SWCP Portal
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*The world of* Star Trek *gets a little closer*

# The 3D Replicator Revolution

While the world has been suffering through the Great Recession and many still worry about all the manufacturing jobs lost overseas, the next industrial revolution was quietly launched in garages, basements, and labs right here at home. This new method of producing goods will cause greater changes and more social upheaval than anything since Henry Ford started up his assembly line.

This new technology is called **3D printing** and it will change how we make everything from what we wear and what we eat to the vehicles we drive and the jobs we perform. 3D printing will give the average person the freedom of expression and specialty crafted goods which was once the exclusive realm of royalty and the super-rich. Not just in the abundance of "bespoke" objects available as customized products or reproductions of rare artworks, either, but in terms of the sheer variety of things also.

The ability to render mathematical expressions in solid form gives designers, engineers, and architects a tool of incredible power. Since the 1980s, expensive professional devices have been able to prototype new gadgets. But the tech is now finally poised to enter the consumer market.

3D printing is, of course, the latest step in the **digitization of the world**. It may be helpful in imagining the effects of this new way of doing things by recalling how digital 2D printing altered everything. Before the invention of the **personal computer**, printing was an established trade involving many arcane specialties. The highly-trained professionals who created books and magazines were limited by the number of typefaces and colors they could use. Images were few and largely custom produced. To prepare a job, print, trim, bind it and all the rest was expensive and time-consuming. Therefore, *only* pieces intended for mass consumption could be produced economically.

When first introduced, computers did not change this. Mainframes that set type and laid out pages required specialized training and were connected to multi-million dollar presses built to make thousands of copies. Then came the **Macintosh** and both the publishing industry and all connected to it were revolutionized almost overnight.

The first personal computers used in small shops and by enthusiasts were not cheap design tools and quite primitive compared to what they can do today. However, their power and sophistication soon made them far more irreplaceable than the people who used them.


Thousands of skilled workers from typesetters to photo-engravers suddenly lost their careers even as surprised secretaries became empowered as layout artists. But designers who kept their jobs soon had dizzying numbers of fonts to choose from, along with a palette of previously unimaginable visual effects, and on any scale desired, too.

The price of printing plummeted even as production options blossomed. It became affordable to print very small runs. **Digital technology democratized design**: a tiny company could now print just as effective, well-made pieces as a big corporation without the same investment.

Now picture much this same process happening in *every manufacturing industry* on the planet, all of them, all at once. That's the sort of change this new tech is bringing in both social disruption and creativity. One-of-a-kind items will become commonplace, allowing both utterly personalized fashions, customized tools, cheap replacement parts, and absolutely amazing works of art. But many of the most lucrative specialties in all industries will unexpectedly vanish into history like typesetters have.

There are still limitations. Unlike traditional manufacturing, 3D printing has no built-in **economy of scale**. In other words, each unit produced costs the same, whether it's one or a thousand. But because set-up is cheap and the models used can be quickly modified, 3D printing will not be limited to specialized goods or prototyping products.

Once digitized, designs or scans of objects can be instantly uploaded and sent to plants wherever it is cheapest to make mass quantities. In digital production methods, the main thing is modeling the object as data. How or where it is used is a later consideration, though that has already proved problematic. But 3D printing, in combination with robotics, nanotechnology, materials science, and biotech, means that the industrial landscape by the end of this century will scarely resemble that with which it began.

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## How 3D printing works

Traditional manufacturing techniques like drilling, cutting, and shaping things on a lathe all remove stuff. But 3D printing methods are **additive**. Objects are made by building up layer after layer according to a digital model.

There are a number of ways to print out solid pieces. They vary mainly in the substances used and the methods employed to build and fuse them. The raw materials can range from cells to sugar candy to several types of plastic to hard metals. There are types of printing which require two materials, one being a removable supporting material to permit complex structures like voids and openings.

