesting than what’s being ordered is who’s doing it.

It’s not just big companies ordering custom parts and molds from global machine shops, but little ones, too: bike makers and furniture shops; electrical contractors and toymakers. Now companies of any size can just upload a CAD file and let the bids come to them. They get the best pricing and best products in the world without leaving their desks. Sound familiar? That’s what the first wave of e-commerce offered regular shoppers. Now we’re

seeing the eBay and Amazon effect play out in manufacturing, too. Why does it work so well now, and not a decade ago? The world just caught up. Along with a Web generation coming into management at traditional companies, the digital fabrication methods that captured Free's imagination have gone mainstream.

The main reason MFG.com can work today when so many B2B marketplaces failed a decade ago is that companies throughout the manufacturing supply chain now all use the same file formats, from CAD to electronics. This is the way all successful technological revolutions work. The Gartner Group describes this boom-bust-boom trajectory as the "Hype Cycle" of tech-driven change. After the "Peak of Inflated Expectations," there is the "Trough of Disillusionment."Then comes the "Slope of Enlightenment," finally ending up in the "Plateau of Productivity."

We've been through the first three already. Now we're enjoying the last. By the time a business process is too boring to comment on, it's probably starting to actually work. So while the rest of us are having our heads turned by the latest buzzy social media thing, sites like MFG.com are quietly going about their work of turbocharging the world's real economic engine, making stuff. You're welcome.

Open Sesame

Aqui la historia del imperio de Alibaba en China.

In 1999, while I was working in Hong Kong as *The Economist's Asia* Business editor, one of the first people I met was a hyperkinetic wisp of a man named Jack Ma, who wanted my advice on a new Web company he was setting up. Four years earlier he had taken a trip to the United States, where he'd seen his first Web browser in action. It blew his mind, as it did for many people back in the day. When he returned to his hometown of Hangzhou, he found a dial-up number for Internet access, gathered friends around, and waited three hours for the first page to load. It was thrilling.

The Web existed in China! He went on to start China Pages, which is considered China's first Internet company, and ran an early e-commerce project for China's Ministry of Foreign Trade and Economic Cooperation. When Ma came to see me, I was struck by three things. First, he was the tiniest adult male I had ever met. Not just short,but small-boned and skinny. I doubt he weighed more than eighty pounds and most of that seemed to be his head, which was probably just normal-sized but appeared huge on his frame. Second, he spoke perfect English and what weight he had seemed to be entirely brain. He was brilliant and incredibly articulate and enthusiastic about the potential of the Internet, which was not a common thing to hear from mainland Chinese nationals in those days.

Finally, in part because of his role with the Trade Ministry, what he was most excited about was not the consumer side, but the Web as a way for smaller Chinese manufacturing companies to break through the language and cultural barriers to doing business directly with foreigners. What he wanted to ask me was what I thought of the name "Alibaba." "You know," he said, "like 'open sesame" I liked it, encouraged him (although I seem to recall that I had some unhelpful advice about changing the tagline), and off he went.

Today, Ma is a billionaire. The Alibaba Group, which owns some of China's biggest Internet companies, has more than 23,000 employees. It's $1.7-billion initial public offering on the Hong Kong Stock Exchange in 2007 was the biggest tech debut since Google. As I write this, he is considering buying Yahoo! Last time we met, in New York, it appeared that he had put on some weight. He may be close to a hundred pounds now. Alibaba.com is still the core of Ma's operation. It has achieved everything he set out to do, and more. It has more than 70 million users and 10 million "storefronts," both Chinese firms and producers elsewhere.

While MFG.com was doing this with machine shops, Alibaba was extending the model to everything and everyone. I've ordered custom electric motors for a robotic blimp from a specialty motor-maker in Dongguan; I specified the shaft length, number of windings, and wire type, and ten days later prototypes were on my doorstep for my review. I was, I have to admit, stunned. I had got a Chinese factory to work for me! What else could I do with this new-found power? From a Maker perspective, the rise of Alibaba and sites like it are an enabling technology like no other.

