White Paper

# The Role of 3D Printing in Factory 4.0

Sponsored by: Stratasys

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## IDC OPINION

3D printing can be a key technology supporting Factory 4.0 transformation. For more than 30 years, 3D printing has been utilized in industrial environments primarily for the development of prototypes. Its value proposition revolved around saving vast amounts of time and money compared to traditional processes for building prototypes. Yet for many mainstream production environments, 3D printing has been too slow, required too much human attention, and has not had the sufficient range of materials. In short, it has not been economically feasible to apply the advantages of 3D printing into higher volume environments.

New developments in 3D printing are dramatically changing what is possible with 3D printing by significantly changing existing cost structures, opening up new market opportunities, and transforming supply chains. Stratasys' Continuous Build 3D Demonstrator shows promise in delivering on the need to overcome historical limitations of 3D printing. This new product should aid in advancing 3D printing into the realm of final-part production by combining automation, workflow, and scalability with the industry's highest quality.

## IN THIS WHITE PAPER

IDC identifies how production-oriented 3D printing systems contribute to Factory 4.0 transformation by accelerating supply chains, creating new business models, and improving service levels for manufacturers and 3D printing service bureaus. Examples from early users illustrate how organizations have been able to improve the speed and quality of their services, which has enriched user experiences and opened up new revenue opportunities.

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## SITUATION OVERVIEW

The global manufacturing industry is transforming. Around the world, manufacturers are constantly seeking ways to make products with enhanced properties. These enhanced properties include a combination of improved performance, lower cost per part and producing output closer to the point of consumption. The latest initiative that is poised to transform this market is referred to as Factory 4.0 and includes four key elements:

- Interoperability: Machines, devices, and people that communicate with each other
- Information transparency: Information about the costs, effectiveness, speed, and best processes are all available to operators and extensible to customers
- Technical assistance: Information systems are designed to support humans in making decisions and solving problems
- Decentralized decision-making: The ability of cyber-physical systems to make simple decisions such as load-balancing on their own.

All of this transformation drives the growth and exchange of digital information in manufacturing. Furthermore, manufacturers are faced with a growing demand for fast turnaround and customized products. The process of setting up molds for short-run injection molding production (e.g., under 10,000 parts) is slow and the cost of each mold must be built into the total cost of producing those pieces. It is simply not economical to produce such volumes of customized products or low volumes of standard products with traditional CNC routing or injection-molding machines.

For many years, 3D printing has played an important role in the design and prototyping stage of the manufacturing process across a wide range of industries. 3D printing prototypes saves enormous amounts of time and money compared to other processes. Using 3D printers allows designs to go from the screen to a physical prototype in minutes or hours, not days or weeks. But while the quality of 3D prints rivals parts made with traditional processes, 3D printing has not historically been feasible for production in manufacturing environments, limited by its speed, cost, narrow range of materials, and lack of automation.

What is needed is an on-demand manufacturing system of high-quality products that can be customized, but are economically manufactured very quickly. This will enable more efficient supply chains, which will allow manufacturers to gain the same advantages provided by 3D printing in manufacturing that have been realized in the prototyping stage.

