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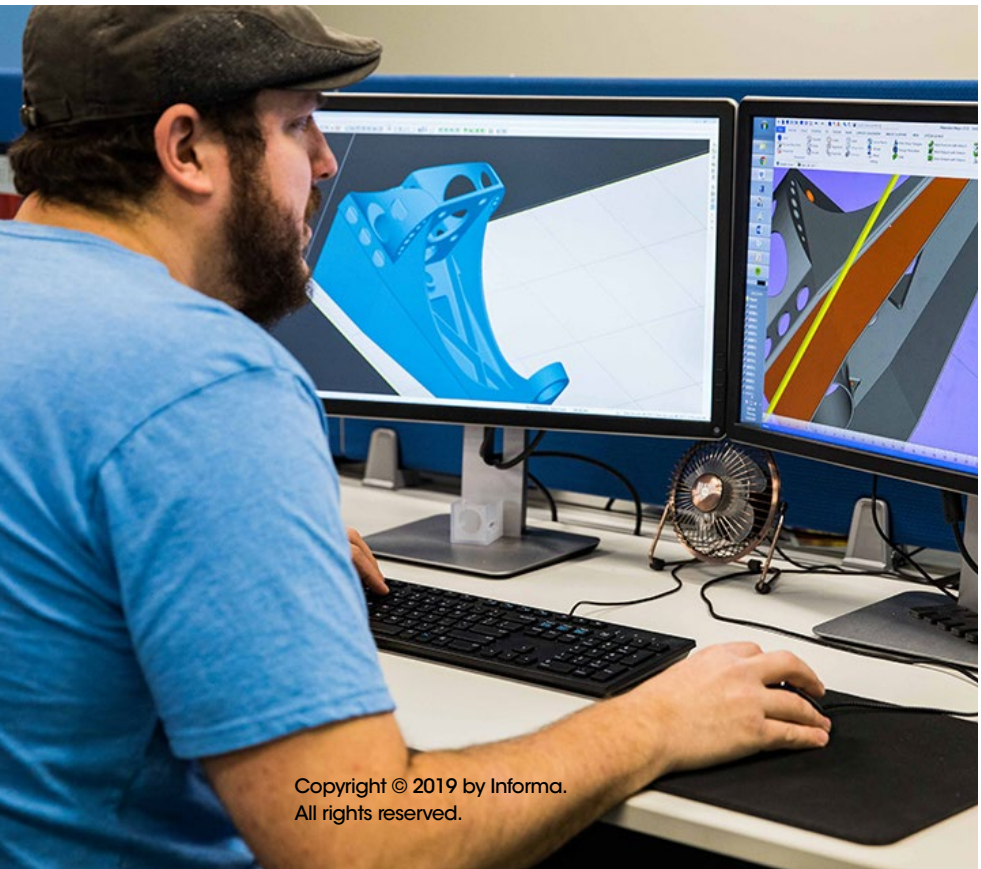
OEM HANDBOOK ON DIGITAL MANUFACTURING



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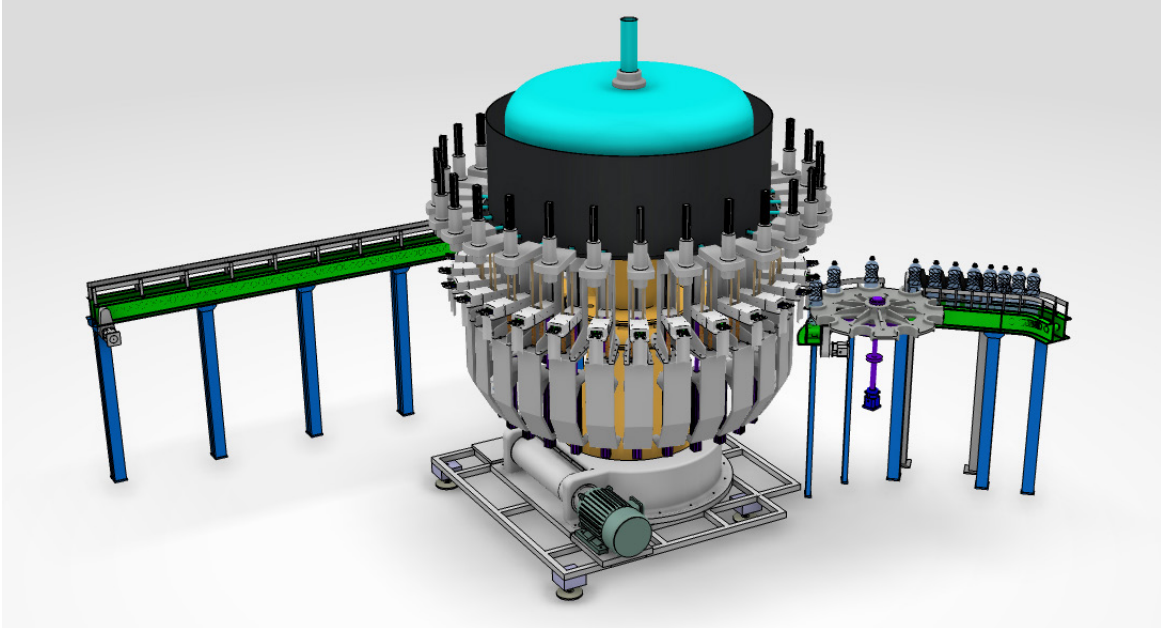
OEM HANDBOOK ON DIGITAL MANUFACTURING

CONTENTS

INTRODUCTION

Karen Auguston Field,
Content Director

DIGITAL MANUFACTURING is fundamentally transforming the way that companies develop, prototype and produce products today, from providing an economical way to deal with low volume quantities and personalization of products to rapid delivery of both prototypes and finished products. This handbook presents the essential information that engineers need today to come up to speed on this critical trend, drilling down into how the software and hardware elements of digital manufacturing work and the notion of the digital thread, to the benefits companies can achieve using the tools of digital manufacturing and a specific example of how one company took a product from conception to market practically overnight.



