ADDITIVE MANUFACTURING RECONFIGURES INDUSTRIAL OPERATIONS

3D PRINTING: THE DIGITALIZATION OF MANUFACTURING

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With 3D printing, the digital economy will make the move from the world of data to the physical world. This technology has the potential to transform manufacturing processes, reconfigure global supply chains and give rise to business models that are hard to imagine today.

3D PRINTING • ADDITIVE MANUFACTURING • FOURTH INDUSTRIAL REVOLUTION • PRINTER FARMS • SUPPLY CHAIN • INDUSTRIAL OPERATIONS • PRODUCTION STRATEGIES

Last November an Airbus took off from the company's headquarters in Toulouse containing the largest 3D-printed part ever to fly as a component of an aircraft. It was the front bearing housing of Rolls-Royce's most powerful motor, the Trent XWB-97. This titanium part, with 48 airfoils, measures 1.5 meters in diameter by 0.5 meters thick. The flight was a test of the new wide-body Airbus A350-1000, which will hit runways in 2017. Thanks to 3D printing, Rolls-Royce reduced production time by 30 percent, while at the same time optimizing the design, functionality, cost and speed of the craft.

Major manufacturers in the aerospace sector have been using 3D printing for several years. Airbus, along with Boeing, GE and Rolls-Royce realized quickly that 3D printing meant cost reductions of 25 to 50 percent and a faster delivery date. Another important advantage in industries such as aerospace or the navy is that parts manufactured with 3D printers can weigh between 10 percent and 30 percent less than those produced by conventional methods. In addition to bringing down costs, weight reduction also lowers fuel consumption and emissions while simultaneously improving power, acceleration and speed. The automotive industry is also using this technology, currently mostly in Formula One and luxury cars.

EOS, located in the Munich area, is one of the most emblematic companies in additive manufacturing. The company is a global leader in metal 3D printing, with customers in the aerospace, automotive and health industries. Its technology is used not only by Airbus, BMW, Boeing and GE, but also in the field of dental implants: more than a million have been produced in Europe. It seems that, for now, innovations in 3D printing don't necessarily come from the US, but rather from the "old world," especially in industrial 3D printing.

ADDITIVE MANUFACTURING VS. TRADITIONAL MANUFACTURING

3D printing encompasses the use of different technologies

(writing, fusion, injection, extrusion, stereolithography and sintering) and of different materials (plastics, resins, glass, ceramics, metals and their alloys), yet they share a trait: in all these technologies, a part is built by depositing layers of a material, rather than molding it or shaping it using lathes and milling machines. These traditional forms of production are known as subtractive manufacturing. In contrast, industrial 3D printing is referred to as additive (or layer-by-layer) manufacturing. This paradigm shift in production has numerous advantages:

