3D Printing, Now and Beyond

Disruptive Principles and Development Episodes

White Paper

3D Printing, Now and Beyond

The Evolution of 3D Printing

3D printing has been around since the 1980s, but it was slow to take off because the peripheral ecosystem such as materials, software, robotics, 3D graphics and the Internet had not yet evolved. The technology was used mostly for industrial prototyping applications.

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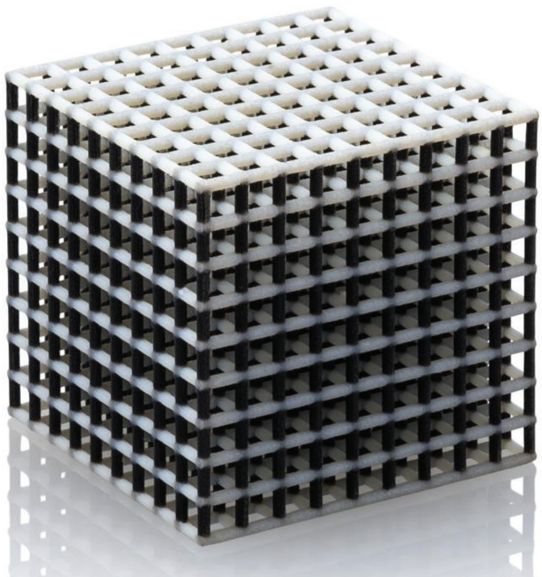
With the proliferation of computer graphics and CAD (computer-aided design), better 3D printing materials, improved process reliability and the Internet, 3D printing, also known as additive manufacturing (AM) took off exponentially in the mid 2000's.

The major factors propelling this exponential growth are the range of materials and accessibility. Until the mid 2000's, 3D printing was possible only with relatively soft plastic, severely limiting its prototyping applications. Since then, the range of materials has increased dramatically, making it possible to create high-resolution, strong and functional products that are ready for end-use.

3D printing is now applied across diverse fields including aerospace, automotive, electronics, medical and education. It is revolutionizing many fields and disciplines, demonstrating that almost every industry could benefit in some way from this technology.



3D printed geometrical shapes

3D Printing Now — Disrupting Manufacturing And Design

Manufacturing Redefined

3D printing is not just another manufacturing technique. It offers an opportunity to rethink traditionally accepted manufacturing conventions and constraints, and open new possibilities.

In traditional manufacturing, the more complex an object's shape and the more parts a product contains, the more it costs to make. With additive manufacturing, the time, effort and cost to create complex designs are comparatively lower, making it possible to produce highly optimized products without being bogged down by manufacturing cost. Traditionally, it is more expensive and takes longer to make a product if it contains more parts, whereas 3D printing decreases cost by reducing part count and eliminating assembly steps.

In addition, while skilled expertise is required to operate traditional manufacturing machines, a 3D printer gets most of its guidance from a design file. This eliminates many of the skills and training requirements associated with traditional manufacturing, opening up new business models and offering more opportunities for people without access to manufacturing expertise. The flexibility of sending digital files and the relative portability of AM machines also suggests opportunities for new supply chain configurations, as well as new distribution networks.

With metals, 3D printing creates less waste than traditional grinding or milling techniques used in mass manufacturing. Machining metal is highly wasteful; an estimated 90 percent of the material ends up on the factory floor.

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A 3D printed air intake using ULTEM™ 1010 resin.

Airbus, a leading aircraft manufacturer, uses 3D printed parts in place of traditionally manufactured parts to increase supply chain flexibility and meet delivery commitments.

Airbus has produced more than 1,000 flight parts on its Stratasys® FDM® 3D Printers for use on A350 XWB aircraft, which began delivery in December 2014.

In 2013, Airbus initiated development and certification of 3D printing as a scheduled risk reduction activity that proved valuable for the A350 XWB program and highlighted a key benefit of 3D printing in the manufacturing industry.

The parts are 3D printed using ULTEM™ 9085 resin for FDM, which is certified to the Airbus material specifications. ULTEM™ 9085 resin provides a high strength-to-weight ratio and is FST (flame, smoke and toxicity) compliant for aircraft interior applications. This enables Airbus to manufacture strong, lighter parts while substantially reducing production time and manufacturing costs.

Additive manufacturing solutions can produce complex parts on-demand, ensuring on-time delivery while streamlining supply chains. It also greatly improves the buy-to-fly ratio as significantly less material is wasted compared to conventional manufacturing methods.

