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3-D printing takes shape

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Additive manufacturing is evolving quickly. Senior executives should begin preparing for five disruptions that will accompany it.

3-D printing, or additive manufacturing,[1] has come a long way from its roots in the production of simple plastic prototypes. Today, 3-D printers can not only handle materials ranging from titanium to human cartilage but also produce fully functional components, including complex mechanisms, batteries, transistors, and LEDs.

The capabilities of 3-D printing hardware are evolving rapidly, too. They can build larger components and achieve greater precision and finer resolution at higher speeds and lower costs. Together, these advances have brought the technology to a tipping point—it appears ready to emerge from its niche status and become a viable alternative to conventional manufacturing processes in an increasing number of applications.

Should this happen, the technology would transform manufacturing flexibility—for example, by allowing companies to slash development time, eliminate tooling costs, and simplify production runs—while making it possible to create complex shapes and structures that weren't feasible before. Moreover, additive manufacturing would help companies improve the productivity of materials by eliminating the waste that accrues in traditional (subtractive) manufacturing and would thus spur the formation of a beneficial circular economy (for

[1] Additive-manufacturing techniques build objects layer by layer, rather than through molding or "subtractive" techniques, such as machining.

more, see "Remaking the industrial economy," available on mckinsey.com, on February 5). The economic implications of 3-D printing are significant: McKinsey Global Institute research suggests that it could have an impact of up to $550 billion a year by 2025.[2]

The advantages of 3-D printing over other manufacturing technologies could lead to profound changes in the way many things are designed, developed, produced, and supported. Here are five 3-D printing disruptions that senior executives should begin preparing for.

1 Accelerated product-development cycles

Reducing time in product development was a key benefit of the first 3-D printing machines, which were designed to speed the creation of product prototypes (and in some cases helped reduce turnaround times to a matter of hours, from days or weeks). Now many industries are poised for a second wave of acceleration as the line between additive and conventional manufacturing blurs.

For example, additive manufacturing is already being used to get prototypes into the hands of customers faster, for quicker and more detailed feedback. (This is happening thanks to advances in printer resolution, higher-definition coloration, and the broader use of materials, such as elastomers, that help customers envision the final product.) The ability to make prototypes without tooling lets companies quickly test multiple configurations to determine customer preferences, thus reducing product-launch risk and time to market. Companies could even go into production using 3-D printed parts and start selling products while the traditional production tools were still being manufactured or before the decision to produce them had been made. When companies did order those tools, they could use additive-manufacturing techniques to make them, saving even more time and money.

We expect that the use of such techniques will contribute to significant reductions in product-development cycle times over the next decade. (For example, 3-D printing makes some aspects of day-to-day R&D

[2] For the full McKinsey Global Institute report, see *Disruptive technologies: Advances that will transform life, business, and the global economy*, May 2013, on mckinsey.com.

work, such as producing simple lab apparatus, vastly more productive.) Over time, 3-D printing will begin to affect how companies think about R&D more broadly, given how the technology enhances the ability to crowdsource ideas through remote cooperation. For some companies, that crowdsourced brainpower might one day begin supplanting R&D activities, making its management a new priority.

2 New manufacturing strategies and footprints

As of 2011, only about 25 percent of the additive-manufacturing market involved the direct manufacture of end products. With a 60 percent annual growth rate, however, that is the industry's fastest-growing segment. As costs continue to fall and the capabilities of 3-D printers increase, the range of parts that can be economically manufactured using additive techniques will broaden dramatically. Boeing, for example, already uses printers to make some 200 part numbers for ten different types of aircraft, and medical-products companies are using them to create offerings such as hip replacements.[3]

Nonetheless, not every component will be a candidate for the technology and reap its benefits (cost reductions, performance improvements, or both). Companies should understand the characteristics that help determine which ones are. These include components with a high labor-cost element (such as time-consuming assembly and secondary machining processes), complex tooling requirements or relatively low volumes (and thus high tooling costs), or high obsolescence or scrap rates. Forward-looking manufacturers are already investigating ways of triaging their existing parts inventories to determine which hold the most potential.

