

# Maker Businesses

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

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 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 things 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 (Burt Rutan)

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. Not much else stays open after 10:00 p.m., although you can find a dogfight if you know whom to ask.

But look to the clouds above Mojave and none of this matters. Up there, in the thin desert air, can be found some of the most fantastic machines ever imagined. The Mojave Air and Space Port, 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. This is Right Stuff territory. Men still wear flight suits, and hangar doors open to reveal vehicles that seem conjured from the covers of sci-fi novels and the sketched imaginations of schoolboys.

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. At the entrance to the Mojave Air and Space Port is a three-story craft called the Rotary Rocket, a Scaled design that was intended to blast off like a rocket and land like a helicopter (it actually flew a short hop once). 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. The vehicles come in a pair: SpaceShipTwo, a sleek bullet of a space plane with a unique tail that pops up to a 45-degree angle on descent to slow the aircraft with a controlled

stall after it has taken its passengers to the edge of space, and WhiteKnightTwo, a 747-sized four-engine giant that carries SpaceShipTwo aloft, along with a cabin full of other passengers who will get a zero-G parabolic ride on the way back. Both are descended from SpaceShipOne and WhiteKnightOne, which won Scaled the Ansari X-Prize for the first commercial flight to space in 2004.

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 among the last vestiges of the metal-aircraft era that Scaled was created to end (thus the Composites in its name). Everything else is fiber, foam, and resin crafted to be stronger, lighter, smoother, and longer lasting than metals.

Composite aircraft have other advantages over aluminum. They can take almost any shape, which is why Scaled's aircraft seem almost *grown*, not built, with graceful organic curves and slender, tapering booms. Composites are light and tough; flexible where they need to be and rigid elsewhere. And, perhaps most important 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 in its biggest factories. No special tools are required—if you've made a papier-mâché bowl, you'll understand the concept. Through the miracle of materials science, resins and threads can transform into surfaces lighter than aluminum and stronger than steel. It takes some skill to do it right, but nothing that can't be learned over a few weekends.

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 take Virgin Galactic passengers to space began as ways to make wings and fuselages that were cheaper and easier to put together by amateurs. (Before you contemplate making one yourself, note that the average kit plane takes five thousand hours to finish, which is the equivalent of two and a half years of full-time work. Your marriage may not survive it.)

Every summer, in Oshkosh, Wisconsin, some 100,000 aviation hobbyists gather for the largest air show in the world, a festival celebrating the DIY spirit. It's run by the Experimental Aircraft Association, which is not just a community but also a Federal Aviation Administration regulatory category, which lets aircraft DIYers fly their own creations without having to go through the normal commercial certification process and flight rules. The show is a fly-in, so homebuilders from around the world fly thousands of miles in their creations to get there. There are hundreds of Rutan-designed planes, along with everything from restored World War II fighters to experimental electric-powered aircraft.

Although people come for the aerobatics and Golden Age of Flight nostalgia, the core of the event is hundreds of lectures and classes in Making. Fiberglass technique and metal machining. Painting and sanding. Foam 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. Others are pushing the innovation envelope, such as a team building an electric-powered single-pilot aircraft that they hope will set an endurance record for that class.

The Scaled engineers use the same techniques in their personal workshops as they use in their day jobs. First they design the aircraft in CAD programs onscreen. Then they either hand-carve huge foam blocks to form the shapes of the aircraft parts, or they send them to Scaled's warehouse-sized CNC machine to carve them by machine. Finally, they lay fiberglass and carbon fiber sheets over the foam and brush resins over them to harden into sheets.

By day, they make spaceships; by night, they apply their skills to their more personal dream machines. The path from hobby to industry that created Scaled in the first place remains central to its culture; scratch any Scaled engineer and you'll find a hobbyist; walk just a hundred yards from their factory and you'll find their garages.

Hobby side projects are how Scaled engineers typically advance. To become an aircraft project leader, you must have proven the ability to run an aircraft project. How do you do this the first time? By doing it yourself. Scaled engineers win the respect of their peers with their homebrew builds; constructing and flying a machine of your own design counts for more than any academic degree in winning the trust and confidence of your peers. Each of the rented hangars holds not just an avocation, but also a resume-builder, a laboratory for new ideas and a test bed for new techniques. Maintaining the link to the garage is how Scaled Composites stays ahead.