Unleashing Design

Traditional manufacturing technologies can make only a finite repertoire of shapes, limiting design versatility. A 3D printer removes these barriers, fabricating shapes that have only been possible in nature until now, thus opening up vast new design opportunities. Now, different shapes can be created in a single 3D print. In contrast, traditional manufacturing machines are much less versatile and can only make things in a limited spectrum of shapes.

Combining different raw materials into a single product is difficult using traditional manufacturing machines. As multi-material 3D printing develops, we will gain the capacity to blend and mix different raw materials. New, previously inaccessible blends of raw material offers a much larger, mostly unexplored palette of materials that have novel properties or useful types of behaviors.

For award-winning bicycle manufacturer Trek, prototyping plays a crucial role in all phases of product development. But when its annual costs for outsourced prototyping reached $275,000, management decided it was time to consider purchasing an in-house rapid prototyping system. Trek added the Objet500 Connex3™ 3D Printer to the workflow, a clean, office-friendly machine that produces PolyJet™ parts that rival those made with SLA in terms of quality and finish. Trek now produces four times as many prototypes as before, while also speeding up time to market.

Trek's 3D printed color helmet prototype.

PolyJet technology offers the unique ability to print parts and assemblies made of multiple materials. Parts with different mechanical and physical properties, smooth, durable surfaces and exceptionally fine details are possible, all in a single build. The system can print living hinges, soft-touch parts and overmolds not possible with other technologies. The superior productivity, high quality output and unique multi-material printing capabilities of the Connex printer enable users to closely emulate the look, feel and function of a wide variety of end products. The ability to mix three materials together via PolyJet technology to increase durometers was a key selling point for Trek, as was the ability to combine materials in one part.

Most recently, 3D printing played a key role in the company's launch of its new, Speed Concept 9 Series bicycle. Its unique frame design features aerodynamic cross-sections that lower wind resistance and improve speed. Virtually every part of the new design was prototyped on the Connex 3D Printer.

Minimized Lead Time

A 3D printer can also print on demand, reducing the need for companies to stockpile physical inventory. New types of business services become possible as 3D printers enable a business to make specialty parts in response to customized orders.

The ability to manufacture objects of different shapes and sizes on the same system shifts manufacturing from a paradigm of "economy of scale" to that of an "economy of scope." Combining these two freedoms—freedom of complexity and freedom of variety—suggests that new business models are enabled around optimized and customized manufacturing solutions.

The Italian division of international consumer goods giant, Unilever, has cut lead times for prototype parts by 40% since introducing PolyJet technology into its manufacturing process. By utilizing 3D printed injection molding tools, the company is able to produce prototype parts for functional and consumer tests using production material, significantly faster than traditional tooling methods. Unilever is using the Objet500 Connex3 3D Printer to produce injection mold tools for its household care and laundry goods divisions, including a wide variety of prototype parts such as bottle caps, closures and toilet rim blocks.

Unilever can now design and print a variety of injection molds for functional and consumer testing, all in the same day, as opposed to several weeks using the traditional process. Long delays not only lengthen lead times, but increase costs if changes are required. With 3D printing, the company is now able to apply design iterations within a matter of hours.

Unilever 3D printed injection mold for Domestos rim block.

Precise Physical Replication

Just as a digital music file can be copied with no loss of audio quality, 3D printing extends digital precision and repeatability to the world of physical objects from the past.

The Yamagata Prefectural Museum in Japan is using 3D printing to create replicas of a 4,500-year-old national treasure, the Jomon Goddess, for museum goers to better learn, explore and touch history. The museum attracted attention with the exhibition of a clay doll replica of the Jomon Goddess. Unearthed in Funagata-cho, Yamagata, the original doll was handcrafted in the Jomon period (12,000 B.C. – 300 B.C.). Using 3D printing, the museum was able to accurately capture the fine details and intricate patterns of the sculpture.

The 3D printed Jomon Goddess sculpture replica (right).

The 3D printed replicas offer researchers, scholars and the general public wider access to historic artifacts. Not only can they be restored and recreated, the artifacts can also be used for educational events and traveling exhibitions.

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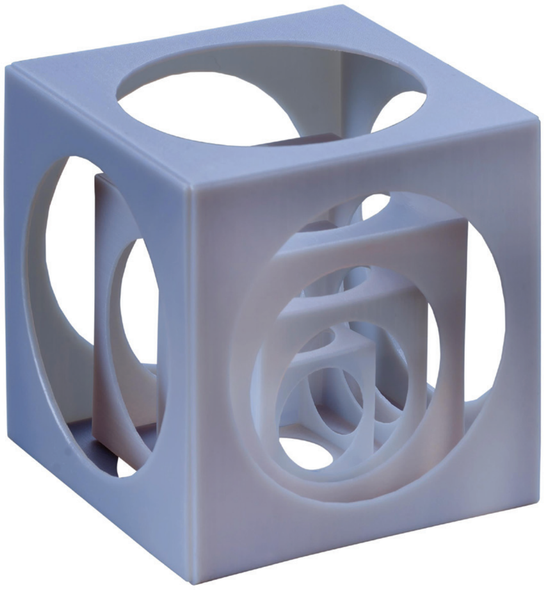

3D printed interlocking cubes.