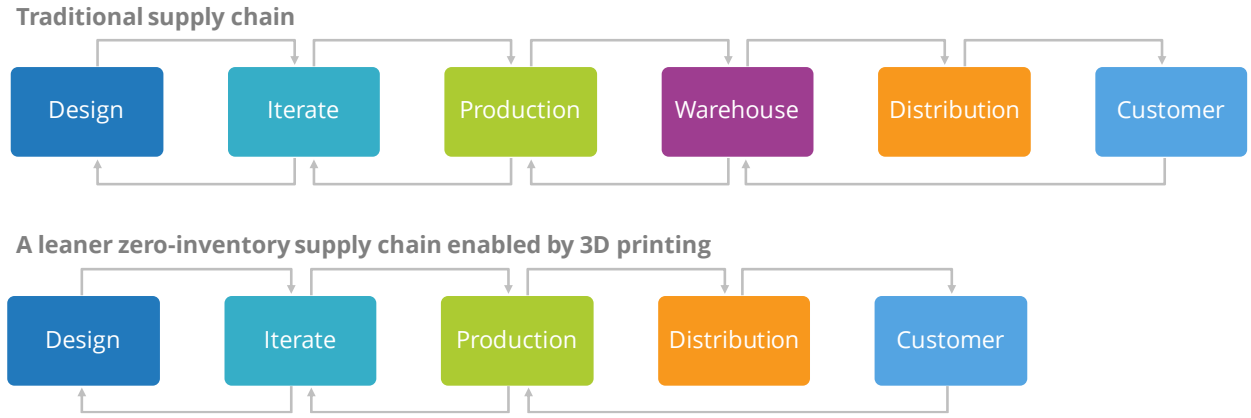
## FUNDAMENTAL VALUE PROPOSITIONS OF 3D PRINTING FOR MANUFACTURING

- **Mass personalization:** Boston Consulting Group finds that "brands that create personalized experiences by integrating advanced digital technologies and proprietary data for customers are seeing revenue increase by 6% to 10%, two to three times faster than those that don't." The trend towards customized products is driving the need to manufacture just as many items, but in smaller and smaller quantities, even down to the individualized product. Currently, huge consumer goods opportunities from eyeglasses and hearing aids to dentistry and fashion are being dramatically impacted by the trend toward mass customization, where thousands and hundreds of thousands of products are manufactured, but each customized for their eventual owner.

- **Managing the Supply Chain:** The same dynamic exists within the supply chain across the global manufacturing market. Industrial parts used in aerospace, automotive and other commercial markets are designed and redesigned constantly. Additionally, many of these parts utilized in these markets are required for several years after their original use. Consider an automobile, which incorporates an average of 30,000 parts. For the "useful life" of that car, all 30,000 parts have to be available. Now consider that somebody, somewhere, may need a specific part for that car several years after most of the models are out of circulation. Currently, these auto parts are built and warehoused by auto parts suppliers or recovered from vehicles taken out of service. There is a tremendous potential in the estimated $318 billion[1] auto parts market to reduce the cost of warehousing all of these parts by simply 3D printing the parts as needed. The printed parts will need to meet or exceed standards in place for the manufacture of current warehoused parts. Increasingly, manufacturers are seeking "zero inventory" solutions. The entry into the auto parts industry by entities like Amazon.com, which thrive off the fast-turn and individualized shopping experience concept, is set to ignite much greater use of "on-demand" manufacturing capabilities worldwide. 3D printing is expected to be at the forefront of such a trend. See Figure 1 for an illustration of a leaner zero-inventory supply chain enabled by 3D printing.

## FIGURE 1

### Leaner Zero-Inventory Supply Chain




Source: IDC, 2017

- **Design Freedom:** An underrated, but key benefit of 3D printing is the inherent design freedom enabled through this technology. Industrial designers are allowed to create completely new geometries with 3D printers. Previously, the ability to produce such output was severely restricted because certain parts were not manufacturable using injection molding, CNC milling or routing technologies. Leveraging the capabilities of a 3D printer, designers can create parts with a combination of advanced properties (e.g., lighter, stronger, lower cost, more complex). For many of the companies that have adopted 3D printing, design freedom creates efficiency gains that far surpass the cost of adopting 3D printing.

[1] Source: Auto Care Association

- **Enabling flexible manufacturing & reducing equipment down time:** Manufacturers are often seeking ways to build and test new products in new ways and 3D printers give them the chance to make necessary tools and parts that enable much faster development of new products. Also, using 3D printers, manufacturers are able to produce parts, pieces, and fixtures that their manufacturing and testing systems require to operate more effectively.
- **Speed:** Many people who have seen 3D printers operate marvel at the capability, but view the time it takes to produce a final part as a severe limitation. However, in many industries, the whole industrial design process is both very slow and very expensive. Designers develop prototypes which are injection-molded on a "one-off" basis. Often, designers require numerous iterations of the same basic design and this can translate into each prototype taking weeks to create at a cost of thousands of dollars. Compared to this process, 3D printing is faster and less costly. 3D printing's speed advantage is accelerated with new solutions that multiply production capabilities and can be scaled up to meet the growing demand for customized parts in quantities of up to several thousand units.

  One of the biggest challenges that many product manufacturers have is time-to-market. New products need to get out into the marketplace at an ever-increasing pace. Being able to produce products and parts closer to the point of integration, packaging, or use is another important advantage offered by 3D printing.
- **Intelligence of the system:** In true Industry 4.0 implementations, 3D printers are integrated with the intelligence of where and what to produce. To that end, it is important that the control systems used to drive these devices are connected not just to the operator, but to any internal or external user. 3D printers that leverage cloud-based computing are a natural progression demanded by an increasingly interconnected manufacturing environment.

