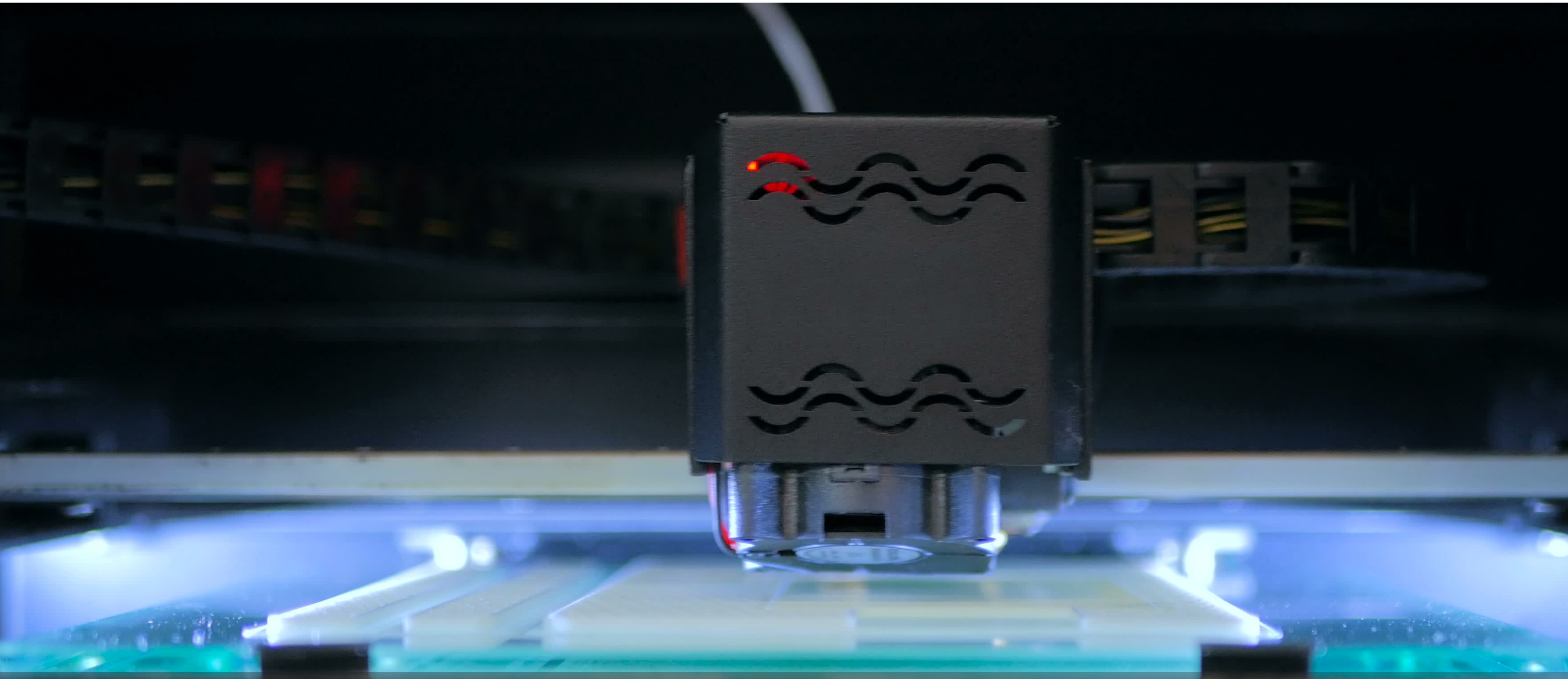
SourceToday
Thought Leadership Series
Issue 08.2017



3D Printing in the Electronics Supply Chain

Exploring best practices within the electronics industry

For most of the past century, industrial manufacturers have focused on large-batch production to generate the economies of scale required to deliver competitively priced goods. From automobiles to home furnishings to electronics, the process relies on sourcing low-cost materials and labor to fabricate high volumes of standardized products for delivery through wholesalers, distributors, retailers, and other channels.

While this supply chain model has generally served industry and consumers well, it nonetheless carries embedded costs, waste, and risk. Upfront and ongoing costs can be significant and include tooling, warehousing of inventory, and transportation. Waste is inherent in the "reductive" method used by today's mass manufacturers, which typically fashion end products by repeatedly cutting matter away from a solid block of material. Business risk—particularly for electronics OEMs whose extended supply chains involve assembly operations in East and South Asia—can derive from geopolitics, quality control, long lead times, and rising labor expenses in these regions as they move up the value chain.