They have essentially opened the global supply chains to buyers of all sizes, including individuals, letting them scale prototypes into full production runs. This is not just due to Alibaba; it's also coming from transformation in the Chinese economy and management culture. Chinese factories increasingly take orders online, communicate with customers by e-mail, and accept payment by credit card or PayPal, a consumer-friendly alternative to traditional bank transfers, letters of credit, and purchase orders. Ma calls this "C to B"-consumer to business. It's a new avenue of trade, and one ideally suited for the micro-entrepreneur of the DIY movement.

Over the past three years, Ma says, more than 1.1 million jobs have been created in China by companies doing e-commerce across Alibaba's platforms. This trend is playing out in many countries, but it's happening fastest in China. One reason is the same cultural dynamism that led to the rise of *shanzhai* industries. The term *shanzhai*, which derives from the Chinese word for "bandit," usually refers to the thriving business of making knockoffs of electronic products, or as Shanzai.com (the spelling of the Chinese word in English sometimes doesn't have the second "h") more generously puts it, "a vendor, who operates a business without observing the traditional rules or practices often resulting in innovative and unusual products or business models."

As he describes it, these companies fit neatly into the Institute for the Future's model for "lightweight innovation."

1. **Network your organizations**: "The bike vendors in Chongqing hang out in tea houses and shanzhai vendors in Shenzhen have a vast network centered in the large electronics malls."

2. **Reward Solution Seekers**: "Penny-a-unit profits force the shanzhai collaborations to be totally solutions-driven. They don't make money if they don't deliver. "Not invented here" is never a problem."

3. **Err on the side of openness**: “The wild west of shanzhai is all about openness. Trade secrets of big companies are flowing freely. Everything is “open sourced” by default. If we take the [intellectual property rights] issue aside, it’s really the ultimate openness we in the open source are looking for.

4. **Engage actively**: “The shanzhai vendors used to produce knock-offs after original vendors had the products on the market. But in the past year I have seen a lot of them act on the latest TechCrunch rumor, especially those related to Apple. It was kind of funny that there were several large-size iPhones (seven-inch and ten-inch) being produced by the shanzhai simply on the rumor that the iPad would look like a large iPhone.”

The rise of shanzhai business practices “suggests a new approach to economic recovery as well, one based on small companies well networked with each other,” observes Tom Igoe, a core developer of the open-source Arduino computing platform. “What happens when that approach hits the manufacturing world? We’re about to find out.”

The DIY factory

Finally, there is a third group of “factories in the cloud”: the Web-based service bureaus that do with digital fabrication tools such as laser cutters and 3-D printers what photo services such as Shutterfly do with your pictures: you simply upload files and get back fabricated objects.

They give you access to high-quality production without your having to own the tools yourself. Perhaps the best known of these are Ponoko and Shapeways. Ponoko (on whose advisory board I sit as an unpaid volunteer) started in New Zealand as a laser-cutting service, but is now global and offers laser-cutting, 3-D printing, and CNC cutting. If it’s a 3-D image, it can be 3-D printed or CNC cut in an even wider range of materials. You can design and make something as small as a ring and as large as a table, and if you’ve made a mistake in your file (which I invariably do), either the software or a human will help you fix it.

Ponoko doesn’t own most of its production machinery. Instead, it’s just a software layer between consumers and fabrication shops with spare capacity. The Ponoko website does the tricky work of coaching potentially inexperienced Makers into creating the design files and uploading them in a form that machines can understand. It recommends materials, calculates pricing, and handles the transaction. Costs are calculated based on the materials chosen and volume needed. Something the size of a toy soldier might cost fifteen dollars in plastic, while bigger metal items could run fifty dollars or more. Objects can be printed in monochrome orfull color.