The DIY culture of Scaled Composites comes from Rutan himself. Born in 1943, his teenage years were full of self-designed model airplanes and competition victories. He figured out how to get a model plane to do a "power stall"-essentially hovering in midair by hanging on its propeller while he remotely controlled the throttle to keep it there. With this trick, he was unbeatable, able to do spot landings on model aircraft carriers and win "slowest flight" competitions with ease, as his airplane hung in the air while the seconds ticked by and the judges scratched their heads over how to handle this kid with his engineering hacks.

After a stint working in the aerospace industry on the Vietnam War-era F4 Phantom jet and some experimental hovering aircraft, he found himself drawn to the possibility that amateurs could build and fly high-performance aircraft, too. Supersonic flight had changed the shape of modern aircraft, but most civilian planes were docile and slow-flying designs that had hardly changed since the golden age of civil aviation between the World Wars. Rutan was taken by the designs of delta-wing jet fighters with "canard" wings in front rather than the usual horizontal stabilizer in the tail. The advantage of such canards is that they were designed to stall before the main wing; if the aircraft was flying too slowly or with its nose pitched up too high, the canard would lose lift first, dropping the nose and returning the aircraft to controlled flight.

Rutan launched the Rutan Aircraft Factory (RAF) and designed a series of groundbreaking amateur aircraft, starting with the VariViggin (inspired by the Swedish Viggin jet fighter) and leading to a series of Vari-Eze home-builts that revolutionized the civilian aircraft industry with their composite materials and relatively simple construction. His designs were easy to build, fast and efficient to fly, safe, and reliable. Plus they looked incredibly cool. If the golden age of civil aviation was the barnstorming years before World War II, the golden age

of the DIY aviation movement was in the late 1970s and early 1980s, when Rutan's designs brought advanced materials and aerodynamics within the reach of anyone.

Eventually, however, the economics of the DIY market proved too daunting and Rutan shut down RAF, instead focusing on Scaled Composites, the company he had started to design aircraft for commercial and military customers. The problem with the homebuilt market of the time was that companies tended to sell plans, not kits. The plans could cost as little as twenty-five dollars, but led to years of customer-support expectations from homebuilders with questions and requests for help. It was, in short, a terrible business.

Even when companies switched to selling kits instead, they ended up with all the aerospace challenges of tooling, component sourcing, and legal liability, but rather than selling hundreds of aircraft for millions of dollars each, they were selling dozens for a few tens of thousands each. It's a tiny market with huge risks. Rutan's most popular homebuilt, the Vari-Eze, sold fewer than eight hundred units in its entire life. A single Scaled Composite commercial customer could offer more profit with infinitely less hassle. As much as Rutan's roots were in the DIY movement, the economics of developing advanced designs in secret for big companies and government contracts were irresistible. Most of all, Rutan wanted to design groundbreaking aircraft, not feed the endless demands of the kit business.

Today Scaled Composites is owned by Northrop Grumman. For every high-profile design like SpaceShipOne, there is a cruise missile prototype or stealthy drone for the defense industry. The DIY roots are still there in all the side projects of the Scaled engineers in their personal hangars along the flight line at the Mojave airport. But the company itself is a high-security operation.

Rutan's career is an object lesson in both the potential and the limits of the Maker Movement. He used the democratized technology of composites to bring advanced aerospace concepts to amateurs. But the barriers to entry in manned flight, from the costs of manufacturing to the risk of lawsuits, turned out to be still too high to create a viable challenge to the existing industrial aerospace model.

Because the aircraft carry humans, they must go through endless regulatory and legal review, at great cost of money and time. That's still something only big aerospace companies can afford, which is why Scaled is now owned by one. But Rutan himself, now rich and retired, is one happy Maker.

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### The Long Tail of Lego (Will Chapman)

Turn back the clock to Rutan's origins as an enthusiast industrializing his hobby, and you've got Will Chapman today. Chapman has three sons who, like many, were obsessed with Lego until about the age of eight. Then, like a lot of boys, they started playing with toy soldiers, and Lego couldn't keep up.

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. Or you can go forward into fantasy and have Lego laser blasters and plasma cannons, but you can't have World War II machine guns and bazookas.