Virtual Assembly Line Component

CHAPTER 1:

Why the Digital Factory of the Future will be Driven by the Value Network

ERIC GREEN, VP of User Experience, Advocacy & Marketing, DELMIA, Dassault Systèmes

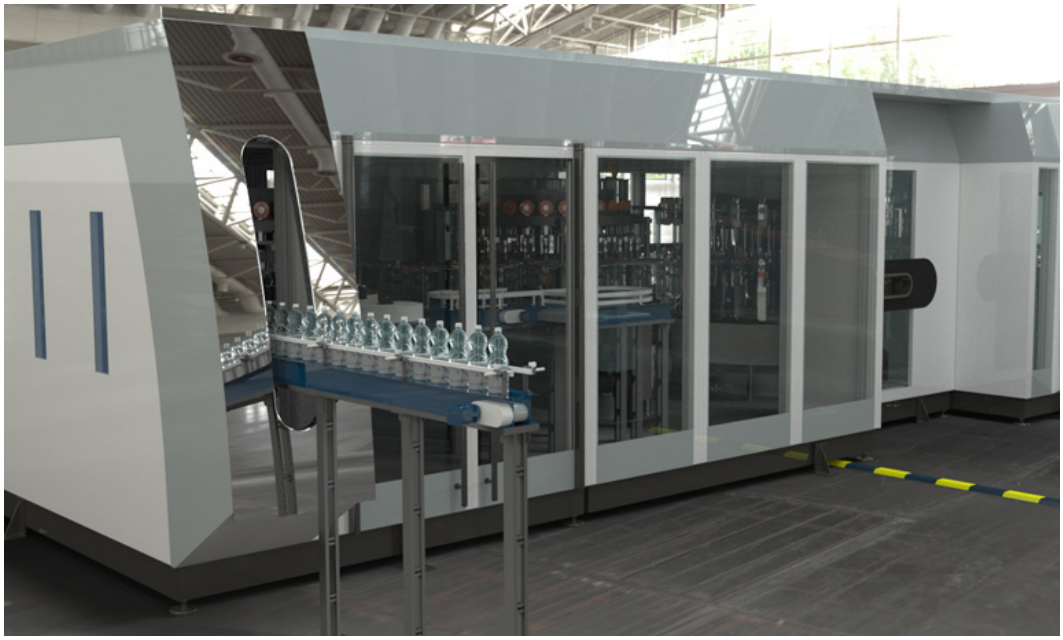
An open-access, end-to-end digital thread is bringing mass customization to mass production.

The world of making is changing, and businesses are digitally transforming from mass production to mass customization as consumers demand individualized, emotional experiences. New technologies such as 3D printing, artificial intelligence (AI), and the Internet of Things (IoT) are starting to significantly impact how products or experiences are designed and manufactured. Meanwhile, social apps, Big Data, and the Cloud are creating opportunities to interact with and understand the consumer in totally new ways. So how do we bring these new data streams and technologies together to produce meaningful business insights?

The key to leveraging the power of these new technologies and the data they generate is finding a way to connect individuals, machines, and processes across the entire manufacturing supply chain, which can now reach from raw materials to consumer interaction. This broader expanse requires shifting away from a linear supply chain to a dynamic network, which enables synchronization and integration of all manufacturing operations and supply chain activities. Achieving this requires digitalization of information and a platform that enables this level of collaboration.

Software solutions implemented within the last decade simply are not up to the task of handling this level of integration, nor the plethora of data now being created. Rather than investing in the new, many companies try overhauling the old by stringing together point solutions, hoping they gain some efficiencies. With today's pace of technological change, incremental improvements to business processes are not enough to achieve the speed and responsiveness needed. It requires an entirely new way of doing business.

Case in point: a recent McKinsey study found that across all industries, executives



Realistic Assembly Line Rendering

identified a need for dramatic improvements in particular software applications, citing dissatisfaction with certain CAD, Enterprise, resource planning (ERP), and manufacturing execution systems (MES) solutions. Among complaints was the fact that some systems are closed—they don't communicate with each other or allow others to build upon them. Yet, the key to a dynamic supply chain is a successful digital manufacturing strategy, which requires fluid digital communication.

Digital Continuity from Concept to Purchase

The concept of digital continuity begins with a digital thread. Since products are virtually designed and engineered in 3D, this data can then be used to verify all products and before any production begins. Today, various areas of a manufacturing enterprise may be digitalized and connected, but not fully integrated into a single product or system. But the notion of digital continuity is defeated if key steps along the way aren't integrated.

For the supply chain to function dynamically, manufacturers need to extend this digital thread beyond the start of production, including integrating feedback from the plant floor, the supply chain, the distribution network, and even consumers offer feedback into the models for improvement. Creating a virtual model linking disparate systems and processes across all departments and functions within the value chain is required. This means there must be integration between product life-cycle management (PLM), ERP, shop floor applications, and equipment to enable the exchange of product-related and process information between the virtual and the actual, physical manufacturing execution, creating digital continuity.

The virtual model also includes the representation of manufacturing operations management solutions. This monitors daily activity, connecting people and machines on the plant floor, assigning tasks, and ensuring proper parts and materials are in place. It communicates material requirements back up the supply chain. Going forward, it has the potential to employ AI to review production data and correlate that with other factors,

such as weather changes or supply changes, which could potentially impact delivery or production.