Anyone can now make anything. Soon this smart fabrication software will be built right into the CAD programs themselves, such as Autodesk’s 123D. Just as you can choose “Print” from your word processor menu, you will soon be able to pick “Make” from your CAD program’s menus. What’s more, you will be able to choose whether to make “locally,” on

your own desktop fabricator if you have one (a 3-D printer, CNC machine, or laser cutter), or “globally” in the cloud using one of these services.

The software will help you choose whether to use 2-D or 3-D methods, and which materials to pick based on their properties and cost. The final barrier against entry to mass fabrication will have fallen. We will all just be a menu click away from getting factories to work for us. What do you want to make today?

Chapter 13

DIY Biology

The ultimate dream of the Fab Age is just that-the universal fabricator.

Just like the Star Trek Replicator, it’s a machine that can make almost anything on command. This idea has fired the imagination of science fiction for decades. In his novel *The Diamond Age*, Neal Stephenson imagines an entire society transformed by “matter compilers” that can make anything, rendering scarcity obsolete:

In the beginning was an empty chamber, a diamond hemisphere, glowing with dim red light. In the center of the floor slab, one could see a naked cross-section of an eight-centimeter Feed, a central vacuum pipe surrounded by a collection of smaller lines, each a bundle of microscopic conveyor belts carrying nanomechanical building blocks- individual atoms, or scores of them linked together in handy modules.

The matter compiler was a machine that sat at the terminus of a Feed and, following a program, plucked molecules from the conveyors one at a time and assembled them into more complicated structures. That’s fiction, but something similar is not impossible. MIT professor Neil Gershenfeld thinks it’s just twenty or thirty years away. How will we get there? The path, Gershenfeld argues, will not be simply making 3-D printers and other CNC machines faster and more precise.

The problem with those approaches, he says, is that they just “smoosh stuff around.” They may squirt it or cut it or heat it, but they’re just moving material or changing its state (hardening it). The material itself has no intelligence or sense of what it’s supposed to be. Your fabrication machine has to do all the work; the material isn’t “helping” Contrast that with simple Lego blocks. When a child plays with Lego, the blocks correct the child’s mistakes-they only fit together if they’re lined up right. The blocks themselves provide a coordinate system-the Lego grid. And when you’re done with the blocks, you don’t throw them away. You disassemble them and use them to build something else, making them the ultimate recyclable material.

Programmable matter

In a sense, even Lego blocks are “intelligent matter.” They carry with them their own rules of assembly and have pre-assigned functions, such as hinges and wheels. Sounds crazy? It’s not-it’s already all around you. That’s the way nature works. Crystals, after all, are

made of atoms self-assembling into incredibly complex structures, from snow flakes to diamonds.Your own body is made up of proteins assembled under the instruction of your DNA/RNA from amino acids, which themselves are made up of self-assembled atoms. Biology is the original factory.

“Intelligent materials” describes some of the basic building blocks of life. Gershenfeld’s favorite example among those are the ribosomes found in your cells. A ribosome is a protein that makes proteins-a biological machine that makes other biological machines. But as Gershenfeld sees it, it’s a model of an advanced fabricator. In your cells, genes coded in DNA are translated into RNA, a sort of mirror image. The ribosome is the “organelle” that reads the RNA and follows that code to assemble amino acids to make up specialized proteins.

Once made, those proteins automatically fold into complex shapes, driven by no more than the electrical charges and the attractive and repulsive forces that come from their atomic bonds. Those shapes, self-assembled in the billions, make up the structural elements of your body, from cell walls to bones. This is a case of a *one-dimensional code* (DNA, four chemical “letters” in different combinations, strung together in a long monodimensional chain) creating a three- dimensional object (proteins).

Because the material DNA is working with-first RNA, then ribosomes, then proteins-are not just smooshed together but instead have their own chemical and structure rules and logic, a little information can create incredible complexity. But researchers elsewhere have taken the concept even further. The most promising programmable matter is DNA itself. The new field of “structural DNA” uses the material not as a genetic code, but as the building material itself, with no biological function.