That's a perfectly fine policy for Lego, but the consequence is that it tends to lose its customers around the age of ten, when they go through their war phase. That included Chapman's sons. In 2006 his youngest one wanted to replicate a World War II battle in Lego and was disappointed that he couldn't do it with the Lego figures he already had.

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.

After some experimentation and revisions, he had some pretty good-looking prototypes, including an M1 infantry rifle and a sniper rifle. His son was impressed, and so he made a few more and started sharing them with other "adult fans of Lego." They started clamoring for more, and so he launched a website to sell them.

Today, his company, BrickArms, goes where the Danish toy giant fears to tread: hardcore weaponry, from Lego-scale AK-47s to frag grenades that look like they came straight out of Halo 3. The parts are more complex than the average Lego component, but they're manufactured to an equal quality and sold online to thousands of Lego fans, both kids and adults, who want to create cooler scenes than the standard kits allow.

Lego operates on an industrial scale, with a team of designers working in a highly secure campus in Billund, Denmark. Engineers model prototypes and have them fabricated in dedicated machine shops. Then, once they meet approval, they're manufactured in large injection-molding plants. Parts are created for kits, and those kits have to be play-tested, priced for mass retail, and shipped and inventoried months in advance of their sale at Target or Wal-Mart. The only parts that make it out of this process are those that will sell in the millions.

Chapman works at a different scale. He continues to design the weapons in CAD software and prototype with his desktop fabrication tools. Once they look good, he sends the file to a local toolmaker to reproduce the mold out of stainless steel, and then to a U.S.-based injection-molding company to make batches of a few thousand.

Why not have the parts made in China? He could, he says, but the result would be "molds that take much longer to produce, with slow communication times and plastic that is subpar" (read: cheap). Furthermore, he says, "if your molds are in China, who knows what happens to them when you're not using them? They could be run in secret to produce parts sold in secondary markets that you would not even know existed." Chapman's three sons package the parts, which he sells direct. Today, BrickArms also has resellers in the UK, Australia, Sweden, Canada, and Germany. The business grew so big that in 2008 he left his seventeen-year career as a software engineer; he now comfortably supports his family of five solely on Lego weapons sales. "I bring in more revenue on a slow BrickArms day than I ever did working as a software engineer."

How does Lego feel about this? Pretty good, actually. BrickArms and the many small companies like it, such as BrickForge and Brickstix, that make everything from custom Lego-sized characters to stickers that allow you to customize official Lego minifigs, represent a *complementary ecosystem* around the Danish giant. They solve two problems for Lego: First, they make products that wouldn't sell in large enough quantities for full Lego production, but nevertheless are wanted by Lego's most discriminating customers. This is the Long Tail of Lego, and such niche demand is as real in plastic building toys as it is in music and movies. The entrepreneurs orbiting around the Lego mother ship collectively fill in the gaps in the market, allowing Lego to continue focusing on the blockbusters its scale requires.

Second, by offering products that are particularly prized by older children, companies

such as BrickArms keep them in the Lego world a few years longer, from around eight or ten to perhaps twelve. This increases the chance that they will graduate from casual play to true Lego obsession, maybe even maintaining that into adulthood (don't laugh-Lego's "Architecture" series of famous building kits is sold in bookstores and museum shops for around \$100 each). If so, they may become the buyers of Lego's most elaborate kits, including a Star Wars Death Star and Star Destroyer, which both have more than three thousand pieces and cost \$400.

So Lego by and large turns a blind eye to this swarm of Lego fan-created businesses around it, as long as they don't violate Lego's trademarks and include cautions about keeping pointy or easy to toys away from young children. Indeed, Lego has even issued informal guidance on using the best plastics that are non-toxic and including holes in parts that could be a choking hazard, to allow for air passage.

What BrickArms and its kin represent are examples of Maker business targeting niche markets, which are often underserved by traditional mass manufacturing.

One of the triumphs of the twentieth-century manufacturing model was that it was optimized for scale. But this was also, at least from a twenty-first-century perspective, a liability. Henry Ford's powerful mass-production methods of standardized interchangeable parts, assembly lines, and routinized jobs created unbeatable economics and brought high-quality goods to the "common consumer. But they were also tyrannical-"any color you want as long as it's black"-and inflexible. The price differences, between small-batch and big-batch products were so great that most buyers could have either affordable products or wide choice, but not both-cheap, mass-produced products beat variety every time.

