MANUFACTURING:

DO IT YOURSELF?

Rapid fabrication technologies allow 3D objects to be created from a computerized design nearly as easily as a DVD burner makes playable disks. Until recently, these objects were limited to a single constituent material, often a fragile wax or imprecise resin. But today, 3D printers can use manufacturing-grade materials to make a limited variety of industrial and commercial objects. On the near horizon are fabricators that will be able to produce electronic gadgetry, toys, and even industrial-grade equipment. And further out is the potential development of molecular manufacturing. As these devices improve, they'll trigger a manufacturing transformation in traditional factories; quite possibly, they'll also end up in homes and offices, reshaping our concept of the consumer economy.

BEYOND DESIGN EXPERIMENTS: FROM PROTOTYPING TO MANUFACTURING

Present-day rapid prototyping allows engineers to make precise working models of objects from CAD files. Two methods for rapid prototyping have become especially important in the last decade. Both are additive processes, which build up objects one layer at a time; neither requires any tooling, which virtually eliminates the set-up times and costs of conventional manufacturing processes. In inkjet manufacturing, an inkjet printer sprays fine beads of plastic or resin instead of ink, eventually building a free-standing structure. In laser sintering, a laser draws the shape of an object in a layer of powder. The laser fuses the powder into a solid; the object is then covered with more layers of powder.

Such rapid prototyping has already had a significant impact on product design. Designers work faster. Users test and comment on early prototypes. And engineers catch problems before they reach production. However, rapid prototyping is now starting to morph into rapid, high-end manufacturing. Hearing-aid manufacturers Siemens and Phonak are laser sintering silicone earbuds. Aerospace companies use rapid prototyping to make small runs of highly complex aircraft parts. And early versions of machines that can fabricate electronics and displays alongside mechanical structures will be more widely available by the end of the decade.

MICRONICHE PRODUCTION: MANUFACTURING FOR THE LONG TAIL

In the near term, rapid manufacturing technologies will continue to allow lower costs for experimentation and small-scale production. But just as the general-purpose computer allowed for innovations in software and information system design, these general-purpose manufacturing devices have the potential to unleash a tremendous wave of design innovation. Moreover, just as the Internet has enabled small producers and even smaller, distributed markets to interact and thrive—what *Wired's* Chris Anderson has termed the "long tail"—fabbing will trigger the rise of microniche production, aimed at diverse, idiosyncratic communities previously ignored by mass producers, but connected over the Internet.

Microniche production is more than simply mass customization; it's a world where unique designs can find a small market foothold because the costs of both small-run manufacturing and targeted marketing have dropped dramatically. In addition, as 3D fabrication systems become more widespread, there's the potential for niche manufacturing to become peer-to-peer design, making it possible to share objects online as easily as music or videos are now shared. In such a world, the rapid rise of "open-source" product design is inevitable.

SMALL WORK: FABBING A NEW INDUSTRIAL REVOLUTION

The technologies could, in fact, bring about an Industrial Revolution in reverse. In this scenario, rapid fabrication (or molecular manufacturing) will turn every home into a personal, flexible factory. Companies and users will sell or share designs that can be manufactured at the point of use: instead of container ships carrying processed goods, the Internet will circulate blueprints and CAD files. With increasingly "smart" materials, we will begin to interact with the world of atoms as if it were the world of bits. Under the unbearable lightness of a billion "spimes" enabling infinite customization and just-in-time local manufacturing, the global economy will deconstruct itself.

This vision is elegant, compelling, and most likely wrong. Design and manufacturing are complex enterprises, and the same technologies that might enable home manufacturing could make factories more nimble and market-savvy. But the two visions—highly flexible factory systems versus home production systems—define a continuum along which we will almost certainly find ourselves disrupting the current producer–consumer models in many different ways.

—Jamais Cascio & Alex Soojung-Kim Pang

SOPHISTICATED 3D PRINTERS WILL NO LONGER BE USED JUST TO MAKE DESIGNER PROTOTYPES—BUT WILL THEY END UP ON THE SHOP FLOOR OR ON YOUR DESK?

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BRUCE STERLING
is a science and science-fiction writer, best known for his novels and his seminal work on the *Mirrorshades* anthology, which defined the cyberpunk genre.