Making with DNA

Aqui el autor hace referencia a todo lo que esta detrás del DNA y como los nuevos científicos utilizaran el DIY para avanzar en explicarlo.

Just before midnight on an April Friday in 1983, Kary Mullis, a chemist with a streak of surf bum, was driving along California’s Pacific Coast Highway 128 between Cloverdale and Booneville sometime when he had an idea that would eventually win him the Nobel Prize. At that time, one of the biggest problems in genetics was that there was never enough DNA to study, and what DNA could be found was often contaminated. As he drove, Mullis was noodling over various ways to analyze mutations in DNA when he realized that he had stumbled on a way to reproduce any DNA region with the use of a special bacterial enzyme called DNA polymerase and a process of applying cycles of heat.

In combination with a version of that enzyme which was derived from bacteria called extremophiles that live in hot springs and are heat-resistant, this led to an automated process of copying DNA that created the modern genetics research industry. Called Polymerase Chain Reaction (PCR), it won Mullis the 1993 Nobel Prize in Chemistry. Biotech advocate Rob Carlson also has a version, called the LavaAmp, that he says could

be easily mass-manufactured just like any consumer product. “It doesn’t have to be a big company”

But PCR machines are only the beginning. Keegan Cooke, a former microbial fuel cell researcher, has been selling a home-built battery called a MudWatt kit. The MudWatt creates energy by capturing electrons released when mud-borne bacteria eat sugars. For just ninety dollars, the device-called a SpikerBox-does something remarkable: It records and makes audible the sound of neurons firing.

In 2009, Marzullo and Gage started a company, Backyard Brains, to sell the box. They’ve shipped over 550 kits and demo’d the device for more than six thousand people (including passengers on a Delta Airlines flight, where they stuck a sign to the bathroom door reading free neuroscience lessons at seat 33a and b). SpikerBoxes are even making their way into real science labs. W. David Stahlman, a professor of psychology at UCLA, recently purchased one to use in his research on hermit crab behavior. Traditionally, he says, psychologists don’t focus on neuroscience. Nature has created the most powerful factories of all. Who knows what can happen when we can command them, too?

Epilogue: The New Shape of the Industrial World

The West can rise again.

What kind of economic future does the rise of the Maker Movement predict? Is it one where Western countries like the United States regain their lost manufacturing might, but rather than with a few big industrial giants, they spawn thousands of smaller fi rms picking off niche markets? Remember that line from Cory Doctorow’s book:

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. Call this Option One: the commercial Web model, one defi ned by low barriers to entry, rapid innovation and intense entrepreneurship. Is this the future of manufacturing, too? Or could it even become more like Option Three: the *real* Web, where the majority of content created is by amateurs, without any intention of creating a business or making money at all? This is a future where the Maker Movement is more about selfsuffi ciency-making stuff for our own use-than it is about building businesses. It is one that hews even closer to the original ideals of the Homebrew Computing Club and *The Whole Earth Catalog*.

The idea, then, was not to create big companies, but rather to free ourselves from big companies. I wonder how long it will take before more of the world of atoms becomes free, like most of the world of bits already has. (I wrote a book about this economic model, too, which now hardly needs explaining as we are awash in free digital goods). Take, for instance, Open Source Ecology, which is an online community creating a “Global Village Construction Set.”

These are open-source designs for the fifty machines necessary to “build a small civilization with modern comforts,” ranging from a small sawmill to a micro-combine for

harvesting. This hearkens back to the Israeli kibbutz model of self-sufficiency, which was forged in a period of need and philosophical belief in collective action, or to Gandhi's model of village industrial independence in India. Of course we're not all going to grow our own food or easily give up the virtues of a well- stocked shopping mall.

But in a future where more things can be fabricated on demand, as opposed to manufactured, shipped, stored, and sold, you can see the opportunity for an industrial economy that is less driven by comercial interests and more by social ones, just as open source software already is. In this future, the pendulum of manufacturing will swing back to the most nimble developed countries, despite their relatively expensive labor. Globalization and communications flattened the world once, drawing manufacturing to low-cost labor in the developing world, a process fi rst observed in the nineteenth century by David Ricardo as the triumph of "comparative advantage."