## THREE PATHS THAT MAKE 3D PRINTING A NECESSITY IN THE DIGITAL MANUFACTURING AGE

Manufacturing is primed for a leap to the next stage in the industrial revolution (e.g., from water/steam power to electrical power to IT automation). The anticipated digital transformation mandated in today's market offers 3D printing a prominent place in fulfilling an eventual digital infrastructure necessary for manufacturing. Factory 4.0 is about the digitization of manufacturing. That means leveraging processing power, networks, and data to create more efficient and effective supply chains. As an enabling technology, 3D printing is entering a pivotal stage as a tool for industrial production environments. The use of 3D printing as a digital manufacturing tool offers three prime avenues to evolve.

- **The need for high-value customized output.** The demographic trend to on-line purchasing is both a B2C and B2B trend, but one of the challenges with on-line purchases is that return rates are between 2- and 5-times higher than with traditional retail. Bringing mass customization to market is one of the key opportunities for manufacturers because custom-built products are discounted and returned at much lower levels. Consumers have choices for some products, for others they don't. Companies like Invisalign and Wiivv.com are making dental molds and custom insoles using 3D printing where the customer requires a customized fit. Mass personalization is also the ultimate answer to important supply chain challenges in many industries. These challenges include transportation and inventory costs as the ability to build to order means the costs of inventory and warehousing are reduced or erased even as manufacturers are able to charge more for customized products.

- **Enabling services with capacity & automation.** There are thousands of companies in the traditional prototyping industry and thousands more 3D printing locations such as within retailers, on-line service providers, educational and government institutions, and contract manufacturers that serve global customers. These organizations need to provide ever-higher levels of service to a growing number of users and contributors. The ability to use high-speed 3D printing resources that provide high-quality capabilities along with "always-on" job submission gives service providers important production capacity. Some companies are taking advantage of the manufacturing, software, and materials expertise in the 3D printing industry to improve product quality by leveraging on-line diagnostics, topology optimization tools and other services. True Factory 4.0 implementations will automate these processes and help manufacturers and industrial designers learn better design techniques.
- **Short to medium-sized production runs.** As 3D printing technologies evolve there is a much greater opportunity to use it for short to medium-sized production runs across a wide range of products. Depending on the geometry, materials, size, surface finish, strength requirements, and a dozen other considerations it may be more cost effective to 3D print parts and products than to use traditional manufacturing processes. Companies are setting up small batch manufacturing pods with 3D printing systems as the production process, ganging up multiple 3D printers to create highly flexible, modular manufacturing sites. Furthermore, shifting small and medium-run work to 3D printing systems enables companies with traditional manufacturing equipment such as injection molding and CNC routing to continue to use these systems on the most cost effective long run production work for which they are better suited. Analysis tools will determine which production process is best suited for a job based on volumes, materials and geometry.

## THE CHANGING 3D PRINTING ECOSYSTEM

As Factory 4.0 continues to emerge IDC sees a whole set of developments within the 3D printing ecosystem that will be critical to wider adoption.

### Demographics

In the past, industrial designers were educated and trained to design products that could be manufactured using injection molding, CNC routing, or even manual fabrication processes. Over the past several years however there has been an increasing focus on how professional industrial designers could use 3D printing/additive manufacturing processes to create products more effectively. Young engineers are "brought up" with access to 3D printing, which allows them to understand what is possible with 3D printing. This education is increasingly being reinforced with comparative and analytical software tools that can inspect the geometry and composition of 3D designs and determine which is the best manufacturing process. IDC believes that in Factory 4.0 implementations design will be largely rules and constraint based, not human skill based. As such engineers won't need to design for process as the software will design and analyze for process.

### Automation

Factory 4.0 implementations featuring 3D printing systems are going to include automation and the combination of 3D printing and robotics. One IDC FutureScape prediction estimates that "By 2021, 20% of manufacturers will have begun to evaluate robotics/3D-printer hybrids for the production floor. The key value proposition offered in these configurations will be the ability to produce larger structures and more intricate parts as well as an aid to lessen the reliance on human labor." Furthermore, these robotics/3D printer hybrids will enable automated integration of 3D printed component parts into wider engineered systems.

Automation will be a key component of future manufacturing systems based on 3D printing, and this will apply at all levels of the 3D printing process. Increasingly, software and hardware will work together to reduce the amount of human intervention required to operate and maintain 3D printing systems. Software will automate the process of deciding how products and parts are manufactured based on complexity, materials, size, desired surface finish, and number of parts produced. Software will also automate processes within 3D printing that require human intervention such as design inspection and support placement, which will reduce the amount of pre- and post-processing, accelerating production times. Furthermore, the whole 3D printing process, from creation to finishing and the devices required for each, are going to communicate to create 3D prints better, smarter, and faster at a lower labor cost.