Visions of the future often come from science fiction, and those visions might be all the more compelling if the sci-fi writer also happens to be a science and technology writer like Bruce Sterling. To explore—and perhaps also explode—some of the sci-fi visions of desktop fabbing, Jamais Cascio invited Bruce and IFTF's own science writer and DIY expert David Pescovitz to think together about the potential of 3D printing over the next decade or so.

Q: IS DESKTOP FABBING A PRACTICAL REALITY? WILL IT TURN OUT THAT EVERYONE IS A FACTORY?

David: At the far end of the decade, you see several trends in engineering intersecting and converging to potentially give us a rough version of the *Star Trek* replicator. What we're talking about are 3D printers that spit out goop, layer by layer, until they make a physical object. We're talking about printable electronics. We're also talking about electro-active polymers—materials to which you apply voltage. They flex. You press on them, and a little bit of voltage change occurs.

Those can be used for actuators or sensors—for buttons or the basis of a motor. You load up the 3D printer on your desktop with plans for a new coffeemaker or a new remote control to replace the one that's lost. It will basically squirt out some working approximation of the device. We have a ways to go, but the idea of enabling everyone to be a factory has a lot of pretty profound implications.

Bruce: I've also found that extremely appealing because I also have an "MIT-Media Lab-MAKE Magazine-GNU/Linux-distributed-everything" take on matters. But even though I find that extremely appealing, both politically and literarily, I'm not sure that's actually the way it's going to blow. I would love to have a little desktop fab myself. I'm not sure it would last any longer than my Treo lasted. It reminds me very much of the sort of classic American technological sublime in the early 1980s when writers like myself first got word processors. We immediately concluded that we were going to disintermediate and distribute the publishing industry.

What really happened with electronic text had very little to do with publishing, per se. Most of the text that is on the net is *net*-texted. It would have been hard to say at the time, say if you were doing Boing Boing Magazine and you suddenly got a laser printer, that the upshot of this would be boingboing.net.

David: What I think is interesting is that industrial design—the actual form of working objects—is historically difficult for the nonprofessional or the amateur to be involved with. It is difficult actually making the physical thing, an object with electronics, which competes aesthetically with what can be mass produced. It harkens back to days of fine woodworking and machining and things like that. Maybe these technologies would democratize industrial design somewhat. I'd like to see more beautiful objects more often.

It reminds me also of when Photoshop first came out. Most of the people who had access to it were techies and not artists. It had this cheesy *Dungeons & Dragons* feel to it. It wasn't until the technology was actually really cheap enough for "real artists" to start using it that you saw some real Photoshop beauty coming out.

Bruce: I don't think it will democratize design exactly, but I think it will digg.com and reddit.com it. In other words, in these peer-to-peer methods of distribution of plans, you don't actually get everybody going out, running the recipe, and making one of their own. You get power-law distributions with someone who was formerly an amateur. They discover how to put the Mentos into the Coke bottle and have a massive viral hit.

Q: WHAT'S REALLY THE UNEXPECTED, THE UNANTICIPATED FUTURE OF 3D PRINTING? WHAT ARE PEOPLE DOING THAT MIGHT BE THE SOURCE OF SOME VERY BIG INNOVATION?

Bruce: I was just at an electronic-printing conference, being done by printers, who are aware of the fabricator thing. A guy was talking about organic semiconductors and how they are printed out on these gigantic plotting machines. They are two meters across. They're like giant newsprint rolls.

I said, "It's a circuit, right?" He said, "Yeah." I said, "Is it spaced as neatly as a core duo circuit?" He said, "No, we can't do ten nanometers, but we can do 100 nanometers." So, it's ten times as big a circuit and is two meters across. How long can it be? He said, "As long as you want." So I said, "You're telling me you just invented a macro chip? You're going to print out a single integrated chip, which is ten times looser than a top-end silica microchip, but not that loose. You can make it basically infinitely long and 2 meters across?" He said, "Yes." I said, "What kind of industrial application would there be for a chip like that?" He had no idea. The thought had never even crossed his mind. He didn't know anything about the limits of chips, the size

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I ACTUALLY THINK THERE IS A COMPUTATIONAL BEHAVIOR IN AN ELECTRONIC OBJECT THAT SIZE THAT WE DON'T REALLY KNOW ANYTHING ABOUT. I THINK IT IS AN ENTIRELY NEW KIND OF ELECTRONIC BEAST.

of chips, or propagation of electrical signals through a chip that size. I don't think anybody knows. I haven't found anyone that would say how a chip would behave if it were 100 meters long.