Now we are flattening it again, but along a different dimension. Thanks to automation, labor costs are a small and shrinking fraction of the cost of making something. For electronics, they can be just a few percent. At that point, other factors, from transportation costs to time, start to matter more. For example, the 3D Robotics factory in San Diego buys its electronics manufacturing equipment and components for essentially the same price our Chinese competitors do. We pay our workers better, but the gap is shrinking: around fifteen dollars an hour in San Diego ($2,400 a month) compared with around $400 a month at Foxconn, the huge manufacturing company in China that makes the iPhone,

iPad, and electronics for many other leading companies. Because of competition, rising skills, and pressure from labor activists, the salaries in Shenzhen have risen 50 percent in the past fi ve years, while manufacturing salaries have remained close to fl at in the West. In our new 3D Robotics factory in Tijuana, twenty minutes away from our factory in San Diego, the salaries are about half the U.S. rate ($1,200 a month), which is just three times the price of China.

For one of our products, such as a $200 autopilot board, the difference in labor costs between making it in Mexico and making it in China amounts to less than a dollar, or about one percent of the product's cost (and half a percent of its retail price). Other costs, such as rent and electricity, are even closer to Chinese levels. In short, for products that can be made robotically, which is more and more of them, the usual global economic calculus of "labor arbitrage" is becoming less and less important. Even Chinese firms are moving toward more robotic production, not just to insulate firms from rising salary pressure, but also to avoid the labor condition controversies that dogged Foxconn and Apple for the past few years. Not everything can automated, of course, and there is a still a lot of handwork in your iPad. But industrial robots are getting cheaper and better all the time, while humans are getting more expensive.

So the decision on where to make things is become less about salaries. Yet China still has a sizable advantage in everything from electronics to toys and textiles, as the labels on your clothes and gadgets prove. Why? Peerless supply chains. Although we do our assembly in the United States and Mexico, the components still come from China and we

have to wait for them or stockpile more than we need at any one time, costing us money and limiting our flexibility. In Shenzhen, where all these parts are made, you can order what you need from a neighboring supplier and have it delivered in a few hours. We have to order with weeks of advance notice.

Likewise, our plastic injection molding is done in China because U.S. and Mexican companies don't have the volume to compete on price. At this point, you can start to see the shape of the twenty-first century manufacturing economy. On the product development side, the Maker Movement tilts the balance toward the cultures with the best innovation model, not the cheapest labor. Societies that have embraced "co-creation," or community-based development, win. They are unbeatable for finding and harnessing the best talent and more motivated people in any domain.

Look for those countries where the most vibrant Web communities flourish and the most innovative Web companies grow. Those are the values that predict success in any twenty-first-century market. On the manufacturing side, the spread and sophistication of automation will increasingly level the playing field between East and West, as will the growing direct and indirect costs of long and brittle supply chains. Every time the price of diesel fuel goes up, so does the price of sending a container from China.

Volcanoes in Iceland and pirates off the coast of Somalia-these are among the risk factors in a global supply chain, and are arguments for making goods closer to their point of consumption. We live in an increasingly volatile and unpredictable world, and everything from political uncertainly to currency fluctuations can erase the cost advantages of offshoring in a flash. But don't think that this means a return to the simple glory days of Detroit or a day when factory jobs were a safe path to the middle class.

Instead, it predicts that the Web model really will hold sway: a fully distributed digital marketplace where good ideas can come from anywhere and take the world by storm. Think more the rise of Angry Birds (created in Finland) and Pinterest (founded in Iowa) than more domination by the traditional manufacturing centers and companies of the twentieth century. General Motors and General Electric aren't disappearing, but then again, neither did AT&T and BT as the Web arose.