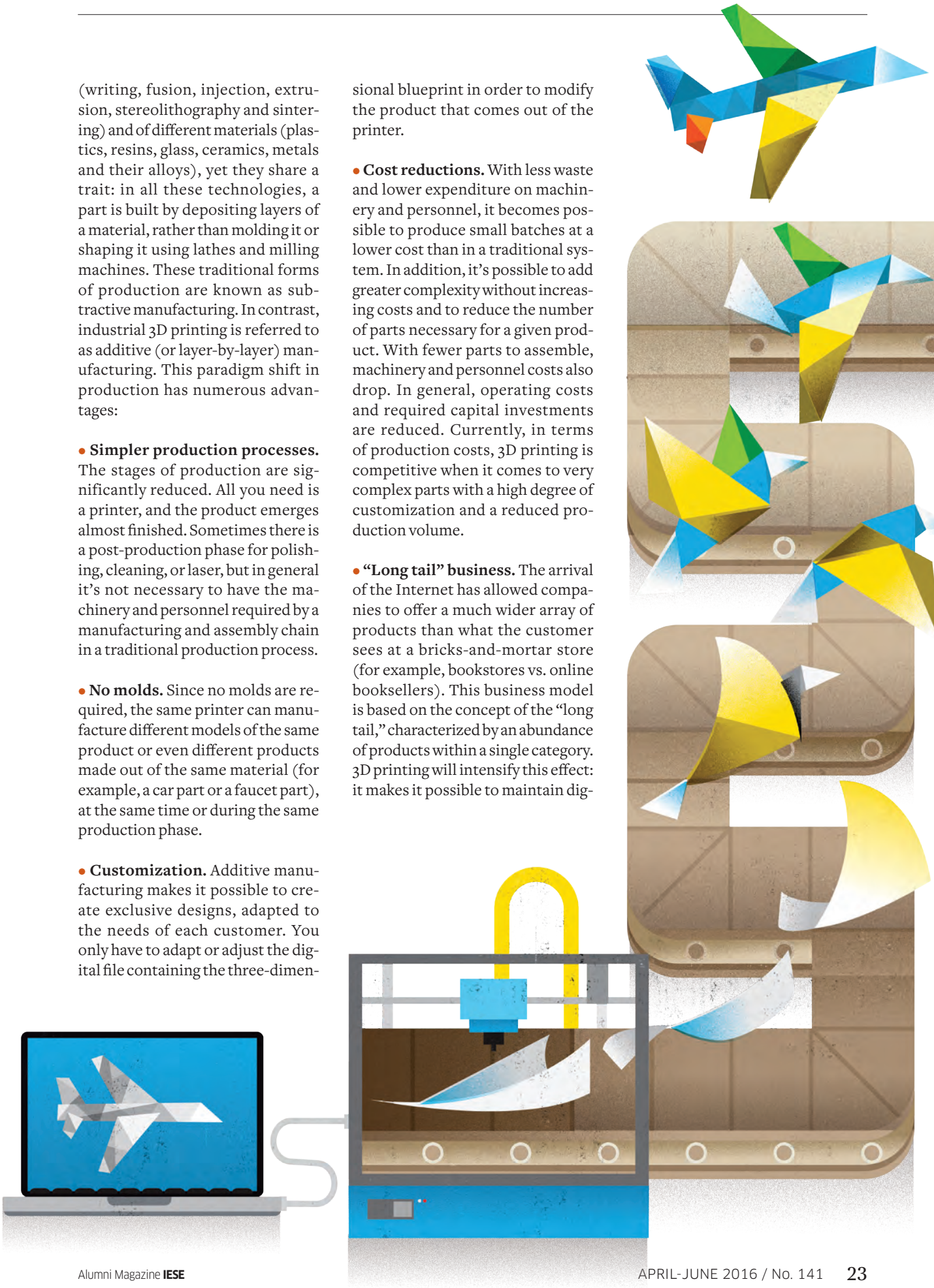
• **Simpler production processes.** The stages of production are significantly reduced. All you need is a printer, and the product emerges almost finished. Sometimes there is a post-production phase for polishing, cleaning, or laser, but in general it's not necessary to have the machinery and personnel required by a manufacturing and assembly chain in a traditional production process.

• **No molds.** Since no molds are required, the same printer can manufacture different models of the same product or even different products made out of the same material (for example, a car part or a faucet part), at the same time or during the same production phase.

• **Customization.** Additive manufacturing makes it possible to create exclusive designs, adapted to the needs of each customer. You only have to adapt or adjust the digital file containing the three-dimensional blueprint in order to modify the product that comes out of the printer.

• **Cost reductions.** With less waste and lower expenditure on machinery and personnel, it becomes possible to produce small batches at a lower cost than in a traditional system. In addition, it's possible to add greater complexity without increasing costs and to reduce the number of parts necessary for a given product. With fewer parts to assemble, machinery and personnel costs also drop. In general, operating costs and required capital investments are reduced. Currently, in terms of production costs, 3D printing is competitive when it comes to very complex parts with a high degree of customization and a reduced production volume.