## Materials

There is a steady stream of new materials that are available for 3D printing thanks to the strong research and development work done by today's industry leaders. Materials in the 3D printing market represent a fraction of the cost of 3D printing, (10-40% depending on materials and geometry) but represent the cutting edge of scientific accomplishment and a key enabler for Factory 4.0. The majority of 3D printing systems use FDM® (fused deposition modeling) technology, which primarily uses ABS and PLA, but newer materials for 3D printing such as nylon and nylon composites provide greater rigidity, resistance to moisture and very high and very low temperatures, and other properties that are critical in both established and new vertical industries.

## Service Providers to Smooth Transition

One of the critical elements to wider 3D printing adoption is the set of 3D printing service bureaus that have emerged and grown with the technology. Many 3D print service bureaus have invested in technology and expertise that enable them to create a vast array of parts and products to service a wide range of industries. These service bureau organizations play a critical role in introducing 3D printing technology to different industries. As such, service bureaus are often the proving ground for different technologies, processes, and materials. Recent IDC research points to a growing desire for manufacturers to take 3D printing in-house, as a way to reduce costs and accelerate timelines. IDC believes that 3D printing service bureaus will have to evolve to take advantage of their strengths in multiple manufacturing processes, pre-and post-processing, and big data analytics. In short, over time today's 3D printing service bureaus will look a lot like today's subcontract manufacturing companies.

## PARTNER FOR THE FUTURE

IDC recommends that companies moving towards a digitized manufacturing model should select partners and suppliers that can facilitate and accelerate the move. There are some key capabilities that any manufacturer should look for in potential 3D printing technology partners that create important advantages.

- The best partners understand that quality and reliability are the foundations for moving 3D printing into production. No manufacturer is willing to sacrifice these key product characteristics for the potential benefits of digital transformation.
- Top 3D printing system manufacturers have developed printers, software and materials that are capable of significant performance benefits (e.g., lighter weight, lower cost, efficiency gains, more intricate part output, faster production, and automated processes) that are passed down through the supply chain, including to the end user.

- Suppliers should have experience with a wide range of 3D printing materials and technologies. This is critical for manufacturers that are new to 3D printing because top 3D printing technology companies have been experimenting and working with different materials, processes, and industries. This experience can both accelerate and help identify additional opportunities to realize the benefits of digital transformation. Different 3D printing hardware, materials and software are suited to different applications. There is no 'one size fits all' solution. Technology partners that understand this and can lead companies towards the 'appropriate technology solution' will provide the best partners
- Manufacturers should have an extensive global service and support network that can help companies that invest in these systems keep their systems operating at the optimal level and identifying opportunities to leverage digital transformation in additional ways.