As with the Long Tail, the new era will not mark the end of the blockbuster, but the end of the *monopoly of the blockbuster*. So, too, for manufacturing. What we will see is simply more. More innovation, in more places, from more people, focused on more narrow niches. Collectively, all these new producers will reinvent the industrial economy, often with just a few thousand units at a time-but exactly the right products for an increasingly discriminating consumer. For every Foxconn with a half-million employees making mass-market goods, there will be thousands of new companies with just a few targeting niches. Together they will reshape the world of making.Welcome to the Long Tail of Things.

Appendix:

The 21st- Century Workshop

How to become a Digital Maker

Esta seccion es fundamental, para entender los mensajes del libro.

I hope at this point in the book you've been inspired enough to want to try it yourself. How to get started? The answer, of course, depends on what you want to do, and there are as many answers to that as there are people asking the question. Making can be as simple as kitchen-table crafting and as complicated as a machine shop. There are many terrific Maker resources out there to guide you including the wonderful *Make* magazine, websites such as Instructibles, and countless crafting magazines and websites.

But the theme of this book is the power of digital tools, the desktop fabrications revolution. So in this appendix, I'll give a guide to starting with that, using the best recommended tools as of this writing. Most of this is based on personal experience. I've got a little workshop in our basement, and it's outfi tted with the sorts of tools I need for projects with the kids, some robotics and electronics and generally experimenting with digital fabrication. It includes elements of those listed here, but everything in the list is something I've got some personal experience with, and can recommend.

Getting started with CAD

Why? All digital design revolves around software. Whether you're downloading designs or creating them from scratch, you'll typically need to use some sort of desktop authoring program to work with the design onscreen. Think of CAD as the word processor of fabrication. It's just a way to get your ideas onscreen and edit them. CAD programs range from the free and relatively easy Google SketchUp to complex multi- thousand-dollar packages such as Solidworks and AutoCAD used by engineers and architects.

There are also all sorts of specialty CAD programs, such as those that allow you to design printed circuit boards for electronics (such as the Cadsoft Eagle program) or even those that let you design biological molecules. But in this appendix I'll just focus on those designed to create the sort of objects that you can fabricate on a 3-D printer, CNC machine, or laser cutter. The first distinction to make is between 2-D design and 3-D design. Some desktop fabrication machines, such as simple laser cutters, just cut flat materials like a pair of scissors. That makes them 2-D machines, and as a result all you need to control them is a 2-D outline image. That's easy to create in any "vector" drawing program, such Adobe Illustrator or CorelDRAW.

Such drawing programs are similar to the simple "paint" programs that come free with Windows and the Mac, but with the difference that each line and shape is an "object" that can be independently edited at any time, moving them, stretching them, or deleting them.

When you're done, those lines will be interpreted as "toolpaths" for the laser head in the laser cutter or simple CNC router: they tell the head where to go and cut. They're easy to use and tend to involve little more than selecting standard shapes such as circles and rectangles and simply stretching and combining them to get the shape you want to cut out of sheets of plywood, plastic, or thin metal. Recommended 2-D drawing programs

- Free option: Inkscape (Windows and Mac)
- Paid option: Adobe Illustrator (Windows and Mac)

For more complex objects that will be printed on a 3-D printer or milled on a 3-axis CNC machine, you'll need a 3-D drawing program. Because you're essentially sculpting a 3-D object on a 2-D computer screen, these require a little more mental and visual gymnastics. These are the same sorts of tools used by Hollywood and the videogame industry to design computer graphic animations, but in this case you'll be making objects that can be fabricated in real materials. It's basically the same process, but you'll need to be more careful to ensure that parts that are supposed to actually touch each other do so and that there are no gaps that will confuse your 3-D printer or CNC machine (the dreaded "leaky mesh" problem).

Typically, in 3-D CAD programs you start with simply placing "geometric primitives" such as rectangles and circles on the screen and then "extruding" them, pulling them out into 3-D objects that you can then manipulate further. Combine enough such elements and you can design anything, from the most complex machinery to the human form.