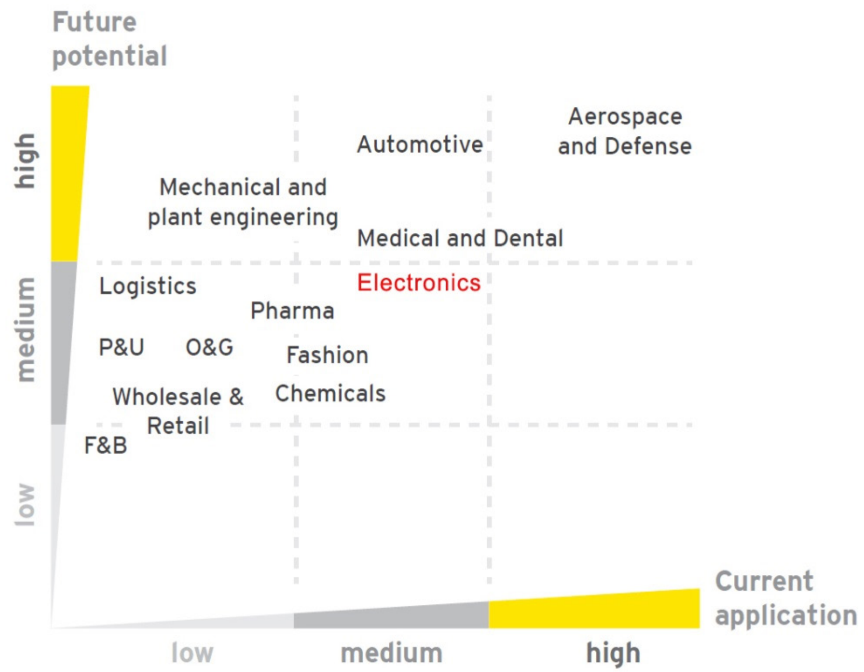
An additional shortcoming of traditional manufacturing—and the supply chains that support it—lies in its difficulty in responding to rapid changes in customer demand. Creation of new tools and dies, which are typically required for each product design iteration, is a slow and exacting process that lengthens time to market. Moreover, the mechanisms intended to deliver information along the supply chain to help balance production and inventory levels with consumer demand too often rely on estimates and inexact forecasts rather than sales and other customer-generated data.

The emergence of additive manufacturing, i.e., 3D printing, may yet solve many of these issues. Additive manufacturing involves essentially a one-step fabrication process near the point of end use using raw materials and a computer-generated 3D blueprint in place of multi-tiered global supply chains engineered to procure materials, parts, and components for processing and assembly by low-cost laborers. In the context of the development of digital supply chains, 3D printing looms as a key enabling technology, substituting in part the conveyance of digital product designs for the shipment of physical goods and materials.

Indeed, a recent *SourceToday survey* of OEM procurement and engineering managers found that 3D printing tops the list of technologies they are investing in to improve procurement and supply chain operations and processes.

For electronics manufacturers, the technology holds considerable potential, as speeding time to market can help the industry keep pace with ever-shortening product life cycles (see Figure 1).[1] For electronics consumers, the ease with which the technology can be used to generate varied product designs holds great potential for creating customized forms and features.

Figure 1. Current application and future potential of 3D printing by industry



Source: Ernst & Young

Additive Manufacturing Comes of Age

While 3D printing is viewed by some as a new technology, it has actually been in commercial use for 30 years. To date, however, 3D printers have not been fast enough or cost-effective for use in high-volume manufacturing. As the price of desktop printers has come down, printing speeds improved, and new materials developed, additive manufacturing is poised to take a more central role in manufacturing operations.

Additive manufacturing uses a three-dimensional digital blueprint, created from computer-aided design (CAD) software, to inform a part's or product's build process. Raw materials, such as metal or plastic, are passed through an extrusion nozzle, heated, and deposited one layer at a time to create solid objects that replicate the 3D digital model. Dozens of raw materials are now available for use in 3D printing, including metals, nylon, ceramics, plaster, acrylic, and edible material.

The electronics industry has been among the early adopters of 3D printing—using the technology to manufacture external cases for electronic devices, for example. Increasingly, however, attention is turning to the creation of materials and processes to build parts' internal circuitry.