• **"Long tail" business.** The arrival of the Internet has allowed companies to offer a much wider array of products than what the customer sees at a bricks-and-mortar store (for example, bookstores vs. online booksellers). This business model is based on the concept of the "long tail," characterized by an abundance of products within a single category. 3D printing will intensify this effect: it makes it possible to maintain dig-



3D PRINTING MAY HAVE EVEN MORE DISRUPTIVE POWER THAN BIG DATA OR THE INTERNET

ital stocks of products rather than physical stock, thereby significantly reducing the working capital while moving the "virtual" stock closer to the end customer (Amazon and DHL are looking into operating 3D printers in their distribution centers).

One example is the automotive industry: in Europe, manufacturers are required by law to ensure that after the last production batch of a given car model, replacement parts will be available for at least ten years. This forces the industry to keep a significant amount of working capital frozen in warehouses throughout Europe (or to absorb significant costs in order to launch an unplanned production batch). With 3D printing, all of these replacement parts become virtual stock, printable on demand.

- **Product optimization.** 3D printing allows designs that are both more complex and more efficient, designs that are often impossible to carry out using traditional methods. They can even imitate nature, for example, reproducing the shape of a leaf or the structure of a honeycomb. In addition, it is possible to alter the properties of the product via the use of lasers and the injection of other materials with different densities. Ultimately, the resulting product has a wider range of features and is stronger, lighter and more flexible.

- **Active quality control.** Quality control can be much more exhaustive and can go so far as to monitor the product layer by layer. It becomes literally possible to look inside a part without X-rays.

- **More efficient supply chains.** 3D printing can bring production to the sales market, because it's no longer necessary to locate labor-intensive work in low-cost countries.

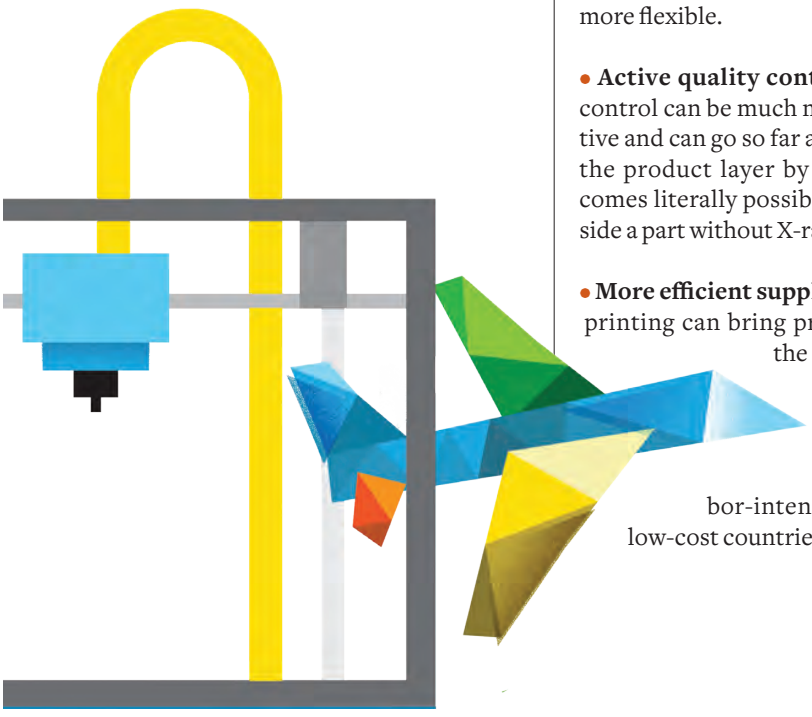
Also, companies can produce on demand with zero stock, because designs are stored in digital archives that are only printed when needed. They can even decide to manufacture on site with a design developed thousands of kilometers away and sent electronically. Shipping company Maersk Line is already using these approaches. It has equipped its cargo ships with 3D printers in order to print on board any replacement part that it might need during a trip. These supply-chain improvements not only generate major savings in logistics and transport, but are bringing about a global restructuring of manufacturing value chains in the medium and long term.