Recommended 3- D drawing programs

- Free options: Google SketchUp (Windows and Mac), Autodesk 123D (Windows)
- Paid option: Solidworks (Windows and Mac)

Getting started with 3- D printing

Why? If you can imagine it, you can make it. A 3-D printer is the ultimate prototyping tool, the fastest way to turn something from from bits on the screen to atoms in your hand. But remember that the ones designed for home use are still pretty crude. The things you make may work, but they won't be pretty. Just a few years ago, 3-D printers cost tens of thousands of dollars and were only used by professionals. Now, thanks to a wave of opensource projects, starting with the RepRap printer and then the popular MakerBot, 3-D printing has fallen below $1,000 and printers are found in schools, homes and countless makerspaces.

All of the 3-D printers around $1,000 create objects with layers of melted ABS plastic, which is fed in spools of filament in varying colors. This can create a tough, flexible material, but it's limited to about half a millimeter in resolution. That can create good-looking prints, but nobody will confuse them with the smooth and seamless quality of professional 3-D printers that use lasers instead. I've recommended the MakerBot Thing-O-Matic below, which is what I currently use, but this is a fast-moving field and there will no doubt be cheaper and better options by the time you read this (some of them no doubt brought to you by MakerBot Industries).

Think of these early consumer-grade 3-D printers as the dot-matrix printers of their day: great for drafts and prototypes, but you'll still probably want to use a professional printing

service such as Shapeways or Ponoko for the final version. Recommended 3-D printing solutions:

- Printers: MakerBot Thing- O- Matic (best community), Ultimaker (bigger, faster, more expensive)
- Services: Shapeways, Ponoko

Getting started with 3-D scanning

Why? Properly set up, 3-D scanners can digitize the world faster than CAD software. One of the hardest parts of working with 3-D objects is creating them in the first place. You can jump-start that process by scanning an existing object and then modifying it in a CAD program. Such 3-D scanning is called “reality capture,” and is typically done with a special scanner or just many shots from a regular camera, all stitched together with smart software.

Professional-grade 3-D scanners cost thousands of dollars, but you can get surprisingly good results with cheap or even free products that use a digital camera if you’re careful with your lighting. The easiest option is to use a good digital camera to take lots of pictures from all angles of your object and then use the free Autodesk 123D Catch software to upload it to the cloud to be stitched together and sent back as a “point cloud,” which can be rotated and manipulated.

This works best for objects you can photograph from all sides in natural light against relatively varied backgrounds, such as a chair or even a room. For smaller objects, you’ll do better with stand-alone 3-D scanner that combines a camera with a “structured light” projector, which shines a known pattern on the object to reveal all of its ins and outs.

If you use an inexpensive webcam-based scanner such as the MakerBot one listed below, it will need a good bit of software cleanup afterward. To avoid that, you’ll need a professional scanner, and those cost thousands of dollars. A better solution if you want to scan relatively small objects and not often is to use a scanning service to whom you can send the object. Someday 3-D scanners will be as ubiquitous as the 2-D flatbed scanner that’s probably built into your current desktop all-in-one paper printer today.

But for now they’re still a somewhat fiddly technology. Capturing the image is easy enough, but using the software to clean it up so you can work with it onscreen is still something of an acquired skill. Recommended 3-D scanning solutions:

- Software: Free Autodesk 123D Catch (Windows, requires a decent digital camera)
- Hardware: MakerBot 3-D scanner (requires a webcam and pico projector). Use the free Meshlab software to clean up the image)

Getting started with laser cutting

Why? Anybody can make something cool with a laser cutter, from jewelry to a bird feeder or even furniture. If you can draw it on paper, you can make it. The easiest digital

fabrication you can do is to use a laser cutter. All you need is a 2-D drawing (see the 2-D CAD section above) or a 3-D drawing that is automatically “sliced” into 2-D layers with software such as the free Autodesk 123D Make app. The machine does all the rest of the work, tracing along that line with a high-powered laser that can cut through wood, plastic, and even thin metal.