Conductive inks containing charged particles are now available that can build live circuitry as a single, continuous part to create functional electronics that require little or no additional assembly following printing.[2] This has opened the door for 3D printing's use in the manufacture of circuits, sensors, batteries, antennae, and other electronics parts. One particularly promising application in this regard is the use of 3D printing to create in-house rapid prototypes of functional printed circuit boards (see case study on page 4).

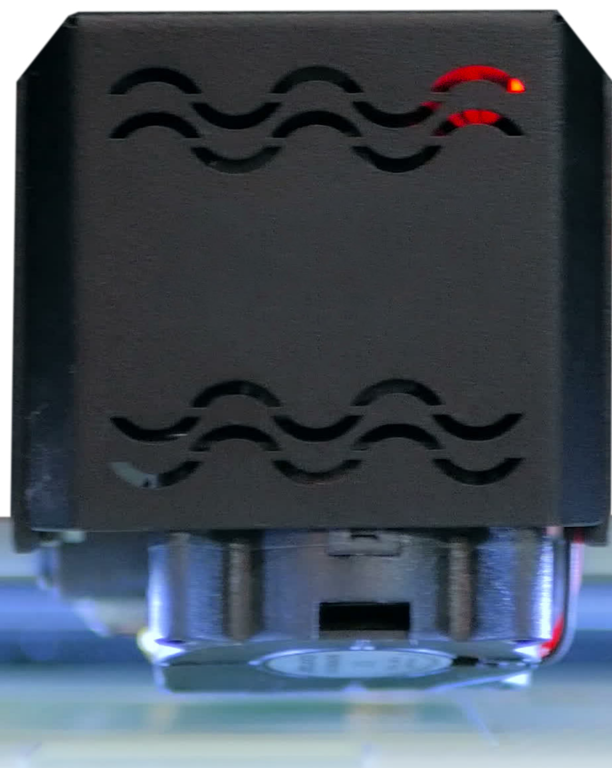
Additive manufacturing holds the potential to disrupt much of the electronics supply chain, from product design/prototyping to materials/supplier sourcing, manufacturing, inventory, distribution, and aftermarket service. *(Continued on page 5)*

Case Study:

Additively Manufactured PCBs Become a Reality

Fundamental to the design and operation of virtually any electronics device—from phones to computers to radar—are printed circuit boards (PCBs). Designing and creating prototypes of these electronic "nerve centers" is a notoriously lengthy process. The current standard reductive manufacturing of PCBs is a multi-stage and labor- and material-intensive undertaking that typically requires electronics engineers to outsource designs to generate their prototypes.

Nano Dimension Ltd. has now launched what is claimed to be the world's first desktop-sized 3D printer designed specifically for the production of professional multilayer PCBs. The company's DragonFly 2020 3D printer accepts industry standard Gerber design files and prints a complete multilayer PCB, including all interconnections between layers, using conductive and dielectric nano-inks.



The DragonFly 2020 3D prints circuits by embedding electrical components as an integral part of the printing process. According to Nano Dimension, this method yields several advantages over conventional practice:

- It improves PCB reliability by maintaining the electronic components internally, keeping them from being exposed to the external environment while protecting against mechanical, temperature, and corrosion damage.
- Soldering is unnecessary, as the components are embedded within the printed board during printing. The connectivity between components then takes place as part of the 3D printing process without the need for a mediating soldering material.
- The process enables printing on electronics components without their complete packaging (i.e., printing directly on the dye) and thus supports the creation of thinner, more protected PCBs.[3]

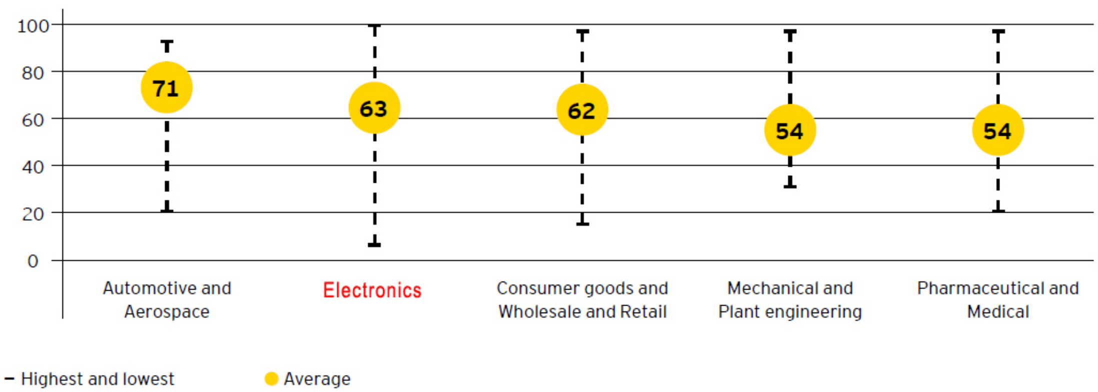
For PCB designers and engineers, the printer eliminates the frustration often faced when they reach the prototyping and testing stage. Moving their work from design to a prototype at an off-site printing facility might require weeks for the board to be ordered, produced, and shipped. If further iterations are needed, the cycle begins anew and time to market is slowed.

