

LESSONS FROM THE

MICROMANUFACTURING

REVOLUTION

A new wave of entrepreneurs is proving you don't have to go overseas to churn out a product—or a profit. Thanks to flexible digital tooling, shared R & D spaces, and crowdsourced funding, it's easier than ever to turn a good little idea into the next big thing.

by **Steven LECKART**

photographs by **Joe PUGLIESE**



DODOCASE

1 CRAIG DALTON,

PATRICK BUCKLEY, MARK MANNING

The founders of this iPad-cover company started by cutting bamboo frames on CNC machines at TechShop in San Francisco. Now they have a 10,000-foot factory in the Dogpatch district.



“This!” shouts Patrick Buckley, “is the Big! Robot! Room!”

Buckley is whisking me through the 10,000-square-foot factory his company, DODOcase, operates in an industrial area of San Francisco. We’ve stopped to admire the 32-year-old CEO’s “Ferrari.” It’s not an Italian sports car, but a very loud programmable CNC router with about the same footprint, and half the price tag. Right now the \$98,000, red-and-white SCM Pratih Z2 is cutting precision details into 18 bamboo frames held in place by a vacuum-sealed jig. Ultimately, each 8 x 10-inch rectangle will be glued into a handmade book cover. The final product: a \$60 iPad case.

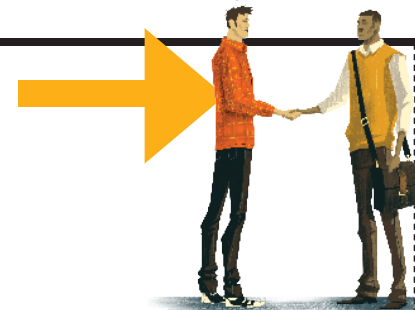
Resembling a Moleskine notebook, the DODOcase has exploded in popularity since debuting alongside the iPad in April 2010. Within a month, orders spiked from 10 to 900 a day. Retailers like J. Crew carry them, and President Obama keeps one on his desk.

DODOcase hasn’t always had a big robot room. Or its own bookbindery. Or 25 full-time employees. When Buckley and co-founders Craig Dalton and Mark Manning started the company, it seemed more like a hobby than an assembly

line. They cut bamboo on routers at the DIY hackerspace, TechShop, outsourced covers to a local bookbinder, and assembled the cases in Buckley’s basement. Three years later, DODOcase has grown into a model of success for a new breed of small-scale manufacturers.

They’re not alone. Manufacturing used to require lots of capital and scale. But new technology is making it easier, faster, and cheaper to transform an idea into a business. Free, easy-to-use computer-aided design (CAD) programs and inexpensive 3D printers help entrepreneurs prototype quickly. Shared R & D spaces such as NextFab and TechShop give anyone access to expensive tools for around \$100 a month. And crowdfunding websites such as Kickstarter let innovators raise capital quickly while maintaining control of their companies.

Starting a business still takes plenty of sweat equity and a bit of luck. But if you want to graduate from spare-time tinkerer to full-time manufacturer, there has never been a better time to do it. Here are five essential strategies for getting started.



Lesson 1 Build Connections.

Manufacturing hasn’t always been a welcoming industry for small-batch entrepreneurs. Equipment and resources were most available to companies that produce hundreds of thousands of products, leaving the little guy on his own. The rise of shared workspaces for innovators is changing that.

In 1997 Edmund Villarreal began crafting magnesium fire starters on his apartment balcony in Euless, Texas. Featuring a compass and thermometer integrated into a wooden handle, the screwdriver-size All-Weather Firestarter wasn’t all that complicated to produce. He had his own magnesium cutter and band saw. But it was time-consuming. At best, Villarreal could crank out one



2 GEORGE YU

VARIABLE TECHNOLOGIES



Yu, an electrical engineer by trade, kept costs down by learning how circuit boards are manufactured and then designing an easy-to-assemble board for his invention, NODE sensor.

Firestarter every 20 to 30 minutes. After a decade of doing odd jobs during the day and manufacturing at night, he had managed to sell a respectable 20,000 units, but he was maxed out.

“I needed to manufacture these things on a bigger scale, but I just didn’t know how,” he says. In 2009, after moving to Raleigh, N.C., Villarreal posted an ad on Craigslist, hoping to find an out-of-work engineer to cut his magnesium. He scored one—and more. The engineer turned out to be a member of TechShop.

Villarreal joined TechShop, too, and other members soon offered helpful tips: Don’t swap out bits every time you drill a countersinker. Try a bit with an integrated countersink! Don’t polish and cut the magnesium one piece at a time. Automate!