David: It's a roll-to-roll printing process. You can imagine printing out massive displays that way or wallpaper that is also your computer. I think about what Vivek Subramanian, who is a pioneer in printable electronics at U.C. Berkeley, says when people ask, "Well, is it as fast as a regular transistor now?" Subramanian isn't necessarily aiming for that. The aim is to just make it good enough. Good enough for whatever application. Good enough for a cheap display screen that rolls up. Good enough for an electronic bar code printed on your can of Coke.

Bruce: I actually think there is computational behavior in an electronic object that size that we don't really know anything about. I think it is an entirely new kind of electronic beast. We don't even know what to call a macro chip or have any understanding of what a macro chip would be. They do seem to be pretty easy to print out. They were talking routinely about printing electronics, just fabbing electronics, on top of cardboard: things like fabbed electronics on baseball cards so that the card has a live display. It would be some kind of Phillip K. Dick nightmare. It would be like a cereal box which was full of dancing, leaping, antic figures. They're looking at it from the point of view of printing packages because that's what they are by trade.

Q: WHAT ARE THE IMPLICATIONS OF DESKTOP PRINTING FOR THE ENVIRONMENT, FOR GREENING OUR MANUFACTURING PROCESSES? ARE WE LOOKING AT A GREEN-GOO SCENARIO?

Bruce: I'm wondering about that. What's the substance that is being fabbed? To date, it's been polymers and some pretty sophisticated material that usually has a high cost per cubic centimeter. They literally sell it to you like printer's ink. It's pricier than champagne.

The ideal thing would be some kind of semi-unstable miracle goop that could sit in an oil drum for 50 years without ever curing. You could pour it in there and fire a laser or electron beam so it would stiffen up. You could obtain any quality you want: elastic, modules, transparency, all this cool industrial-designer stuff. At the end of the day, you could throw it back into the hopper and unkink its Van der Waals forces, and it would turn right back into the original goo—straight out of the William McDonough's *Cradle to Cradle* handbook. That stuff does not exist.

On the other hand, we haven't ever had a reason to look hard for something with those properties. I just wrote a science fiction story that is coming out in a couple of months. It has a device that does exactly this. It uses carbon nanotubes, which are the magic sci-fi gizmo of choice for 2006. This guy gets this tub of carbon nanotubes, and it's just yellow dust. You pour it through some kind of spark gap device, and it turns into a super-hard black ceramic. If you put the ceramic back in and zap it again, it magically unkinks the nanotubes, and they turn back into nanodust, and everything is hunky-dory.

Is that realistic? I don't know. Would it surprise me if it happened? Not particularly. Materials processing is unbelievably advanced these days. It is incredible what they can do with plastics and the rest of it. It strikes me as being one of the few things we can do from a green perspective that actually does disintermediate practically everything we have done in the last 200 years. I think it could get some traction. So much of the industrial base is being shipped off to China, not just from the United States but from all over the place. There actually is a vacuum that fabs could fill.

David: Maybe what we need along with the desktop fabricator is the desktop biodegrader where you put in some programmed organisms coming out of synthetic biology that can degrade the 50 blenders that you've made that aren't quite right until you get the one that actually works.