One of the first methods developed should be familar to anyone who's decorated cakes or owned a Playdough Fun Factory as a kid. It works by **extrusion**. Unlike the frosting bags or toys that squeeze a gooey substance through special-shaped holes, these machines melt a plastic or metal filament from a spool through a heated nozzle to be deposited precisely on a computer-driven platform.

Extrusion is great for creating different kinds of plastic parts for prototyping, rapid manufacturing, or molding. One new kind of plastic, PLA, is derived from corn starch and is said to smell like cooking waffles while printing.

Other types of materials require other techniques. **Candy**, for instance, can be printed by melting grains of sugar or chocolate with hot air. **Metals**, even titanium alloys, can be fused similarly using laser beams to supply the heat. Or they can cut thin sheets to shape and melt them together.

Lasers are also utilized in **photopolymerization** processes by sending beams into vats of clear liquid polymer that hardens on exposure. And the same technology used in **ink-jet** printers can spray binders on plaster or resin particles to create full-color models complete with hollows and overhangs, but it may have even more exotic uses.

Similar devices may soon print out biological materials. Experiments are underway to create **synthetic meat** which might eventually be indistinguishable in taste and texture from "real" flesh, or even **engineering living tissues** like replacement skin or entire organs for people.

## Killer apps

As with 2D printing, the evolution of printing in 3D is following much the same path of being able to handle more materials faster with ever-greater sophistication and finer resolution. Just as the first dot-matrix printers produced crude, jagged letters, so too the early models were slow and clunky. They left thick, visible layers and rough edges.

But this new technology seems to be developing at a very rapid rate. There are already HD printers where no layering is visible. New model gadgets for home experimenters now include software to automatically put in struts or supports where needed or leave the interiors hollow. This makes for better copies, saving material, money, and time.

A top-line professional fabricator by a company like Stratasys can cost $380,000 and weigh 8 tons. There are much cheaper and smaller systems coming out, however. One of them, MakerBot's just-released **Replicator 2**, may be the Mac of this revolution. It is a desktop printer about the size and shape of a microwave oven that makes objects up to 6 x 6 x 11 inches, using PLA plastic with a resolution so fine no sanding is required. At $2,199, it's not exactly cheap, but other manufacturers are getting in on the act with the least expensive machine being offered for only $600, so the technology is getting within reach of anyone interested.

3D printing is taking off rapidly largely because of its enthusiastic adoption by tinkerers. The grand Yankee tradition of invention still flourishes right here with the Duke City's own hackerspace, **Quelab** (**quelab.net/wordpress/**) and there are groups like **MakerFaire** bringing the tools to the masses. Design files can be shared at websites such as **Shapeways** (**www.shapeways.com**), and **Thingiverse** (**www.thingiverse.com**), or Google's **3D Warehouse** (**sketchup.google.com/3dwarehouse**) containing thousands upon thousands of free downloadable CAD files.

The market for custom and innovative designs should be big. So far the most popular items seem to be plastic game pieces and small toys. But no "killer app" has yet emerged and a recent attempt to make a literal one hints at some of the complex social and economic conflicts that can arise.

Cody Wilson, a law student from Austin, recently announced a project called **Wiki Weapon**, whose aim was to design a printable gun and put the plans on the Net free for anyone. But before he could unpack the 3D printer he'd leased from Stratasys, they demanded its return.

The company claimed they could not allow their product to be used illegally, citing Wilson's lack of a firearms manufacturer's or dealer's license and a law that prohibits making guns that can't be detected at airports. Wilson, however, claimed he was not going to sell anything whatsover and that the law would be respected somehow.

But there may be more to it than that. Stratasys, WIRED magazine reports, is "working with some of the world's top firearms-makers today" including Remington Arms, the country's top gun maker, to prototype parts or even print plastic guns. So did the company take its machine back out of social responsibility or to protect its own future sales?

Digital manufacturing faces much the same legal issues as digital movies, music, and books. But fights over patents and copyrights may be even more fierce due to the vast potential of this new technology. It's safe to say that for both better *and* worse, we ain't seen nothing yet.



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