Villarreal gained instant access to high-end equipment and skilled workers. “I’m learning how to work smarter, not harder,” he says. Today, whenever he gets an order, he hires an *ad hoc* team of four part-time engineers to set up and run a custom line at TechShop. The guy who programs the ShopBot PRSalpha router gets \$50 an hour, but it’s worth the money. The team produces one Firestarter every 10 minutes. Sales have picked up too. In 2012 Villarreal sold 6000 Firestarters.



3 CHRIS ANDERSON

3D ROBOTICS



Anderson quit his job as editor-in-chief of *Wired* magazine in 2012 to focus on his startup, which makes flying drones such as this ArduCopter 3DR Quad D.

Lesson 2

Keep Inventory Lean.



Matching supply to demand is the most critical balancing act in business. Ramping up production requires investments in equipment, materials, and staff. For companies that are just getting off the ground, gauging demand often amounts to a lot of guesswork.

The fund-raising website Kickstarter fundamentally flips that equation, with small investors promising money up front for early access to goods that haven't been produced yet. It's a transformative idea, and it's launched a lot of little companies into the big time faster than they expected. Last spring the smart watch start-up Pebble started a campaign on the site to raise \$100,000 but raised 100 times that amount. The company suddenly had an obligation to produce 85,000 smart watches. So instead of continuing in its small factory in San Jose, Calif., where the team had made its batch of 1500 samples, the founders turned to Dragon Innovation, a firm that helps companies outsource manufacturing to Asia.

But an initial flood of orders doesn't guarantee long-term success. In 2011 Dave Petrillo and his partner started a Kickstarter campaign for Coffee Joulies, stainless steel beans filled with a phase-change material to keep coffee at a desired temperature. They planned to raise \$9500 to cover half the initial cost of tooling, but the company ended up with \$306,944. That's when they decided to set up manufacturing in a 110-year-old silverware plant in Sherrill, New York. Six months later the company had filled the 4818 Kickstarter orders. But then it hit a speed bump.

After the holidays demand slowed but the factory didn't—soon the company had a backlog of 32,000 unsold units. “Just when we got into a comfortable work pace, we had to stop. We underestimated the seasonality of our product,” Petrillo says. Good PR saved the day—after a January 2013 appearance on the ABC show *Shark Tank*, sales boomed, and now Joulies are on back order.

The perfect balance, according to DODOcase's Buckley, is producing on demand. “We control the manufacturing process. We can turn our machines on and off whenever we want,” he says. “We won't ever have more than two weeks of inventory.”



Lesson 3

Get Parts-Savvy.

Even the leanest production process relies upon a supply chain of parts and materials. Before the Internet, finding reliable suppliers could take years of relationship building. Now it takes seconds. Websites such as MFG.com automate the search for manufacturers and suppliers, and build in quality control with user reviews and a five-star rating system.

The supplier culture is changing too. Entrenched vendors are more willing to work with startups. The runs may be small, and

there's no guarantee that the products will lead to further orders, but vendors often have no choice. Many big manufacturers have cut back since the economic downturn, and factories are seeking to make up the loss of big orders with many smaller projects. The result is the growth of an ecosystem that lives and breathes small batches.

“Finding vendors for this project has been easier than anything I've ever worked on,” says Ben Cohen, who founded a bicycle-headlight company called Blink/Steady in Brooklyn, N.Y., with two robotics engineers who formerly had freelanced for NASA. “The old guard is stepping back, and the younger people at these companies are willing to work with you.”

In July Blink/Steady filled the first orders of its \$95 (now \$125) bicycle headlight, a multisensor device that automatically turns on when the bicycle is in motion or it's dark outside. The product is constructed with a sleek aluminum body (anodized in Pittsburgh) that's been laser-etched (in Walingford, Conn.), outfitted with a waterproof O-ring (fabricated in Lancaster, N.Y.), and stocked with a circuit board (assembled in San Jose, Calif., and programmed in Brooklyn, N.Y.).

Knowing how your parts are designed is just as important as knowing where to get them—especially when it comes to electronics. George Yu is the CEO of Variable Technologies, a startup in Chattanooga, Tenn., that makes a wireless iPhone accessory called NODE. “The whole world of circuit-board assembly is a little mysterious to small-batch creators,” he says. “Vendors are not geared toward amateurs or beginners at all.”

NODE, which packs together sensors for measuring data such as light, motion, and temperature, is only 3 inches long, so the circuit

board had to be designed tightly. Yu had earned a Ph.D. in electrical engineering from Georgia Tech, but he had no clue how circuit boards are mass-produced. So he spent days watching videos of circuit-board pick-and-place machines on YouTube and scouring websites for written information. He arrived at two ahas: 1) pick-and-place machines employ different-size nozzles to pick up parts, and 2) those nozzles are changed manually.

Therefore, Yu realized, if he designed every part and resistor on his circuit board to be roughly the same size, there would be no need to change nozzles. Ultimately, that insight streamlined the process of manufacturing NODE, saving Yu time, effort, and money.