Another related area of manufacturing involves supply chain planning and operations tools that enable manufacturers to decide how much capacity they need and where they need it. They can improve their visibility into a global manufacturing and supply chain footprint and better synchronize it, eliminating bottlenecks through the entire value chain by matching supply and demand efficiently.

To meet new consumer expectations and realize cost savings, manufacturers need to establish more than a digital thread. Digital continuity is needed to provide the formal digital framework for information exchange throughout the manufacturing process as well as feeding a new dynamic supply chain. This requires an infrastructure built upon a platform that is flexible enough to integrate various IT applications. This platformization can achieve a "single source of truth" that provides a federated and dynamic view of models, processes, operations, and planning optimization across the supply chain.

This level of connection and data synchronization will help to realize the power of today's emerging technologies, helping manufacturers gain the insight to make actionable decisions to optimize operations while delivering a better consumer experience.

ERIC GREEN brings 27 years of manufacturing, supply chain, and software experience to Dassault Systèmes in his role of managing DELMIA user experience and marketing. Leveraging his knowledge of technology, industry, and solution development, Green provides a unique perspective to address the changing landscape of business challenges in today's companies.

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CHAPTER 2:

The Dawn of Digital Manufacturing

WILL MARTIN, Protolabs

The digital age of manufacturing is here and it's being powered by intelligent factories playing host to a perpetual dialog between software and hardware. To understand how the industry got to this point, let's take a brief trip through history.

The first Industrial Revolution—which signaled a shift from basic hand-production methods to manufacturing machines and industrial tooling—emerged in the late 1700s and was in full swing at the start of the 1800s. As America moved into the mid-1800s, the Second Industrial Revolution developed. The next 75 years (and beyond) would be characterized by production lines, mass production and heavy use of manufacturing equipment. The Third Industrial Revolution arrived in the 1950s and '60s, marked by another disruptive shift as technology began evolving from analog to digital.

At the arrival of 21st century, Protolabs was a budding manufacturing company founded by a self-proclaimed "computer nerd" named Larry Lukis who wrote a million lines of code to automate the process of making injection molding tooling. He laid the technological groundwork for what became a complex system of proprietary software with the ability to communicate to a network of advanced manufacturing machines.

The way in which we manufacture things is changing again. We're three industrial revolutions deep and on the brink of a fourth, buoyed by a concept called digital manufacturing.

An Introduction to the Digital Thread

In custom prototyping and low-volume part production, 3D CAD models not only start the conversation, but are the focal point throughout the digital thread. Protolabs accepts multiple CAD files formats that can be uploaded online at any time, and once a CAD model is submitted, automation software takes over.

The quoting software contains design and manufacturing rules that were extracted from human experts and then embodied in the code used to analyze the geometry of parts that will eventually be additively manufactured (3D printed), CNC machined, or injection molded.

With injection molding, for example, the software determines optimal part orientation in the mold and placement of the parting line, so the A and B sides of the mold can be established. From there, potential issues—like thick sections or absence of draft—are identified, and the part can even be digitally tested against a virtual representation of the model to predict material flow in the mold.

While molding considerations like parting lines and draft are of limited concern in additive manufacturing, the orientation of a 3D-printed part during the build, and its relationship to other parts on the build platform, do need to be established. All four additive manufacturing processes at Protolabs—stereolithography (SL), selective laser sintering (SLS), PolyJet, and direct metal laser sintering (DMLS)—undergo this level of preparation to create an optimal build.

Automated Design Analysis

In traditional manufacturing, an experienced molder or machinist may be able to substitute experience for analysis by simply looking at a part, but that's certainly not scalable, timely nor repeatable when immediate feedback on a design is needed.

With digital manufacturing, all of the analysis and preparation is automated, meaning an interactive quote with design for manufacturability (DFM) analysis and pricing feedback can be returned to the product designer or engineer inside 24 hours. If a design has potential manufacturability issues, recommended and/or required changes are highlighted directly within the quote so design iterations can be made before production begins.

On injection-molded parts with minor changes, Protolabs sometimes provides a second CAD model—called a Protolabs Proposed Revision (PPR)—with changes already made. The revised model can be used immediately or the designer can transfer the modifications the original model, maintaining the design history in the designer's product life cycle management system. When a CAD model is ready, a mold designer initiates another Protolabs proprietary application to design a mold system around the part, and add necessary features such as gates and runners, side-actions, perhaps pickouts, and an ejection system.

Again, pre-production prep on additive parts differs from CNC machining and injection

molding. On parts built with SL and DMLS processes, for example, support structures are designed into the CAD models. These supports help prevent the parts from curling or sagging during the build process, and are later removed during post-process finishing. Additive models are also digitally deconstruction, or sliced, into thousands of file layers and then reassembled into a production-ready build file by yet another proprietary computer application.

When a CAD model is ready to be 3D printed, machined or molded, the digital thread continues towards the factory floor.