Looking Through The Crystal Glass – Four Development Episodes

Over the next few years, 3D printing material standards and communication between printers and design tools will mature significantly, in addition to growth in manufacturing production parts. This is true across all verticals from fashion to medical and aerospace.

Looking at the long-term evolution of 3D printing, we can see four distinct episodes. The first episode, which we are in currently, has been about control over shape and form. The second episode will be about control over composition. We will be able to create materials by combining basic materials on a micro-scale level, thereby enabling completely different meta-materials.

The third episode will be the emergence of programmable matter. While it is technically possible to 3D print a robot body today, it is still difficult to 3D print electronics, sensors, actuators, batteries and processors. But in the future, the ability to print integrated active systems like these will transform manufacturing as we know it.

The fourth episode may be the transition from analog to digital, which would make the capabilities of 3D printed products substantially more advanced. Episode 4 will be about printing digital matter consisting of prefabricated voxels (tiny building blocks). Each type of voxel would enable a different functionality; some voxels will be conductive, while others will be structural, soft or hard. Other voxels will have sensors, actuators, or transistors. A relatively small repertoire of voxels would enable a vast design space of different capabilities.

While the future looks promising, we're still only somewhere at the end of the first episode. We're in an age where the marginal cost of complexity is approaching zero, thereby enabling new designs and concepts that would have been considered unfeasible for manufacturing until now.

But for 3D printing to truly transform our world, the ecosystem needs to evolve further in the following ways.

Design maturity: While 3D printing makes it possible to fabricate any shape or form with almost any material, current design software tools have not yet caught up. Translating thought into design is a very challenging process even for the best designers, especially when it comes to multi-material printing. In the future, design automation and artificial intelligence will help bridge this gap.

NASA installed 3D printed parts on their Mars rover concept vehicle.

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Material complexity: The ability to create new materials on the fly, to create meta-materials that will mimic natural materials, will drive the 3D printing revolution. Our limited capacity to model, simulate and predict properties of such new materials restricts our ability to develop them.

Replicating active systems: The ability to print integrated active systems, like conductors, sensors and actuators rather than passive parts, will transform manufacturing as we know it. Yet most designers are challenged about thinking in this new design space. New artificial intelligence and design automation tools may be able to help us explore these new opportunities.

How Is The 3D Printing Industry Facilitating The Next Episode?

From Rapid Prototyping To Assembly Line

To really come of age, 3D printing needs to make the transition from a rapid prototyping tool to a manufacturing tool, used to create the final product. This has already happened to some extent, as production parts now account for nearly a third of the additive manufacturing market.

As proof of this transition, in November 2014, NASA's Jet Propulsion Laboratory installed 3D printed parts onto one of its satellites bound for outer space. Airbus is using Stratasys production-grade printers to make flight parts for its new A350 XWB airplane.

Multiple Consistencies and Colors

With innovations such as Connex3™ triple-jetting technology, it is possible to create different material consistencies and color shades within the same part. In the dental industry, this enables the creation of lifelike gingival texture and color; jaw models created directly from CBCT scan data with high-definition tooth, root and nerve canal anatomy, and groups of models that require several materials to be built simultaneously in one unattended job.

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At Nicklaus Children's Hospital in Miami, Florida, Dr. Redmond Burke's team used Stratasys solutions to create an anatomically precise 3D model of Mia Gonzalez's heart, using her CT scan. Mia was diagnosed with a double aortic arch that needed corrective surgery. The model mimicked the flexibility of the human heart by combining photopolymers for a range of textural characteristics. Using the model, Burke and his team were able to determine which part of Mia's heart arch should be divided to achieve the best surgical outcome.

The ability to print models made from a wide array of materials, colors and varied Shore values in one build also allows the Adidas Group to accurately simulate the real outer soles of its running shoes, leading to time-savings and a competitive edge.

3D printing is set to become an exponential technology, shaping the future as it is applied to more industries around the world every day, from aerospace to automotive, education to medical. It is capable of revolutionizing almost every industry in some way. The question is only how.

Mia Gonzalez holding her 3D printed heart model.

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