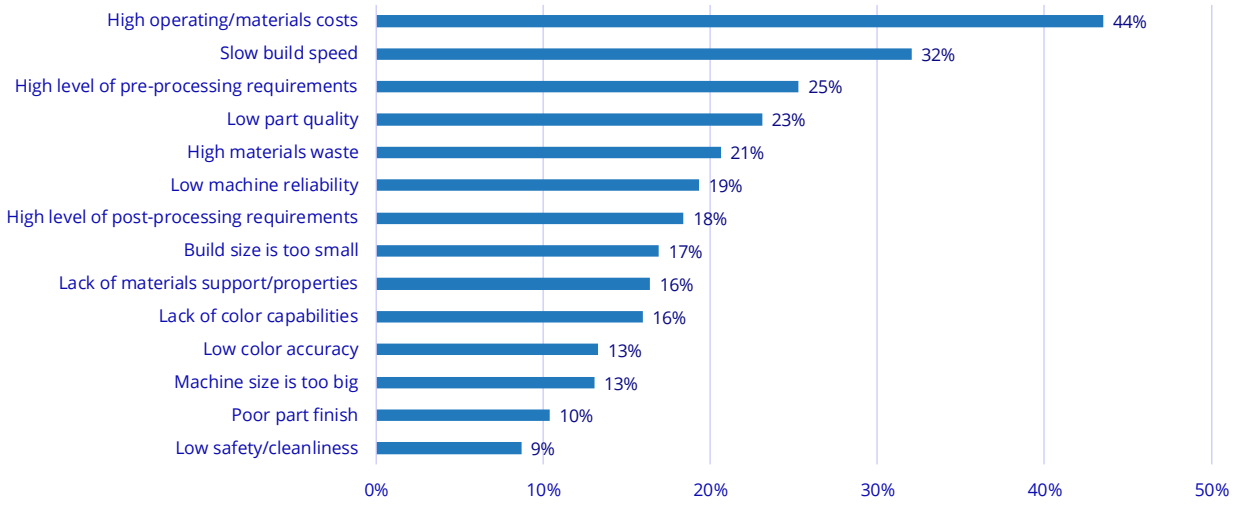
## CHALLENGES

IDC is encouraged by the ongoing development and evolution for 3D printing in the industrial market. Still, there are a number of technology challenges that need to be addressed in order for 3D printing solutions to become the norm in Factory 4.0 environments. A recent IDC survey uncovered the top frustrations with 3D printers and clearly identify the perceived shortcomings that need to be addressed (see Figure 2).

## FIGURE 2

### Top Frustrations with 3D Printers

*Q. Please indicate your company's top frustrations with your company's current use of 3D printing technology.*




n = 300 manufacturing companies with 3D printers

Source: IDC's *3D Printing in Manufacturing Study,* 2017

- **Getting past the "only for prototyping" perception.** In commercial environments, 3D printing is extensively used for prototyping versus final production. Production speed is one of the key enablers to wider adoption of 3D printing in manufacturing because speed is increasingly important to the market, and speed-to-market is increasingly important for manufacturers across a range of industries.
  - The connection of multiple printers to scale up 3D print production capacity is one solution to the demand for higher speed while leveraging existing investments.
- **Time to go mainstream.** Factory 4.0 is in its infancy, but manufacturers around the world recognize the need to invest in technologies and systems that enable digitization of manufacturing. In the bigger picture, Factory 4.0 is a concept, one that includes a system of feedback and constant iteration to maximize operations. 3D printing is well suited to meet the needs of manufacturers undergoing Factory 4.0 transformation, but it will take time for all of the investments to manifest into a streamlined and intelligent manufacturing operation. IDC sees that very large manufacturing organizations will be in a position to go from pre-4.0 to 4.0-enabled. Manufacturers in the automotive and aerospace industries that need to set up whole new manufacturing lines for updated cars and jets will plan Industry 4.0 from the foundation up. Smaller companies are more likely to go through incremental transformation. For this reason 3D printing vendors need to ensure 3D printing architecture is ready for Industry 4.0 implementation as soon as possible.
  - Real results and success stories from production environments and real manufacturers are proving the value of 3D printing every day. Companies that can possibly achieve strategic advantage using 3D printing should be seeking opportunities to do so quickly.
- **Incomplete solutions.** There is substantial competition in the 3D printing industry from manufacturers around the world, but the vast majority of these manufacturers are developing single technologies, not complete solutions. Few manufacturers provide robust software, hardware, and finishing solutions that meet the needs of Factory 4.0 implementations and fewer still are able to do so across a range of industries.
  - Manufacturers are providing much more "plug-and-play" 3D printing solutions and dealers have a large and growing level of deployment expertise in getting 3D printing systems up-and-running, providing competitive advantages to the customers that embrace the technology.
- **Beyond the niche.** Vertical markets such as automotive and aerospace industries represent some of the early adopters of 3D printing systems because of their need to constantly innovate and refresh designs. These industries also represent important opportunities as they seek to gain the same advantages for small-batch manufacturing that they have in prototyping. However, IDC expects that there are thousands of companies across a range of industries in these types of production environments that create an additional market for production 3D printing solutions.
  - The market for some products either have already, or are currently undergoing digital transformation enabled by 3D printing. The hearing aid market is a great example of highly customized products where 3D printers exist right beside injection molding and micro-mechanical manufacturing.
- **Materials.** More than 80% of production using 3D printing systems is thermoplastics. This robust market for plastic 3D printing is expected to continue to grow and the expansion of the range of materials helps address an ever-larger section of the manufacturing market. New plastic materials and processes can create bonds that are actually stronger than metal, which is critical in die-and mold-making applications.

## HOW STRATASYS IS PREPARING FOR DIGITAL MANUFACTURING WITH 3D PRINTING

Since 3D printing is expected to play an important role in the advance of digital manufacturing, the current activities of leading 3D printing providers offers insight into how this transition could develop. One of the 3D printer market leaders, Stratasys, has recently previewed a set of solutions designed to take on this opportunity.

In late-2016, Stratasys previewed its Infinite Build 3D Demonstrator and Robotic Composite 3D Demonstrator. Both solutions were intended to demonstrate the evolution of industrial 3D printing opportunities that Stratasys is targeting as part of its "What's Next for Manufacturing" mantra.