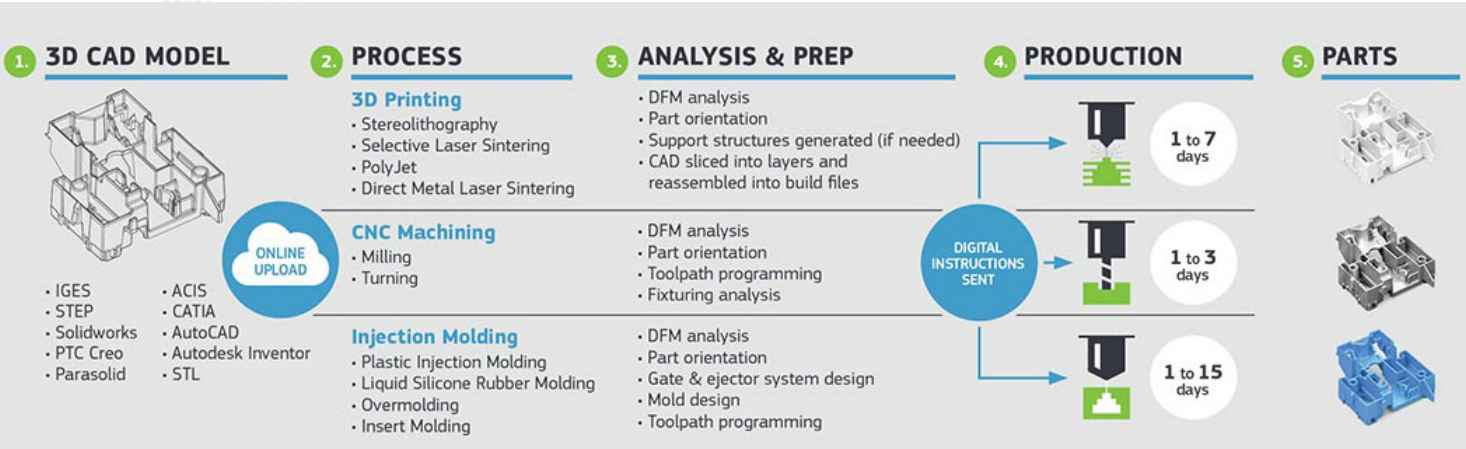
The Convergence of Software and Hardware

We've reached a point in the conversation where the mold or part design needs to be translated into a language (called G-code at Protolabs) understood by a network of manufacturing machines. This translation process is called toolpathing. Now bear with us as we throw a few acronyms your way. Automated toolpathing starts when non-uniform rational basis spline (NURBS) information and boundary representations (BREPS) on the CAD model and the injection mold are tessellated into a comprehensive geometric model in the software.

All that needs to be done next is a bit of geometric reasoning to decide which machining strategies will work best with various areas of the mold or part, then some reach analysis and collision detection are added to decide which end mills can cut which areas, and an automated fixture generation algorithm or two are tossed in.

Simple, right?

From there, it's a matter handing the design over to a digital toolpath generator, which decides where and how fast to steer the machine tools, in the process creating a program in the G-code language that Protolabs' automated machines understand. A block of material and a G-code program are loaded into a selected machine and the machine takes



it from there, based on the G-code instructions. The end result is a final machined part or a set of mold halves that are polished and sent to a press to begin part production.

Limited toolpathing is needed in additive manufacturing to begin a build, but rather the production-ready file (or file packet) we spoke of earlier is sent directly to computer-equipped SL, SLS and DMLS machines. Material is then loaded into the machine, and parts are only a few clicks away from the start of production.

Why Digital Manufacturing is Important

The beauty of digital manufacturing is that this entire thread—from CAD model to final part—is finished in less than two weeks, sometimes within a day or two. Multiple design iterations can be made. Development is accelerated. Products are launched to market fast. And supply chains are better maintained throughout a product's entire life cycle.

As the flicker of a fourth industrial revolution begins, manufacturing is poised to fully embrace the digital age for decades to follow.

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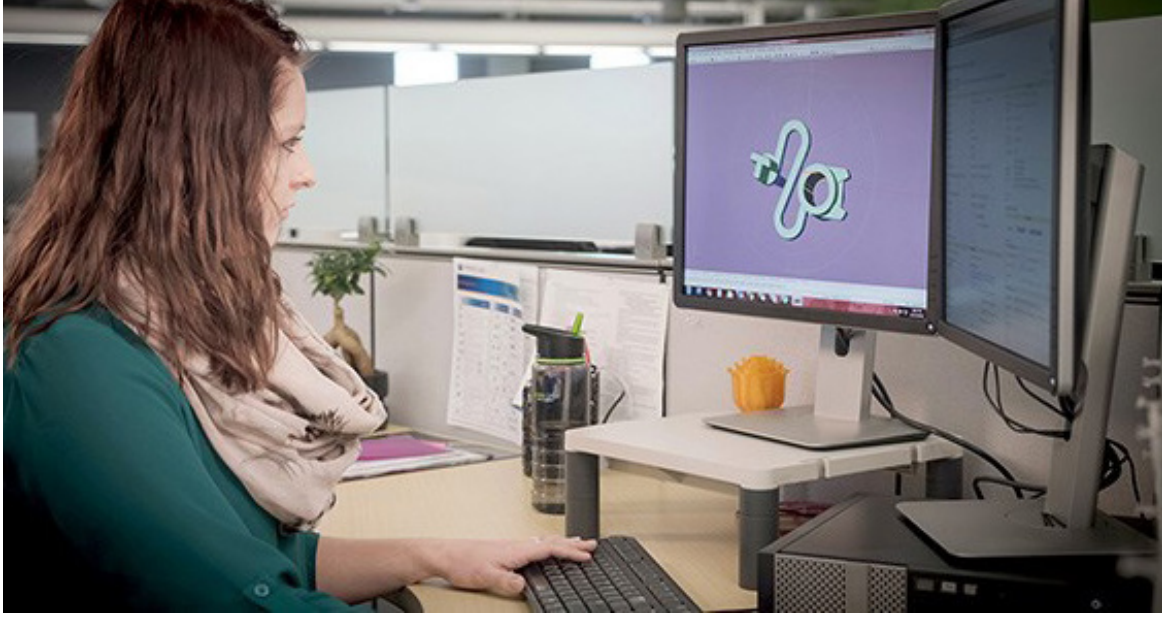


CHAPTER 3:

How Digital Manufacturing Accelerates Time to Market and Improves Efficiencies

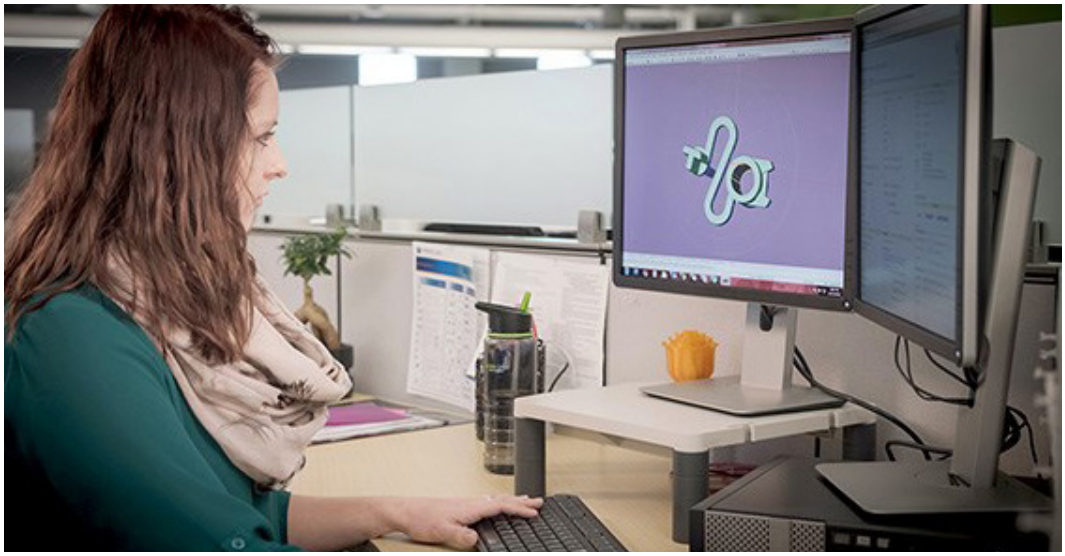
ROB BODOR, Protolabs

The digital supply chain is technology-driven, but peel away the technical layers, and, like most business initiatives, digitalization is really about achieving results faster than traditional means and at lower cost. Digital capabilities and digital manufacturing produces high quality, complex goods in less time, without the traditional handoffs and delays between disciplines. In other words, technology is a prime feature of digital manufacturers, and rapid, flexible production is the prime benefit.

Beyond speed, a digital supply chain is "on demand" by nature because a company can seamlessly move from design to manufacturing in a few quick steps. Along these lines, finding a contract manufacturer that can incorporate on-demand capability into a company's supply chain, allows that company to create a supply chain that is truly driven by customer demand, not by (and dependent on) a supplier's lead time. This can have the added benefit of dramatically improving a company's operational efficiencies.

Yes, technology such as 3D computer aided design (CAD) models and networked production machinery are on-demand enablers, but digitalization is really about a rapid response that meets design requirements. Additionally, because production and quality control are part of the same model-driven process, there is much less chance for surprises or delays when it comes to manufacturability or quality.

This article explores the emergence of digital manufacturers, how they work, tips for choosing digital suppliers, and a brief look at the benefits of using on-demand manufacturing.

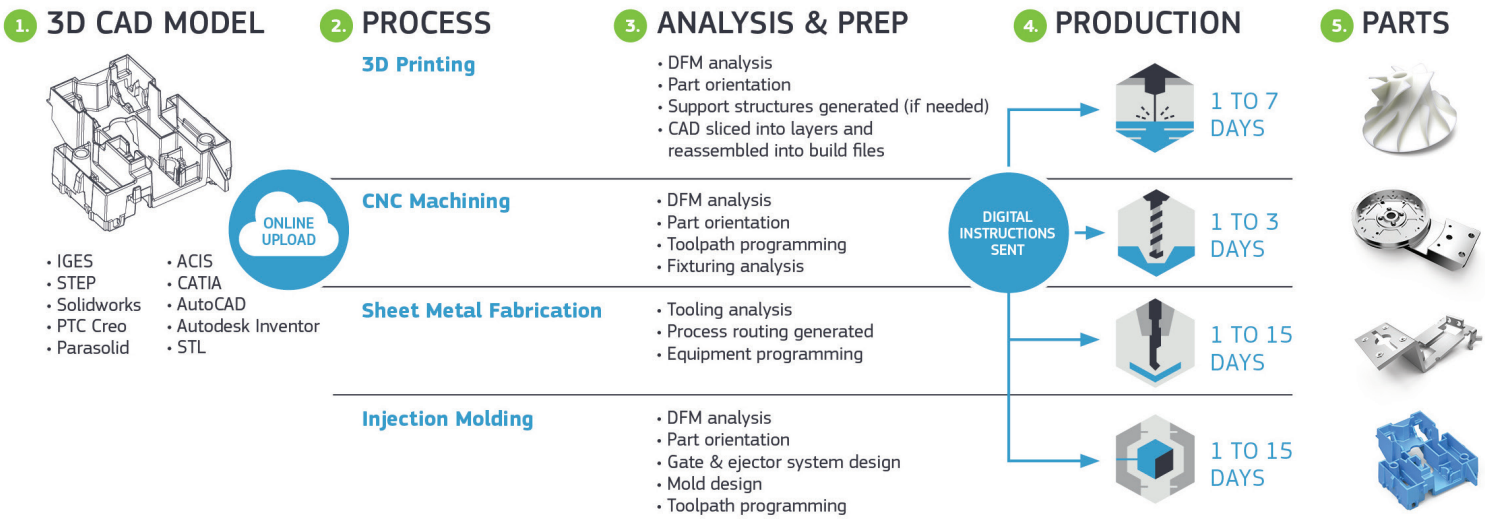


The 3D CAD model provides the foundation for digital manufacturing. The digital file makes it easier to implement design changes and simplifies the hand off that occurs between the customer and contract manufacturer.