Lesson 4

If America Can Build It, Build It in America.

Your heart says build in the U.S.A., while the economics of international labor markets say build in China. But as Dave Petrillo and David Jackson discovered when they decided to make Coffee Joulies—domestically, the logistics of small-batch manufacturing are more complicated than that.

“Our decision wasn’t patriotic, as nice as that would sound,” Petrillo says. “But manufacturing in the U.S. can be an asset.” There’s no language barrier. No 12- to 15-hour time change to contend with. And no international airline tickets to eat into your budget. Whether you’re in Asia or Arkansas, setting up a new manufacturing line requires a lot of trial and error. Then comes more back-and-forth once production begins. Long distances and time-

zone changes can clog up the process.

Scott Miller, the CEO of Dragon Innovation, is an expert in offshore outsourcing, but even he tells many small startups not to produce in Asia. He points out that many factories in China impose a “magic number” threshold that small companies can’t meet. Volume producers may require a minimum order quantity (MOQ) of 5000. Even if your small batch meets that number, do the math to make sure you’re really coming out ahead by outsourcing abroad: Miller assembles a decision matrix weighing factors such as margins, labor rates, and the price of components.

Products that have to ramp up quickly, such as Pebble, may need to take advantage of the massive manufacturing capabilities in Asia. Likewise, products that require a lot of manual labor are cheaper to make in China—but that may not be true for long. In 2001 the average manufacturing wage there was \$0.58 an hour. Today it’s closer to \$3 an hour. The Boston Consulting Group predicts that there may be no economic advantage to producing

Launch a Startup in 7 Easy Steps!

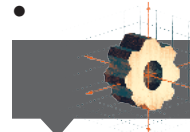
by The Editors

With the right tools and technology, a smart guy like you can design, prototype, and manufacture the product of your dreams. Just follow this plan for success!

illustrations by Orlin Culture Shop

OPEN THE FOLDOUT

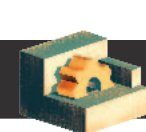
Step 1



DESIGN

The first step is to perfect your world-changing widget. Computer-aided design (CAD) software used to be pricey and hard to use, but new tools such as Autodesk 123D Design, Blender, Google Sketchup, and Tinkercad make designing virtual 3D objects easy. Or build your widget by hand, and use Autodesk’s 123D Catch to convert digital images of it into a CAD file.

Step 2



Prototyping

Good job! You’ve figured out the basic shape of your widget. Now it’s time to build a prototype to test and show off to investors. You can do it the old-fashioned way—in your basement with X-ACTO knives and glue—or you can take advantage of a wealth of new resources and tools. Desktop 3D printers, laser cutters, and CNC routers can whip out precision parts—and they have gotten cheap enough for ordinary citizens to own. If you’d rather not spend your seed money on equipment, you can send away your CAD files to Shapeways’ 3D printing service, or join a maker collective such as TechShop or NextFab for access to any tool you can think of for less than \$125 per month.

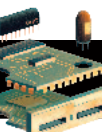
Step 3



FINANCING

To turn your prototype into a product for the masses, you need a healthy injection of startup cash. That used to mean handing over a stake in your company to venture capitalists, but the crowdsourcing site Kickstarter lets you fund up while maintaining full ownership. You can lure potential investors with a sliding scale of incentives, promising backers anything from karmic satisfaction to discounts on your first batch of products.

Step 4



Sourcing

Online ordering has democratized the sourcing of parts and materials. Vendors such as Grainger and MSC Direct will sell you stainless steel, aluminum, and brass by the bar or by the truckload. Thanks to the ubiquity of the smartphone, electronics parts such as accelerometers and GPS antennas are now cheap. Buy them piecemeal or in volume from suppliers such as DigiKey and Sparkfun.

Step 5



STAFFING

Even with today’s high unemployment, finding skilled workers is a challenge. Try starting your business at a hacker-space with like-minded tinkerers to help you fill key positions. Big staffing companies such as SimplyHired and Kelly Services can help fill temporary positions. Or you can farm out tasks to an elastic army of freelancers using Elance for digital tasks (programming, writing, data entry) and TaskRabbit for random day work (office and event help, cleaning).

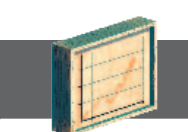
Step 6



Manufacturing

People love your widget! Now that orders have skyrocketed, demand can quickly outpace the production capacity of your living-room assembly line. That’s a good problem to have, but ramp up in a hurry or you risk alienating customers. If you’re looking to set up your own factory, you can search for industrial spaces through Showcase.com, and find used industrial equipment on Biditup.com. Or you can seek out a contract manufacturer anywhere in the world using MFG.com. The site can help you find an electronics plant in Mexico or a metal fabrication facility in Des Moines, Iowa.