The Infinite Build 3D Demonstrator, as its name would suggest, gives manufacturers the ability to produce very large output, literally as long (Z-plane) as you want. This printing system turns the part on its side to realize an "infinite-build" approach that prints parts horizontally on a vertical plane. Currently, large manufacturer beta sites in the automotive and aerospace industries are using this system to produce low-volume, but very large-sized parts.

The Robotic Composite 3D Demonstrator brings 3D printing and robotics together in one system. The product, currently in beta, enables the production of intricately designed, lightweight composite parts. This demonstrator uses an eight-axis motion system that provides precise material placement while reducing the need for support materials that slows down production. With this system, one section of a printed part might be produced in the conventional layering method, while other sections of the part might require rotation. In these cases, rotating the part in a specific manner helps enable and optimize the production of the desired output. Future enhancements already being envisioned revolve around adding other print heads to enable finishing (e.g., polishing, painting, and enhancing part quality).

### Stratasys' Continuous Build 3D Demonstrator

The third demonstrator in the Stratasys lineup is the Continuous Build 3D Demonstrator (see Figure 3). This solution provides the ability to produce parts (up to a size of 5 x 5 x 5 in.) on an ongoing basis without the need for human intervention. The elimination of manual intervention is key. 3D printer operators, at times, function almost as babysitters and take on simple, mechanical acts (e.g., removing a printed part from the platen). If these mundane processes are automated, the manufacturer can minimize time and resource costs.

## FIGURE 3

### Stratasys' Continuous Build 3D Demonstrator


Source: Stratasys, 2017

To address this vision for a truly scalable additive manufacturing environment, the Continuous Build 3D Demonstrator sets out to address several key requirements:

- Automatic work order and print setup
- Modular and automated print cells
- Load balancing
- Scalable, distributed architecture
- High availability/failover
- Proven and repeatable with production-level part quality

From a print technology and CAD software perspective, Stratasys is utilizing established technologies. This includes its Fortus® FDM print technology and GrabCAD Print® management software. The true innovation is in the utilization of the print cells working in tandem through the cloud for a scalable printing solution. The cloud components offer work order (start/end time estimates, material volume estimate, and automatic print optimization), production grid control (queue/load balancing, printer monitoring, and managing failover), and additive manufacturing cell (automatic part slice, job status, tracking, and metadata).

The Continuous Build 3D Demonstrator has the look and feel of a conventional file cabinet. Instead of drawers, each cell (drawer) contains a 3D printer. Configurations can be as small as 1 (cabinet) x 3 (printers) and up to an almost unlimited number of printers in the entire unit. Each cell could be producing different parts that vary by size, shape, and color, to enable true mass customization. Additional cells can be augmented to a unit to increase production as demanded. If a cell fails, the job is automatically routed

to the next available cell. The inherent built-in redundancy with multiple printing cells significantly reduces the impact of failure and ensures that 3D-printed part orders can be completed in a timely fashion.

The target opportunity is to introduce a 3D printing solution that addresses low-volume production and mass customization requirements with no tooling. The economic break-even target for this solution versus traditional manufacturing techniques ranges from hundreds to thousands of one part, or thousands of customized parts.

Like the other two demonstrators, the Continuous Build 3D Demonstrator is operational in three known beta sites as well as a few other undisclosed locations. Thousands of parts have been created at the three known beta sites and running at a reported 99.4% efficiency rate. In detail, these beta sites include:

## *The Savannah College of Art and Design*

Savannah College of Art & Design (SCAD) is one of the leading design schools in the world serving over 13,000 students at campuses in Georgia, Hong Kong, and France. SCAD faced the challenge of keeping up with the student demand for 3D printing. The college's rapid prototyping lab has numerous 3D printers, but managing all of the devices was manual and time-consuming. Printing took too long and access was limited to physically going to the lab to submit 3D print jobs.

> *"We do distance learning, we have campuses around the world, so we need to be able to print 24/7. Our students submit these builds using the cloud-based interface at any time day or night."*
>
> SCAD Dean Viktor Ermoli

The Stratasys Continuous Build 3D Demonstrator has enabled a print lab environment that allows students to load CAD files from anywhere at any time. Print queues and wait times have been reduced from weeks to days.