Innovation Enabled by Digital Suppliers

In product development, digitalization speeds up time to market by automating the transfer of information. This digitalization has revolutionized manufacturing, making manufacturers more innovative and agile than ever.

Using digital technologies for different functions is not a new concept, but model-driven, integrated processes are, in fact, relatively new. Computerized systems such as CAD, computer-aided manufacturing (CAM) software, management systems with bills of materials (BOMs), and so on, have been around for decades, but only recently have companies been able to enjoy a holistic, digitized process that spans from design through to manufacturing and quality—a true end-to-end digital thread running through the



manufacturing process.

According to IT research firm Gartner, digitalization changes business models and provides new revenue opportunities. If one thinks about new models in contract manufacturing, digitalization allows for design requirements to be quickly analyzed and transferred into the manufacturing process, even for relatively complex parts. This had led to the rise of digital contract manufacturers, and permits original equipment manufacturers (OEMs) to focus on what really sets their products apart.

For many companies today, the point of differentiation is in how software or electrical systems interact with the mechanical engineering in their products, or how they've integrated internet of things (IoT) and product-as-a service concepts into their product portfolio. Therefore, product life cycles are shortened, which requires digital, on-demand contract manufacturers.

How Digital Suppliers Work

In terms of evaluating contract manufacturers, the digital partners are those that can offer an agile response. Under a fully digitized process, accurate price quotes can be provided in hours, if not instantly, and the manufacturing completed often in a matter of days, sometimes even the same day.

The primary starting point in digital contract manufacturing is leveraging 3D CAD technology to capture and visualize the customer's design intent. According to Rich Baker, Protolabs' Chief Technology Officer, "The key is to start with a model-driven process, rather than generating and working with drawings. It sounds like a simple starting point, but it makes all the difference in speed."

In the case of Protolabs, "models flow into our quoting and analysis software, which highlights manufacturability issues, and from there, into Protolabs' integrated CAD/CAM environment. From this digital, model-driven foundation, data on how to produce parts is relayed to networked machinery where the physical manufacturing takes place."

Quoting and design analysis software that examines requirements to see if specific parts can be made with specific machines, and plans out the tool path, injection molding, or other manufacturing steps, is an important enabler of rapid response. Protolabs' analysis software quickly generates a design for manufacturability or DFM report that highlights any differences between details the model calls for and how the machine can make the part.

In a non-digitized contract manufacturing relationship, manufacturability analysis is a painstaking process that may take days or weeks because humans have to manually comb through all the details, rather than allowing digital systems to automate most of the analysis. "The speed really comes from using digital technology to automate many of the planning steps involved in manufacturing specific parts," Baker said. "By automating much of the analysis, along with the quoting, the toolpathing, and other manufacturing engineering issues involved, that allows us, as a digital contract manufacturer, to be much faster than traditional manufacturing providers."

"Additionally, under the digital approach, because DFM analysis has already reconciled any deviations between requirement in the design model and how the parts will actually be made, once an order is approved, the digital contract manufacturer can leverage pre-established quality control plans and inspection points for the part being made," explained Kevin Ashton, Quality Manager at Protolabs.

"Once that manufacturability report is examined and approved by a customer and the

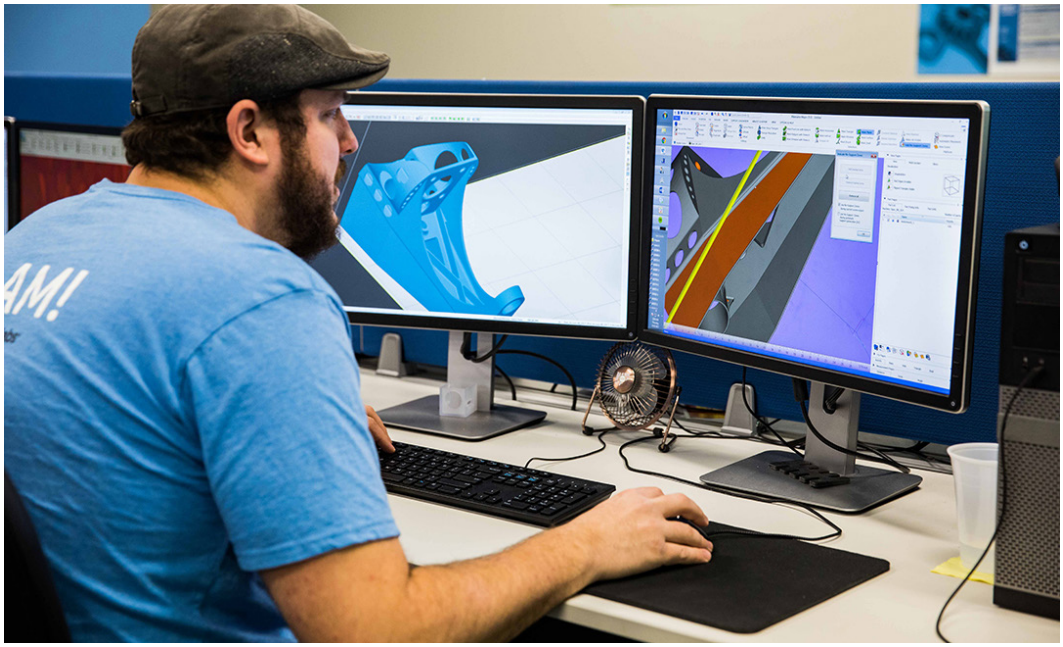
order is placed, it's as if we've manufactured that part digitally, upfront in the process," Ashton said. "Then all that code from the order can flow into our manufacturing execution system and we can apply our established processes, including quality control plans and inspection points."