- **Flexibility and lower entry barriers.** 3D manufacturing does not require major technical infrastructure, which significantly reduces the time and costs for production start-up. With lower initial capital requirements, the door is open to new competitors – small and mid-sized companies that specialize in small volumes and niche markets, for example – and the emergence of new business models.

FROM 'PROTOTYPING' TO MASS PRODUCTION

Little by little, 3D printing is overcoming some of the technological challenges that keep it out of mass production. For one thing, the size of manufactured parts is still limited by the size of the machines and the capacity of their printing chambers. It's also important to keep in mind the current price of the printers (which ranges from €150,000 to €1.5 million) and the cost of the materials (which are between four and 100 times more expensive than those used in traditional manufacturing).

Production time is also an important factor. All 3D printing techniques subject materials to very high temperatures. Under these conditions, both "printing" and cooling require a complex, sensitive process that takes time.



Over the short and medium term, traditional manufacturing isn't going to disappear, especially not in mass production. We're still a long way from seeing a generalized, massive use of this revolutionary technology. But the 3D production of parts and components is a reality in advanced, high value-add industries: hip prostheses and dental implants in the medical industry, airplane parts in the aerospace industry, components and replacement parts for the automotive industry. For now, 3D printing is used in relatively short series and small batches of expensive, sophisticated parts in the most cutting-edge industries. But the number of products manufactured in 3D is growing exponentially.

And so are projections of global sales of 3D printers. According to the latest estimates by the consulting firm Gartner, this year they could already exceed 490,000 units (more than four times the 106,000 units sold in 2014). Gartner estimates that in the next three years, sales will skyrocket to reach 5.6 million units in 2019.

BUSINESS CHALLENGES

Twenty or thirty years from now, industrial 3D printing may have even more disruptive power than Big Data or the Internet. In fact, along with artificial intelligence, robotics, the Internet of Things and nanotechnology, 3D printing is one of the focuses of what's being called the Fourth Industrial Revolution.

This transformation is characterized by the fusion of technologies that blur the lines between the physical, digital and biological. 3D printing has the potential to drastically reconfigure manufacturing ecosystems the world over. And that will pose major challenges for businesses:

- **New manufacturing strategies.** Additive manufacturing creates a range of choices about how, when and where to manufacture products and their components; which assets to keep in the supply chain and which to outsource; and how to optimize the mix of old and new processes for each part at any given moment. That is, industrial 3D printing will force companies to reconsider their manufacturing strategies and to rethink where they produce, what they outsource and what they produce in-house.

- **Organizational challenges.** In terms of general management, the biggest challenge will be to align company strategy with new industrial operations and to align research and development with the change in production systems. It will also be crucial to develop new capabilities: engineers need to be reeducated to think not in terms of "design for manufacturability," but rather "design for the maximum performance of each component." In addition, companies will have to create transition plans in order to get the workforce accustomed to the new production methods and professional retraining plans to relocate employees affected by the changes.

- **Changing cost structures.** In general terms, fixed capital investments and direct costs (such as labor) will drop, but at the same time, general expenses, such as those related to product design or the purchase and maintenance of printers, will rise.

- **Protecting intellectual property.** Developing piracy protection for STL/AMF files, the industry standard for 3D printing, will be paramount.

- **New business models.** In addition to the emergence of "printer farms," 3D printing will inspire a range of other new business models. Some of them we can't even imagine, just as in 1990 it would have been difficult to imagine Amazon or Uber, but others – the "long tail" model, whose profitability lies in amassing sales from a long list of low-demand products – are already beginning to emerge.

"PRINTER FARMS"

One standout among the new business models to emerge with industrial 3D printing is the "printer farm," an analog to the already-existing "server farm." The printer farm will make it possible for customers to print in 3D without incurring the expense of purchasing a printer. The idea is to apply the logic of pooling, which concentrates demand on a set of centralized resources, to the world of industrial 3D printing. In addition, "printer farms" make it possible to relocate production near to the areas of demand and allow companies to outsource manufacturing in order to focus on activities with higher added value, such as design, R&D or marketing and sales.