> *"We have a large 3D printing lab with lots of 3D printers, but because we were only operational when the lab is staffed we had students waiting up to four weeks for their builds. Now that is down to days and that includes the time to ship their models overseas".*
>
> SCAD Dean Viktor Ermoli

College staff no longer need to intervene for 3D print production. High levels of pre- and post-processing time is addressed with the use of GrabCAD's front-end, Stratasys' water-soluble support technology, and new automation available with the Continuous Build Demonstrator. On the front-end, cloud-based GrabCAD Print software provides user assistance with an easy interface that provides file optimization, orientation, and support generation. Users don't need special CAD 3D file slicing software that has been challenging to users in the past. On the back-end, the Continuous Build Demonstrator uses Stratasys' proven water-soluble supports and an automated take-away system to make unattended production a reality. With its additional capacity the school is able to offer more 3D printing courses that are now deemed essential for future designers. As a very intriguing side benefit, Ermoli reports that the ability to iterate faster has led to much better quality of build from a design perspective. The Continuous Build 3D Demonstrator gives educators the confidence that all 3D printing projects will be completed without their intervention while giving students the needed attention and the opportunity to further develop their artistic skills.

> *"The work they [students] are turning in is so much better because they are able to easily inspect and optimize their designs now."*
>
> SCAD Dean Viktor Ermoli

## *In'Tech Industries Desired Zero Tooling Production*

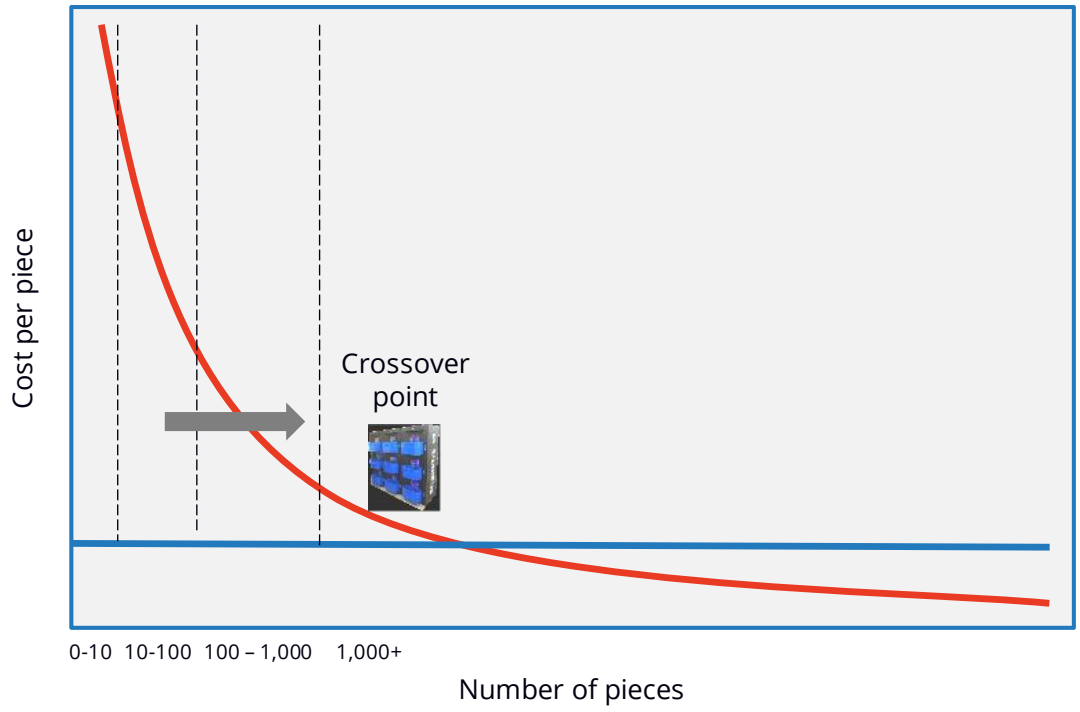
In'Tech Industries is a prototyping and small-batch manufacturing company based in Ramsey, Minnesota. In'Tech offers tooling, engineering, and injection molding manufacturing in addition to its 3D printing services. Since the company manufactures using multiple processes, it has a thorough understanding of the quality, capabilities, and economics of each process. The company wanted to increase its business potential, but it needed a scalable 3D printing system. It was also limited in its ability to produce low-run quantities as a bridge to higher-volume production projects. The Demonstrator has allowed In'Tech to keep up with customer needs with the ability to produce significant quantities (up to 1,000 parts) without tooling (see Figure 4 for the increasing economic crossover point enabled with the advanced 3D printing systems). The system is running at 99.99% efficiency.