Hallmarks of Digital: Choosing a Digital Supplier

Digital supply chains span many technologies, from IoT-based monitoring of machines and shipments, to cloud-based analytics and more, making it daunting to try to evaluate everything impacted by the digitalization trend. However, if you think of digital manufacturing in terms of what matters most to your company, certain capabilities come into clearer view.

In terms of evaluating a digital contract manufacturer, essential capabilities to consider include:

- Does the process begin with a 3D model that captures design requirements digitally, so the model can be analyzed for manufacturability, and easily moved into the contractor's CAD/CAM platform and manufacturing process?
- Does the process leverage online quoting and design analysis tools that highlight differences between the model's design details and the capabilities and limitations of specific machinery? A digital manufacturability report and a 3D model make it easy to visualize and review manufacturability issues.
- Does the process utilize a highly integrated CAD to CAM environment? This allows specific part geometries to flow into the proper tool pathing and/or manufacturing steps for making a part.
- Can the contractor apply proven quality controls and inspection points for how specific machines will make a part? This is made possible by a complete digital thread that begins with manufacturability analysis on the front end, followed by CAD/CAM integration and digital inspection.



Since the manufacturing process begins with a digital model, software can analyze part geometry for manufacturability during the quoting process.

Reducing Risk with On-Demand Manufacturing

Digital manufacturers can bring a new level of speed and agility to the manufacturing supply chain. Speed and agility allow companies to respond appropriately and swiftly to unforeseen market forces—leveraging on-demand manufacturing to adapt to changing customer needs, volatile demand, supply chain interruptions, and a number of other circumstances. In addition, on-demand digital manufacturing is often the most cost effective for low- to mid-volume production.

Ultimately, digital manufacturing needs to be nimble. A digital contract manufacturer needs to be fast and cost competitive while hitting design and quality requirements. The OEM doesn't want delays, quality issues, or revisions because of the lack of an integrated, digitized process. For many parts, OEMs can tap into the speed offered by a digital contract manufacturer, which allows them to launch new products to market sooner, and build a more responsive and cost-effective supply chain ecosystem.

ROB BODOR is currently Vice President and General Manager, Americas, at Protolabs, the leading online and technology-enabled quick-turn manufacturer of custom parts for prototyping and low-volume production. Bodor has also held roles as Chief Technology Officer and Director of Business Development during his time at Protolabs. Bodor held leadership roles at Honeywell and McKinsey & Company as well, and has been on the executive team of two early-stage software companies in the Twin Cities. Bodor holds B.S., M.S., and Ph.D. degrees in Engineering and Computer Science.

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CHAPTER 4:

Product Development in the Age of Digital Manufacturing

LEANNE LUCE, Product Manufacturer, Voodoo Manufacturing

Digital manufacturers helps entrepreneurs of all sizes to get to market faster and maintain flexibility.

Everything is moving at a rapid pace. Online trends occur over the course of weeks: content, games, and other digital products that were popular yesterday appear and disappear with equal speed. As product development in the physical world tries to keep up, development and manufacturing processes reveal a jarring mismatch of pace.

With physical goods, production can take months to ramp up, leaving manufacturers and brands scrambling to find solutions to bring physical products to market fast enough to stay relevant to contemporary trends and technology.

To keep up, product development for physical goods is entering a new era. Digital manufacturing can captivate the growing expectations of today's customers at lightning speeds by meeting expectations for personalization, introducing novelty, taking advantage of economies of small, and getting products to market faster.

Meeting Expectations for Personalization

Around 250 years ago, the first industrial revolution changed our relationships with the objects that are a part of our daily lives. We shifted from artisanal objects with personal stories to disposable objects bought on the go.

The emergence of digital products has reintroduced the concept of personalization to the masses. We interact with digital products that remember what we watched and liked, and that infer preferences we didn't even know we had. As the amount and accessibility of information and content has grown quickly over the past several decades, this type of personalization has gone from being a convenience to a necessity.

Hyper-personalized recommendations for music, movies, games, and other digital products and services have become expected. For example, Netflix doesn't show you





Making low-volume custom parts is possible with digital manufacturing due to the elimination of tooling.

every movie in existence when you log in, but it does make personalized recommendations based on other movies you've watched and specific interests relevant to your profile. Netflix even personalizes the thumbnails for movies and shows with images that will best resonate with you. As this has become the norm, consumers are demanding it in other (physical) product categories as well.

These days, personalization for physical goods needs to move beyond simple gimmicks such as embroidering someone's initials on their backpack. Top-tier tech firms have trained consumers to expect products that magically understand their desires.

With digital manufacturing, you can make products that are unique to an individual. When consumers can use a digital interface to recombine physical objects with different colors, graphics, and text, it gives the objects meaning and story.

Making Something Novel

You can make something feel personal without creating custom products on an individual basis. Our brains flood with dopamine whenever we encounter something new or novel. In fact, they're hardwired for it. Seeing something new or unusual is like unlocking an achievement on a psychological level. Novel products might be creative and unexpected recombinations of pop-cultural icons like home state candles,

Zooheads is a brand of novelty showerheads that demonstrate the ability to manufacture custom complex quick parts with digital manufacturing (powered by Fulfilled by Voodoo).

mason jar cookie cutters, or animal showerheads. They evoke an element of surprise, excitement, and an enthusiasm to pass along the secret.

Digital manufacturing processes like 3D printing enable creators to take risks developing and producing novel products without large capital investments. By being able to put products in the marketplace and test their performance and audience, they can continually improve and develop while proving the products' viability.