With turnaround times for a 10-layer PCB typically two weeks or more using conventional reductive technologies, engineers are often conservative in their designs, as mistakes can waste time and money. With in-house 3D-printed electronics, engineers can innovate more freely, iterating designs in hours rather than weeks to help them create better products. ■

The driving forces behind its inevitable expansion are its ability to reduce expense, time, and risk while boosting product customization:

- The upstream supply chain can be shortened and simplified as raw materials are substituted for semi-fabricated products. Procurement expenses can be lowered as embedded labor costs are shed from manufacturing inputs.
- At the manufacturing stage, 3D prototyping eliminates the need for tooling and molds, allowing for fast, cost-effective manufacturing of smaller lots and greater product customization (see Figure 2).[4] As a single-step process, 3D printing can consolidate the traditional electronics manufacturing steps of film deposition, lithography, and etching into one.
- Downstream services, such as warehousing and distribution channels, can be reduced or eliminated altogether as on-demand manufacturing of products and spare parts replaces physical inventory with virtual (digital) inventory. Orders can be filled by the manufacturer and delivered directly to the customer.

Figure 2. Prototyping time reduction with 3DP (%)



Source: Ernst & Young

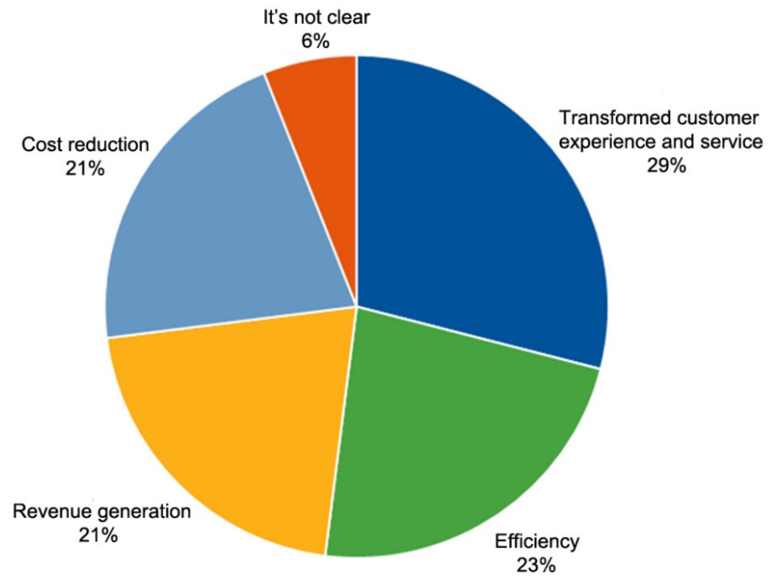
How, then, should manufacturers go about assessing the potential for using 3D printing to help them streamline supply chain operations?

Incorporating 3D Printing into Your Manufacturing Operation

To be sure, 3D printing should not necessarily be viewed as a wholesale replacement to traditional manufacturing. Additive manufacturing in some instances may be best suited as a backup to primary production operations—mitigating risk and allowing for order fulfillment in the event of a disruption to the conventional supply chain.

“3D printing can reduce cost and improve efficiency, but it is rarely used to replace an automated process that is generating product at high volume,” notes Pete Basiliere, research vice president at Gartner Inc., which surveyed 248 supply chain professionals from across industries in 2016 for their views on additive manufacturing uses and trends (see Figure 3).[5] “More often, 3D printing is used to enhance the customer experience by producing unique product or augmenting manufacturing tooling.”

Figure 3. Supply chain view of the primary value of 3D printing



Source: Gartner Inc.