*"Our Stratasys Continuous Build 3D Demonstrator has allowed us to do mass customization, which is critical for us. We're able to produce more than a thousand parts a day, which we never could have done before, which is helping us get into new markets, find some new customers, in our area."*

Mark Neilson - VP Operations & Engineering In'Tech

## FIGURE 4

### The 3D Printing Economic Crossover Point




Source: IDC, 2017

### *Design and Manufacturing at Fathom*

Fathom is a Northern California-based prototyping service provider founded in 2008 that was one of the first owners of the Stratasys Continuous Build 3D System. The company was looking for ways to satisfy demands for small-batch manufacturing in new market segments. Fathom needed a way to scale up production but maintain the fast turnaround and design freedom capabilities its customers and new customers demand.

*"We're now able to turn jobs around faster and compete in markets where we couldn't before based on the speed and production capacity we have now with this system."*

Fathom Co-Founder Rich Stump

The Stratasys Continuous Build Demonstrator is based on the company's proven Fortus printing systems, which use FDM print technology, the most widely accepted 3D printing/additive manufacturing technology available on the market. This is critically important because other additive manufacturing processes have not all gone through the rigorous evaluation of end customers.

*"Our customers are well-acquainted with FDM technology and its capabilities."*

Fathom Co-Founder Rich Stump

The case studies show that organizations are adopting the concept of bringing 3D printing solutions into critical application opportunities beyond prototyping. The global transfer of ideas and information, the smart utilization of unattended manufacturing capacity, and the creation of new lines of revenue based on those developments are signs of Factory 4.0 implementation. These implementations involve an intimate relationship between the 3D printer provider and the manufacturer, which is often required for the solution to be specifically tailored to the manufacturer's mass customization production requirements.

## FUTURE OUTLOOK

The historical barriers to adoption of 3D printing in higher-volume production environments are already starting to fall, which is driving investment and growth in 3D printing. IDC expects shipments of "production" 3D printers to grow at a 5-year compound annual growth rate of 21.7% in North America from 2016 to 2021. By 2021, the value of 3D prints produced in production environments is expected to grow to more than $4 billion based on IDC research[2].

IDC expects that systems like the Stratasys Continuous Build 3D Demonstrator will set the market for solutions that address the historical barriers to wider adoption and utilization of 3D printing systems.

Presently, a general lack of understanding into how best to apply 3D printing technology and for what is a limiting factor for adoption in production environments. IDC believes that as more companies embrace Factory 4.0 principles the market will become much more educated about the role 3D printing can have as an enabling technology.

For those companies that are already embracing Factory 4.0, IDC believes the single-largest barrier to adoption and utilization of 3D printing in production facilities is speed, which is increasingly being addressed by multiplying production capacity through multi-printer production systems. Another key

[2] Source: IDC

element to wider adoption will be scalability as companies want to add production capacity based on proven technologies without having to invest in entirely new 3D printing platforms. The ability to add modules based on demand, then have the system manage the load balancing, job ticketing, and other workflow, will ease integration and accelerate production using 3D printing systems.

Production speed also comes from the reduction of pre- and post-processing, which often add hours or even days to the production of 3D builds. Users will focus on reducing pre- and post-processing to get 3D printing technology into the hands of their creative and manufacturing personnel to meet customer needs for customized products which will drive greater utilization of 3D printers.

Factory 4.0 environments will be highly automated. 3D printing solutions will increasingly meet the need for "always-on" production and widely available capacity through system intelligence that Stratasys achieves with GrabCAD Print front-end software and by automating build removal and new build preparation reducing the need to have operators attend printers.

## CONCLUSION

3D printing already has an important role in manufacturing but primarily in the prototyping phase. Manufacturers around the world are trying to accelerate time to market even as they increasingly customize every product. There is a multi-billion dollar revenue opportunity in moving to a zero-inventory model, satisfying customer demands more quickly and efficiently by streamlining supply chains and reducing costs.

The integration of on-demand manufacturing solutions represent a leap forward for 3D printing in manufacturing and production environments. This solution combines key elements such as high-quality production technology with advanced materials, automation, and smart-device management to address many of the historical barriers to wider adoption and greater utilization of 3D printing systems in production environments.

## About IDC

International Data Corporation (IDC) is the premier global provider of market intelligence, advisory services, and events for the information technology, telecommunications and consumer technology markets. IDC helps IT professionals, business executives, and the investment community make fact-based decisions on technology purchases and business strategy. More than 1,100 IDC analysts provide global, regional, and local expertise on technology and industry opportunities and trends in over 110 countries worldwide. For 50 years, IDC has provided strategic insights to help our clients achieve their key business objectives. IDC is a subsidiary of IDG, the world's leading technology media, research, and events company.

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