JAMAIS CASCIO
is a co-founder of WorldChanging, an IFTF Research Affiliate, and guest editor of this year's collection of *Ten-Year Forecast: Perspectives.*

THE IFTF DO-IT-YOURSELF INDEX: A SELF-ORGANIZING ALTERNATIVE ECONOMY

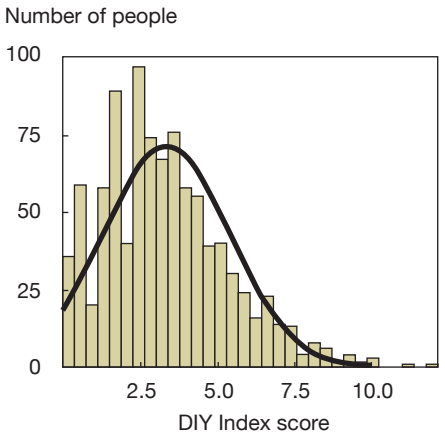
The growth of a do-it-yourself (DIY) movement in the past decade has led to a boom in the home improvement industry, in home-made media, and in customizable products. It has even supported new publications like *MAKE:* magazine, which caters to the DIY crowd.

The 2006 Ten-Year Forecast Signals Survey suggests that a self-motivating, self-educating, and self-organizing sector of society is emerging that may define an alternative economy. This sector tends to seek out customized or alternative goods, services, and entertainment—preferring to have a more active hand in shaping their own goods, environments, and experiences in conjunction with relatively small groups of like-minded people.

While these do-it-yourselfers could be seen as having other-than-corporate values, they are willing to use corporate institutions to create their own innovative and alternative social structures and activities. They also tend to exploit the new online world and its tools for social connectivity, taking some of their self-organizing habits from the physical world and translating them into the virtual world—and vice versa.

Those with the self-organizing DIY profile are still a minority in the population. However, as manufacturing technologies and online sharing of technique grow, they may turn out to be lead users in the way Eric von Hippel defines them: those who are early adopters of products and practices that will eventually be taken up by the larger population.

DISTRIBUTION OF DO-IT-YOURSELF INDEX SCORES



Source: 2006 Ten-Year Forecast Signals Survey

WHAT DEFINES A SELF-ORGANIZING DO-IT-YOURSELFER?

Self-Organized Lifestyle

- Transactions in alternative market spaces

  For example: eBay, garage sales, farmer's markets, and craft fairs

- Home work

  For example: kitchen, gardening, major or minor home renovations, and home-organization projects

- Self-expression

  For example: drawing, painting, photography, music, dance, amateur theater, reading and writing poetry and stories, collecting valuable items, playing sports in organized or informal groups, volunteering locally, playing online games

- Skill-based sharing

  For example: exchanging job contacts with fellow hobbyists, exchanging resources with fellow hobbyists

Online Sociability

- Self as online source

  For example: maintaining personal, household, or family Web site, creating media, blogging

- Self as online contributor

  For example: regularly contributing comments or pictures to a blog, posting family or personal pictures online for others to see, using tagging services like del.icio.us, contributing to a public wiki such as Wikipedia

WHO ARE DO-IT-YOURSELFERS?

- Those who score high on the IFTF DIY Index are likely to be young and married: nearly one-third of married people scored high.
- Self-employed people are more likely to score high: 41% scored high compared to 23% of others.
- DIY high-scorers are actively engaged in their health, showing positive correlations with seeking health information, engaging with health-based communities, and looking for health benefits in products and services.
- High scores also are more likely to go to people who use digital tools for collaboration in teams, who seek learning activities, and who make religious and political contributions.
- Do-it-yourselfers are more likely to score high on IFTF's Sustainability Index (see "Community: Citizens of Sustainability").
- There are no correlations between high scores on the DIY Index and gender, race, religion, native U.S. citizenship, or political views. There is a weak positive correlation with income.

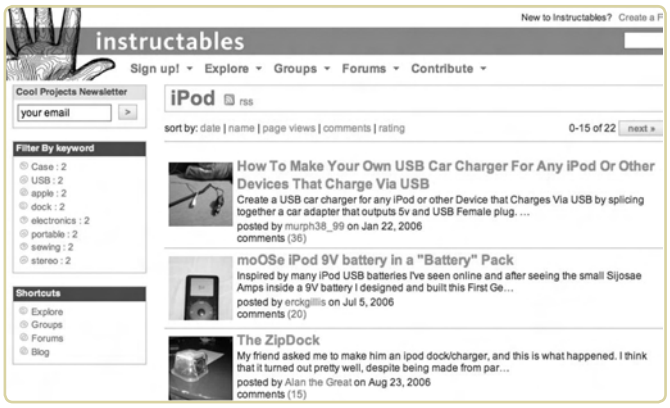
FABBING ON THE DESKTOP

The big question surrounding the rise of rapid fabrication systems is whether or not they move to the desktop. Some experts argue that 3D printers are more like book-binding systems than laser printers—specialized tools that might be found at a neighborhood service center but are of little use in the home. Others see fabbers as being more akin to CD burners: when combined with design software and easy, inexpensive distribution, they blur the distinction between hobbyist and professional.