Additive-manufacturing techniques also have implications for manufacturing-footprint decisions. While there is still a meaningful labor component to 3-D printed parts, the fact that it is lower than that of conventionally manufactured ones might, for example, tip the balance toward production closer to end customers. Alternatively, companies could find that the fully digital nature of 3-D printing

[3]For example, the Mayo Clinic uses 3-D printed hip-joint models—which are based on patient CT scans—to run practice surgeries. Later, the models are sent to a manufacturer that produces custom implants.

makes it possible to produce complex parts in remote countries with lower input costs for electricity and labor.

A related area that executives should watch with interest is the development of the market for printing materials. The cost of future materials is uncertain, as today many printers use proprietary ones owned or licensed by the manufacturer of the printing equipment. Should this change and more universal standards develop—thus lowering prices—the implications for executives devising manufacturing strategies and making footprint decisions would become very significant very quickly.

Shifting sources of profit

Additive-manufacturing technologies could alter the way companies add value to their products and services. The outsourcing of conventional manufacturing helped spur companies such as Nike to rely more on their design skills. Likewise, 3-D printing techniques could reduce the cost and complexity of other kinds of production and force companies to differentiate their products in other ways. These could include everything from making products more easily reparable (and thus longer lived) to creating personalized designs.

Indeed, reducing the reliance on hard tooling (which facilitates the manufacture of thousands of identical items) creates an opportunity to offer customized or bespoke designs at lower cost—and to a far broader range of customers. The additive manufacture of individualized orthodontic braces is just one example of the potential of these technologies. As more such offerings become technically viable, companies will have to determine which are sufficiently appealing and commercially worthwhile. The combination of mass customization and new design possibilities will up the ante for many companies and could prove very disruptive to traditional players in some segments.

In certain parts of the value chain, the application of additive manufacturing will be less visible to customers, although its impact may be just as profound. A key challenge in traditional aftermarket supply chains, for example, is managing appropriate inventories of spare parts, particularly for older, legacy products. The ability to

manufacture replacement parts on demand using 3-D printers could transform the economics of aftermarket service and the structure of industries. Relatively small facilities with on-site additive-manufacturing capabilities could replace large regional warehouses. The supply of service parts might even be outsourced: small fabricators (or fabs) located, for example, at airports, hospitals, or major manufacturing venues could make these parts for much of the equipment used on site, with data supplied directly by the manufacturers.

Of course, retailers too could someday use fabs—for example, to let customers tailor products such as toys or building materials to suit their needs. That business model could represent a value-chain play for manufacturers if, for instance, they owned the machines, core designs, or both.

New capabilities

Design is inherently linked to methods of fabrication. Architects can't design houses without considering construction techniques, and engineers can't design machines without considering the benefits and limitations of casting, forging, milling, turning, and welding. While there is a wealth of knowledge around design for manufacturing, much less is available on design for printing. Our conversations with executives at manufacturing companies suggest that many are aware of this gap and scrambling to catalog their design know-how.

Getting the most out of additive-manufacturing techniques also involves technical challenges, which include setting environmental parameters to prevent shape distortion, optimizing the speed of printing, and adjusting the properties of novel materials. Indeed, tuning materials is quite a challenge. While plastics are relatively straightforward to work with, metals are more difficult. Slurries and gels (for example, living tissue or the material for printed zinc–air batteries) are extremely difficult.

The most successful players will understand these challenges. Some are already creating centers of excellence and hiring engineers with strong experience in additive manufacturing.

Disruptive competitors

Many benefits of 3-D printing could cut the cost of market entry for new players: for example, the use of the technology to lower tooling costs makes it cheaper to begin manufacturing, even at low volumes, or to serve niche segments. The direct manufacturing of end products greatly simplifies and reduces the work of a designer who would only have to take products from the computer screen to commercial viability. New businesses are already popping up to offer highly customized or collaboratively designed products. Others act as platforms for the manufacture and distribution of products designed and sold online by their customers. These businesses are gaining insights into consumer tastes and building relationships that established companies could struggle to match.

Initially, these new competitors will be niche players, operating where consumers are willing to pay a premium for a bespoke design, complex geometry, or rapid delivery. Over the longer term, however, they could transform industries in unexpected ways, moving the source of competitive advantage away from the ability to manufacture in high volumes at low cost and toward other areas of the value chain, such as design or even the ownership of customer networks. Moreover, the availability of open-source designs for 3-D printed firearms shows how such technologies have the potential to create ethical and regulatory dilemmas and to disrupt industries.

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