Going forward, supply chain managers need to assess the competitive landscape and determine whether and how additive manufacturing might be utilized to improve their company's position within it. Is the company losing sales to competitors due to the latter's 3D printing capabilities? Are current customers inquiring about additive manufacturing capability? "Determine the level of need within your target customers for mass customization capabilities to ascertain where [3D printing] might be most effective," Deloitte notes in its 2015 report *3D Opportunity for the Supply Chain.*[6]

The report advises that companies looking to reduce production costs through additive manufacturing should seek opportunities where multiple individual piece parts are produced using tooling in low volumes and then assembled manually. Product and part designs should be reviewed to determine which components can be consolidated into a single object to reduce part numbers and production costs.

In a 2017 follow-up study, *3D Opportunity for Electronics*, Deloitte suggests that electronics manufacturers review their product portfolio to evaluate whether those with complex shapes or containing electronics on curved or nonflat surfaces can be effectively manufactured via 3D printing[7] (see Figure 4).[8] Additive manufacturing can also potentially be used to facilitate design of electronics that fit into a product rather than the product being designed to fit around the electronics, helping to reduce size and weight and improve form factor, the study's authors note.

Figure 4. PCBs can be 3D printed with flexible connections

Source: Nano Dimension Ltd.

Electronics manufacturers should also assess where costs or resource outlays are highest in their conventional production operations. Wastage of expensive materials, for example, can be a significant cost in reductive manufacturing. Tooling, assembly labor, and inventory expenses in conventional manufacturing operations should be tallied and compared with those of a comparable additive manufacturing approach to assess whether 3D printing can generate products of equal quality at lower cost.

Deloitte further recommends that companies evaluate the potential advantages of distributed manufacturing using 3D printing. Under such a production model, electronics companies could theoretically reach markets in remote locations that would otherwise be inaccessible via their conventional supply chain. To judge the viability of such a scenario, companies need to assess the resources, capabilities, and investment required to make this model function—as well as whether the associated costs would be offset by the additional sales opportunities that could accrue as a result.

Perhaps foremost among the questions to be answered as companies consider potential additive manufacturing strategies is whether they have the talent to launch a 3D printing program in-house or if it is preferable to outsource most or all of the processes involved. In the case of the latter, companies will need to establish a process to identify the most suitable suppliers with whom to engage. Alternatively, a joint venture or acquisition might prove to be a better way of attaining the required skills and knowledge to add 3D printing capabilities.

What the Future Holds for 3D Printed Electronics

For all its potential to support manufacturers' supply chain operations, a variety of intellectual property (IP) and technological challenges relating to 3D printing remain that could slow its adoption. CAD files, which hold the valuable digital models used to create additively manufactured products, are easily transmitted and thus are prime targets for cyber theft. Gartner has estimated that 3D printing could result in the loss of at least $100 billion per year in IP globally by 2018.[9]

Deloitte notes that to develop electronics for 3D printing, design software must be able to incorporate electronics in the build sequence of the part itself. However, such software is still at the nascent stage of development. As to 3D printers' ability to manufacture microelectronics, additive manufacturing systems currently in use typically print electronic parts at the micrometer scale; integrated circuit chips used in electronic products, however, are sized in nanometers.[10]

"[Additive manufacturing] is not a magic bullet that will render factory mass production and manufacturing obsolete," says Matthias Heutger, senior vice president at DHL and author of the company's 2016 report *3D Printing and the Future of Supply Chains*.[11] According to the report, 3D printing will have the most impact in the medium term on logistics in spare parts and individualized parts manufacturing.

Nonetheless, manufacturers that fail to investigate and experiment with additive manufacturing risk losing competitive advantage to those that do. As has been shown with other digital technologies—notably cloud computing—advances that reduce the capital costs associated with market entry bring with them a host of start-ups eager to compete in the new landscape.

In the case of 3D printing, these avoided costs include tooling and mold-making, physical inventory, and the need to recoup large capital expenses with high-volume production. Armed with open-source software, new entrants will be able to design cheaply and iterate quickly in response to customers' desire for mass customization.

Across the electronics and other customer-centric industries, "push" manufacturing is giving way to "pull" models, and supply chains may never be the same.

By John Simpson

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4 "EY Global 3D Printing Survey," Ernst & Young, 2016.
5 "What 3D Printing Means for Your Supply Chain," Gartner Inc., 2016.
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