Although laser cutting is simple to use, it’s probably the least necessary tool in a home workshop. That’s because it’s so easy to upload files to a service bureau and get them made for you cheaply in a few days. Unlike more-complex 3-D fabrication, with laser cutting it’s pretty easy to predict what you’re going to get, sight unseen, and the service bureau websites will help you choose the right material to use. Laser cutters also tend to be pretty expensive for a home workshop, with the cheapest ones that cut any decent thickness of material costing around $2,000.

And they can spew out some unpleasant fumes when they’re cutting plastic, so you’ll need a good ventilation system. All in all, I recommend that you either do your laser cutting at a local makerspace such as TechShop, or send it to a service bureau that can also source the raw material for you cheaply. Recommended laser cutting solutions:

- Service bureau: Ponoko.com
- Software: Autodesk 123- D Make (Mac only at the time of this writing, but Windows in the works)

Getting started with CNC machines

Why? They’re relatively easy to use, can fabricate in almost any material, and come in desktop versions cheaper and smaller than a laser cutter. All 3-D printers are an “additive” technology, which means that they lay down layers of some material to make an object. That means you’re typically limited to the kinds of materials that you can melt, and for low-cost printers that means plastics. If you want to make things inexpensively out of other materials, such as wood or metal, you’ll be better off with a “subtractive” technology, which means rotating grinding or cutting heads that can remove material.

So, rather than lay down material where the thing “is,” you remove material where it “isn’t” The simplest CNC machines are just a holder for a rotary power tool like a Dremel that can move in three directions (x, y, and z) on rods in response to computer control. Software on a desktop computer determines the tool paths for a 3-D object and moves the spinning power tool head accordingly. A milling bit grinds away material until just the desired object is left. More expensive ones use specialized power tool heads and bits the can grind, cut or even polish.

Unlike a laser cutter, CNC routers and mills can cut precisely in three dimensions, so they can make complex shapes with layers. The more expensive ones have four or even five axes of movement, so the head can twist around to get into nooks and crannies in the object. Beginners can use a CNC machine as they might use a manual jigsaw, precisely cutting out patterns in fl at material such as plywood. More-advanced users can extend

that to 3-D, milling more-complex objects ranging from aluminum molds for injection plastic molding to metal robot parts. Recommended CNC Solutions:

- Hobby- sized (Dremel tool): MyDIYCNC
- Semi-pro: ShopBot Desktop

Getting started with electronics

Why? A big part of the Maker Movement is making physical objects smarter-giving them sensors, making them programmable, and connecting them to the Web. This is the emerging “Internet of Things,” and it starts with simple electronics such as the Arduino physical computing board. All you really need to get started with digital electronics is an Arduino starter kit, a multimeter, and a decent soldering iron.

Depending on what you want to do, you may want to try various sensors or actuators such as servos or motors. There has never been a better time to find what you need, and companies such as Sparkfun and Adafruit offer not only all the parts you’ll need, but also tutorials, great product instructions, and large communities to help. It really is the second Golden Age of electronics tinkering! (The first being the post–World War II ham radio days that culminated in the Heathkit era in the 1970s.

Then inscrutable microchips ruined tinkering for a generation or so until open-source hardware brought it back in the last few years). If you want to take it further, you can get a digital logic analyzer, a USB oscilloscope, and a fancy solder rework station. But for starting, the items listed below will take you further than you may have thought possible. Recommended electronics gear:

- Starter kit: Adafruit budget Arduino kit
- Soldering iron: Weller WES51 solder station
- Multimeter: Sparkfun digital multimeter

Aquí pueden leer el libro: https://historyoftheuser.files.wordpress.com/2013/10/makers_-the-new-industrial-revolution-chris-anderson.pdf

Académico, Ing. Diego J. González Cruz.
e-mail: gonzalezdw@gmail.com
Teléf. +58 416 605.8299,

Caracas, 06 de marzo 2021