Meanwhile, the long tooling cycles of mass production meant that products had to be designed years in advance of sale, and the cost of innovation rose as the consequences of failed experimentation at mass scale rose (witness the Edsel, a radical car that set back innovation at Ford for decades). Today the same is true: the local furniture maker can compete with IKEA only by serving the rich. All those Billy bookcases out there (and I've got my share) are the marketplace saying that they don't care enough about differentiated shelving to pay more for it.

A more pernicious cost of the triumph of mass production was the decline of small-scale manufacturing. Just as in retail, where the local specialty retailer was driven out by Wal-Mart, in manufacturing, scores of car companies were overwhelmed by Detroit's Big Five (or subsumed into them) in the first half of the twentieth century. So too in textiles, ceramics, metalware, sporting equipment, and countless other industries. All succumbed to the lure of labor arbitrage abroad, while wage pressure made union relations increasingly toxic at home.

To be sure, many of these smaller manufacturers lost on their merits: their products were no better than imported goods and their costs uncompetitive. But others failed because they lost their distribution' channels to the few consumers who still wanted their specialized goods (or just wanted to buy American). The grinding race to the bottom of price competition at the big-box retailers made it increasingly hard to find niche goods.

Fast-forward a half-century, and two things have changed. First, thanks to desktop fabrication and easy access to manufacturing capacity, anyone with an idea can start a business making real things. And second, thanks to the Web, they can sell those things globally. The barriers against entry to entrepreneurship in physical goods are dropping like a stone.

"Markets of ten thousand" defines the successful niche strategy for products and services delivered online. That number is large enough to build a business on, but small enough to remain focused and avoid huge competition. It is the missing space in the mass-production industry, the dark matter in the marketplace-the Long Tail of stuff. It is also the opportunity for smaller, nimbler companies that have emerged from the very markets they serve, enabled by the new tools of democratized manufacturing to route around the old retail and production barriers.

Even better, some of those companies that start with niche markets may graduate to huge ones.

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### **The ultimate combination of atoms and bits (Jim McKelvey and Jack Dorsey)**

In early 2009, if you had visited the TechShop makerspace in Menlo Park, California, south of San Francisco, you would have seen a tall, somewhat gangly guy named Jim McKelvey at a bench, fiddling with a little block of plastic. For all anyone could tell, he was just another guy trying to learn how to use a CNC machine, albeit with a particularly unimpressive little project. What no one knew was what that little block of plastic might someday do.

McKelvey, then forty-three, was a technology entrepreneur from St. Louis. In 1990 he had started an early digital publishing company called Mira, which rose in the first multimedia wave of CD-ROMs and pre-Web online data. In those heady years in the early nineties, he and his team often gathered at a local coffee shop for brainstorming sessions. One day the coffee shop owner, Marcia Dorsey, mentioned that her son Jack was interested in computers and was looking for an internship. McKelvey agreed to meet him at the Mira offices.

At the agreed time, McKelvey was head down over his keyboard in the midst of a hellish deadline when a kid tapped him on the shoulder and said, "Hi, I'm Jack. My mom said you need some help." McKelvey looked up, surprised (he'd forgotten about the appointment), and said, "Hi. Can you wait a second while I finish this?" and returned to his work.

Thirty minutes later, McKelvey realized that he had totally forgotten about the visitor. He looked up and Dorsey was, amazingly, still standing in the exact same place, with his arms straight at his sides. He apparently hadn't moved or said a word for half an hour. This was strange, even by programmer standards.

To be fair, it was equally strange for McKelvey to have forgotten he was there. (Dorsey, in his defense, has said that he was happily entertained looking over McKelvey's shoulder and trying to find the bug in his code.) But this just means they were well matched. McKelvey's own quirks are legendary, including spending three years teaching himself to play only the notoriously difficult third movement of Beethoven's "Moonlight Sonata," which today remains the sole piano piece he knows.

McKelvey liked Dorsey's intensity and hired him on the spot. Over time they developed an easy and successful relationship, two of the smartest geeks in St. Louis, one ten years older than the other. McKelvey gradually brought Dorsey out of his shell, while Dorsey blew everyone away with his programming prowess.