One highly-visible driver of a desktop fabrication future will be the DIY culture represented by IFTF's self-organizing do-it-yourselfers. Today, this growing movement of hackers and hobbyists trade schematics and plans for a staggering array of devices, mixing an open-source aesthetic with a design school sense of cool. They will be among the first to acquire fabbing systems and figure out how to use them in ways that the producers never imagined. This sub-culture personifies William Gibson's observation that "the street finds its own uses for things."

2 IPOD INNOVATIONS AT INSTRUCTABLES.COM

The Web site instructables.com bills itself as "step-by-step collaboration" for sharing what you make and how others can make it.



Source: http://www.instructables.com/tag/keyword:iPod/

3 MAKE: MAGAZINE

As the "first magazine devoted entirely to DIY technology projects," *MAKE:* "unites, inspires, and informs a growing community of resourceful people who undertake amazing projects in their backyards, basements, and garages."

Source: *MAKE:*

4 A DORKBOT CHAPTER WEB SITE

Organized by the Web site dorkbot.org, groups of art and design communities meet worldwide to support bottom–up design.

Source: http://dorkbot.org/

REINVENTING THE FACTORY

Regardless of the trajectory for desktop fabrication, the factory model of production will still be commonplace. Even if some consumer goods can be manufactured at home, there will still be a need for commercial and industrial products: the days of printing a suspension bridge or jet engine are still far off. Yet rapid prototyping technologies will have an important role here, for one very big reason: they require virtually no set-up time compared to more conventional manufacturing methods, so these new flexible factories can potentially shift product lines in just a few hours.

This will make for a very new kind of factory space: open and reconfigurable. Just as the office of yesteryear, with its vast rows of desks or cubicle farms, was a giant information-processing machine organized to produce standardized information products and services, so too is the traditional factory designed to maximize the efficiency of well-established, stable processes. But companies that need innovation and creativity have driven the movement to create offices that are more flexible, open, and customizable, and spaces that gently encourage serendipity, support collaboration, and facilitate discovery. This change is about to hit the factory floor.

Rapid fabrication systems could turn the factory floor into a center for a new kind of knowledge work, and make manufacturing more flexible, responsive, and information-intensive. These flexible factories won't be organized around production, but around demand. The ease and speed with which they respond to inputs, reconfigure to demand, even move to where they're needed will reshape our concept of the factory.

The flexible factory will consume physical resources more efficiently than ever before, but its most important raw material will be up-to-date information: from designers (about how users are reacting to both the company's latest products and still-under-NDA prototypes); from market-watching software agents, blogs, and discussion boards; and, perhaps most importantly, from prototypes, active and recycled units themselves, uploading data about their histories, uses, and problems to the factory. The combined effects of cascades of information and pressure for constant innovation will turn the factory floor into a space in which production and innovation blend together, and designers, industrial engineers, and machinists work together to update products. By incorporating these insights into a readily-reconfigured production process, the flexible factory itself may become a constantly iterated, evolving design.

The flexible factory will demand a smarter approach to people. Traditional assembly lines needed workers who were as reliable as machines, while managers wanted workers who were interchangeable, and labor unions advocated and enforced strict rules governing what employees could and couldn't do. The shift from mass production or rapid manufacturing will create a demand for workers who are entrepreneurial, highly skilled, and able to collaborate with others—and a shop floor flexible enough to let that happen. Fortunately, through games, a generation of kids are acquiring design and manufacturing skills that can move straight from the living room to the factory floor. Countries with the most advanced game cultures today may have an advantage in the world of rapid manufacturing tomorrow.