Step 7



SALES & MARKETING

Getting your product onto Walmart shelves might seem like a victory, but big retailers demand high volume and deliver low margins, so many small manufacturers sell directly to consumers. Online services such as Amazon, Shopify, and Volusion take care of many of the details (hosting, payment processing, security) in exchange for a cut of each sale or a monthly fee. Next, get the word out through your social network. Talk up your product on Facebook and Twitter.

HOW TO TALK FACTORY

3D PRINTING

Now available for as little as \$500, 3D printers can turn almost any CAD creation into a physical object. Sophisticated desktop units, such as this MakerBot Replicator 2X (\$2800) use dual extruders to print in multiple colors of plastic.

LASER CUTTING

3D printers are extremely useful, but for fashioning quick and precise parts from materials such as acrylic, wood, and metal, nothing beats a laser cutter. The machines are expensive, but they are available at shared R & D work spaces.

CNC ROUTING/MILLING

These two machines are similar in concept, but they operate differently. Routers direct a rotating bit to shape wood and plastic, while mills usually move the material (mills are good at cutting metal). Both are the inverse of a 3D printer, subtracting material instead of adding it.

PRESSING & STAMPING

A standby of large-scale industrial manufacturing, machine presses force the manufacturing material against a premade form. Stamping machines cut out shapes much as a cookie cutter does. Both kinds of machine can produce parts much faster than printers and milling machines, but they are not as flexible.

HYDRO/VACUUM FORMING

Vacuum forming is great for making plastic parts, such as electronics casings and packaging, which are heated, then vacuum sealed to a mold, then cooled. Hydro forming, which uses liquid pressure instead of a vacuum, is better for metals and other heavy materials.

INJECTION MOLDING

Rather than pressing material against a mold, an injection molder forces material into one. These high-volume machines make parts out of glass, metal, or plastic.

SQUARE PAYMENTS

Online retailing may be frictionless, but sometimes you out in the physical world. Technologies such as Square turn any smartphone into a credit-card reader.

BLINK/STEADY

The inventors of this bicycle accessory aimed to raise \$35,000 through the crowdfunding site Kickstarter—and ended up with more than double that sum.

BENJAMIN COHEN, STUART HEYS

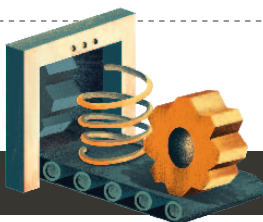


in China by 2015. That's why even big companies are following small manufacturers back to North America. Companies such as Ford and GE, are "reshoring" some of their production to the U.S.

For some small manufacturers, the best strategy takes advantage of the U.S.'s friendly trade relationships with its neighbors. 3D Robotics, launched in 2009 by then-*Wired* editor-in-chief Chris Anderson, sells both assembled and DIY unmanned aerial vehicles. The company initially used circuit boards assembled in China. But by 2010 Anderson's co-founder Jordi Muñoz had learned how to construct custom boards at home. After months of soldering by hand, Muñoz spent \$3000 on eBay for a used pick-and-place machine to create the boards faster. The company graduated from a tiny garage to a warehouse in San Diego. When it needed to expand to a second facility, the founders looked south—to a 14,000-square-foot factory in Tijuana, Mexico, the city where Muñoz was born. In 2012 Anderson quit his day job.

"The day I finally decided maybe it was time to consider leaving *Wired* was the day Jordi sent me a picture of our forklift," Anderson says with a laugh, "Real companies have forklifts."

Lesson 5 Prepare to Pivot.



Even if you achieve success with your first small-batch widget, a number of factors can throw a kink in your business plan. Unexpected competitors, market changes, or technological shifts can demand new products or a change of design. Chris Anderson says that the same general-purpose, digitally controlled manufacturing tools that enable small-batch production also allow entrepreneurs to be nimble. "With older, analog methods such as injection molding you get great economies of scale," he says. "But the downside is that once you've made a part, you don't dare change the design, because it's expensive. With digital manufacturing tools, you can change the design every day."

Buckley from DODOcase agrees: "I come from the startup world where we're constantly thinking, 'What's the pivot?' If all



of a sudden our iPad business dried up, we would start trying new stuff." He's already doing just that. As my tour wraps up, I notice a surfboard sitting in a dusty corner of DODOcase's wood shop. Buckley tells me he assembled the board using the same bamboo he uses for iPad cases. Eventually he wants to commercialize a line of DIY, home-assembly surfboards. All he has to do is upload a new file to his Ferrari. Instead of automatically cutting 18 DODOcases, that SCM PratiX Z2 could just as easily mill the dimensions of, say, eight 6-foot surfboards. "That's my dream," he says.

That could be the ultimate attraction of the flexible, small-batch model: Once you succeed with your first product, it's even easier to get cranking on your next idea.

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