Eventually, McKelvey sold Mira and decided to turn to glassblowing, an early love and something he resolved to become really expert in (more on this shortly). Dorsey, meanwhile, moved to Oakland, California, and joined a small Web startup called Odeo, which was trying to make some inroads with podcasting software.

A year passed, Apple built its own podcasting software into iTunes, and Odeo was clearly in trouble. Its founder, Evan Williams, asked the staff whether anybody had another idea for a business. Dorsey, as it happened, did-it revolved around a concept he'd sketched out a few years earlier about instant status updates. He, fellow Odeo employee Noah Glass, and Florian Weber, a contract programmer, hacked together a little proof-of-concept that let people broadcast SMS-style messages to people who signed up to "follow" them. They called it Twtr. Williams and the rest of the team liked it, shut down Odeo, and returned the money it had raised to its investors, and started a new company around the idea. They added the missing vowels and called it Twitter. The rest, as they say, is history.

Dorsey had finally hit the big time. But Williams was now running Twitter, and Dorsey wanted his own company. He struck up a conversation with his old boss, McKelvey, and they resolved to start a new company together. They had a few ideas about what it would do, probably involving mobile in some way. Dorsey, however, was forbidden from doing anything like Twitter as part of his non-compete agreement, and that eliminated a lot (as McKelvey dryly puts it, "there is a lot of surface area in Twitter's future"). So they went looking for another big problem to solve.

At that point, as McKelvey tells it, he was having trouble completing the sale of one of his glass pieces over the phone. A woman in Panama wanted to buy a glass bathroom faucet that cost more than \$20,000, and she had only an American Express card, which McKelvey couldn't take. He had a sinking feeling that because of the limitations of the credit-card industry, he was going to lose the sale. And in that moment, he realized what he and 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, each making increasingly technical arguments about why his 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 proto typing the devices himself at TechShop, even though he knew little about this kind of hardware engineering, was to get firsthand 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. Outsourcing the design and production processes to a contract manufacturer would have been cheaper and easier, but risky. How would they even know which design and manufacturer to choose if they didn't really understand their own product? The only way to ensure that was the case was to make the first devices themselves, to learn everything about them, inside and out.

"I hand-built fifty of those things. There's nothing like that," he says. "I know about azimuth errors and torsion errors. The knowledge of actually doing it, of having the machines under your control, is a huge multiplier. If you see it happen-see how the flash comes off the injection-molding-you realize it matters which way the head moves . when you pull the injection lines to deal with the shrinkage.

"If I hadn't done it myself, that knowledge would have been intermediated. We'd have had a clunky, committee-designed product. Later, more expensive, and it wouldn't have been as cool."

When it was time to go into mass production, the loyal Missourian tried first to find a suitable injection-molding company in St. Louis, but there were none that could handle the volume and pricing. So he went to China. The final design process took place in Guangdong, with McKelvey and an engineer who didn't speak English working together until 3:00 a.m. over an outdated version of the Solidworks CAD software (the Chinese factories wouldn't use any version of Solidworks after 2007, when there was an anti-piracy crackdown). The path from Maker to Industrialist was complete.

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 as tuned for the mobile age as Visa was for the plastic age. In the mornings Dorsey runs Twitter, where he has returned as executive chairman; 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.

Poignantly, Square's offices are in the former *San Francisco Chronicle* building, a symbol of twentieth-century industrial might. Once, huge printing presses ran day and night and fleets of trucks brought massive rolls of paper to be turned into newsprint. Now the newspaper is in decline, the presses are gone, and the space is being recolonized by Web and Maker companies. In another building in the complex, which was once used to store paper rolls, TechShop opened its San Francisco branch, and every day it's full of people just like McKelvey making what they hope will be the next big thing.

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.

The connection is this: glassblowing went through its own Maker moment thirty years ago. Glass artistry has required the same skills for two thousand years. High and very constant temperatures are required to keep the glass at just the right malleability, which means huge furnaces with ceramic walls that hold the heat to ensure an even distribution. Glass ovens take four days to come up to temperature and can never be turned off lest you crack their walls. You have to constantly feed them with fuel. That's why, McKelvey says, there are no forests around Venice. Venetian glassmakers used all the trees.

Making glass this way has traditionally required industrial-sized operations. 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. Cheaper, smaller, more powerful tools means that ever more complex activities become accessible to regular people and a thriving glass art movement began, which McKelvey is part of 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.