5 FACTORY SPACE WILL BE OPEN AND RECONFIGURABLE

Source: http://flickr.com/photos/confusedvision/96390866/

	Desktop Manufacturing	Flexible Factories
Raw materials	• The equivalent of printer cartridges for semiconductors, plastics, insulators, dyes, etc. • Must be low or no toxicity • Recyclable and reusable	• Proprietary high-performance materials • Efficiency-driven choices and uses
Information	• Open-source designs • Peer-to-peer instruction sets • Materials safety and handling	• Design feeds • Early user feedback • Data from market-watching software agents, blogs, and discussion boards • Data from instrumented prototypes, active, and recycled units
Innovation	• A focus on simple devices that users can customize: toys, office equipment, family heirlooms, prosthetics • Device-centered innovation, e.g., iPod extensions	• Continuous updating and reinvention of products • Continuous reinvention or reconfiguration of production processes • Blurring of innovation, design, and production on factory floor
Costs	• Opportunity costs of cheaper factory-produced goods • Relatively high price of complex 3D printers	• Collaboration and coordination costs • New kinds of factory spaces
Labor	• Self-employed • Semi-retired boomers • Youth • Hobbyists • Stay-at-home moms • Gamers	• Entrepreneurial • Highly skilled • Collaborative • Gamers • “Emergent” managers

Source: Institute for the Future

WHAT TO DO

PRODUCT DESIGN:

TAP THE "HOME HACKING" MARKET FOR EARLY INNOVATION

Design and manufacturing are complex tasks, and many people may never have the skills or interest to turn their homes into factories. However, our DIY research suggests that there's a strong community of people with latent design skills, a DIY or hacker mentality, and a passion for particular kinds of products—and these are likely to be the first people to embrace home manufacturing. While they may think of themselves as hackers in an alternative economy, they could actually be enlisted as open-source designers and fabbers, creating a pool of product innovations for more wide-scale manufacturing and distribution by those with large-scale systems in place, following the model of open-source pharma perhaps. A key here will be setting up the incentives and licensing so that everyone wins.

HEALTH AND SAFETY:

CONSIDER NEW CHAINS OF LIABILITY

The expanding pool of potential manufacturers will bring new risks. For products where outsourcing design and production makes sense—whether it's to local micro-manufacturers or consumers—safety and quality control will raise new issues. Corporations with brands to protect should pick products and partners carefully. Now is also the time to begin thinking about chains of liability. While outsourcing production is not a new idea, outsourcing down to the level of consumers is. What happens when a consumer makes a defective product from your design or material? What happens if they "melt down" your product and make a new defective product from the resulting material? Thinking through the issues now will set the stage for taking advantage of new fabrication opportunities a decade from now.

SUPPLY CHAIN:

BRING YOUR SUPPLY CHAIN IN-HOUSE?

Rapid fabrication techniques will make the biggest impact inside businesses in the next ten years. While these new manufacturing techniques will transform in-house design—with prototyping becoming cheaper, faster, and better—some of the most surprising impacts could be in the way companies supply their own parts and materials. While some will take advantage of a growth of micro-manufacturers—at both ends of the fabrication process—one of the opportunities will be to rethink what is outsourced and what is produced in house. As design drives manufacturing from more generic materials and machines, the existing division of labor in many plants may shift, and supply chains could be scrambled.

WHAT TO PONDER

FABBING SMART STUFF

It could happen. Not only will people make lots of things that suit their particular needs. They may make those things smart enough to sense, remember, and communicate with other things—and with people who know how to communicate with things.

For YouTube videos of a "blogject" workshop, go to: www.youtube.com/?v=D8jDXhmy288

Soon flexible and printable electronics and displays will let us embed electronics in fabric, building supplies, packaging, and even paint. As more physical goods contain cheap processors and network connections, however, we see a new kind of world emerge, one that isn't necessarily comforting. Adam Greenfield describes in *Everyware* a world in which user behavior is monitored by objects and the environment. UCLA's Julian Bleecker describes objects that connect to the Internet to tell their own stories about their use, history, and conditions, calling them "blogjects." As cheap rapid fabrication tools become more widely available, smart goods (or even smart add-ons for previously "dumb" objects, something that designer Eric Townsend calls "proto-spimes") will proliferate faster than many of us might expect or be prepared for. "Guaranteed dumb" versions of fabricated objects may end up being a popular category.