Taking Advantage of the Economies of Small

Historically, creating novel products for small niches would have had a high cost and low potential for reward. Today, the costs are much lower and the potential reward is much higher. Not only do creators have access to full featured ecommerce platforms like Shopify and Squarespace, but they have access to insights about their customers and can learn how to get in touch with them.

To add to the equation, digital manufacturing processes further reduce the barrier to entry by making it possible to launch businesses for significantly less capital. These capital-light methods create unlimited potential for businesses based on personalized products that could not exist before. Manufacturing custom robotic prostheses has only recently become economically viable due to on-demand digital manufacturing, and they radically improve the daily lives of the people who use them.

Getting to Market Faster

Products have a shorter shelf life than they used to. Retailers and brands have to capture value in small moments of opportunity. Riding these trend waves means being

At an event, Enable allowed attendees to assemble and decorate a prosthetic hand. These hands were printed and donated by Voodoo Manufacturing in Brooklyn, N.Y.

With easy-to-produce custom parts, board games can be more engaging and faster to produce for beta testing, or to fulfill pre-orders.

agile and flexible enough to respond to the speed of change, reaching customers directly and immediately. It means ramping down on a dying idea as fast as ramping up on a growing one.

Retailers can gain market validation before jumping into production through methods like crowdfunding. Kickstarter and Indiegogo are examples of this presale trend. As time goes on, these methods of presale are becoming more sophisticated. To speed up development, retailers like L.A.-based custom apparel company Frilly even sell products before they exist by posting renderings (a photo-realistic image of a 2D or 3D model) online. For customers, there might be little difference between those early rendered images and the end-product they receive later on.

Manufacture Your Next Idea

Have an idea you're thinking about producing? Look for companies that make it easy to start and scale your business' products online. By dramatically decreasing the barrier to entry, entrepreneurs of any experience level can manufacture and scale the production of physical products, which means that almost anyone can become the next Yves Behar.

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Tervis turned to Protolabs' injection molding service for help with rapid prototyping and final-part manufacturing for the covers of Tervis' popular plastic wine glasses.

CHAPTER 5:

Drinkware Maker Uses Digital Manufacturing to Quench Demand

Call it innovation driven by customer demand—with a little help from Protolabs.

Tervis, a manufacturer of double-walled insulated tumblers, has developed a wine glass that customers "absolutely love," said Matt Tosi, a product innovation engineer for the company, which manufactures its products in the U.S. Tervis sells its products through major retail outlets such as Bed, Bath & Beyond and also sells personalized tumblers, sippy cups, and water bottles directly to consumers.

What Tervis didn't anticipate, though, was that "a whole lot of people like to have their wine outdoors, on patios, and poolside, especially in places like Florida," Tosi said. "So we were getting a lot of customer requests for a wine glass with a cover or lid." As a result, the race was on to bring a covered wine glass model to market, with Tervis turning to Protolabs' injection molding service for help with both rapid prototyping and final-part manufacturing.

Development Challenge, Manufacturing Solution: Finding a Fit—Fast

A design challenge emerged in the early product development stages. It came from a fairly mundane household source: dishwashers. Tosi explained that "our products generally undergo repeated dishwashing cycles," which can create part shrinkage and cause an ill fit for any sort of lid or covering. "The covers become too tight or too loose. We needed a cover that was designed to ensure a snug fit, regardless of how many times the parts have gone through the dishwasher."

Tosi turned to Protolabs' injection molding service for help with the covers. He said

Protolabs' quick-turn injection molding service helped Florida-based Tervis Tumbler swiftly meet a major, unanticipated customer demand for these covered, insulated wine glass covers.

the automated quoting system, and, in particular, the design for manufacturability (DFM) analysis that the quoting system provided, helped guide the cover's design and development. Tosi said he also received valuable assistance from Protolabs' applications engineers, who provided advice on mold design elements such as gating and ejector pins. Two iterations of injection-molded parts were run. The eventual design, and the material used—a food-safe, BPA-free polypropylene resin—resulted in a finished prototype Tosi said he was "quite pleased with."

Beyond the "fit" issue, Tosi said Protolabs' quick-turn capabilities also came through to meet "our need for speed. [Protolabs'] lead times were very short, and using Protolabs was really the best way for us to get this new product into our customers' hands quickly."

Product Outcome: An Immediate Sellout

A first run of covers for the wine glasses was ordered from Protolabs, Tosi said, so that Tervis could test the market. Small shipments of the covered wine glasses were then sent to each of Tervis' retail outlets in the U.S. "We ran out almost immediately," Tosi explained. "They sold a lot faster than anticipated." Luckily, Tosi said, they could deploy Protolabs' on-demand manufacturing services to produce more covers in a hurry. "Protolabs shipped in 10 days," Tosi said. "Without Protolabs' quick-turn manufacturing services, we wouldn't have been in a position to meet this unanticipated market demand."

"Using Protolabs was really the best way for us to get this new product into our customers' hands quickly."

From prototyping through to low-volume, end-use production parts, Tosi said he has been satisfied with Protolabs' services, and particularly lauded Protolabs' speed. "Everything I asked for, whether I had questions of your customer service people, or I was waiting on quotes, or waiting for parts, there was nothing slow about it. It was immediate. It was all about getting stuff done. I hate waiting."

But Wait, There's More: A Suite of Services

Beyond the wine glass covers, Tervis has used Protolabs' CNC machining and 3D printing services, too. "We've purchased several other molds for other parts as well as numerous machined and SLA (stereolithography) parts," Tosi said. Like other Protolabs customers, Tervis has benefitted from the entire suite of services that the on-demand manufacturing company offers. And, no matter the manufacturing method, "We love the turnaround," Tosi said. "We are able to react quickly to our customer requests…and get feedback."

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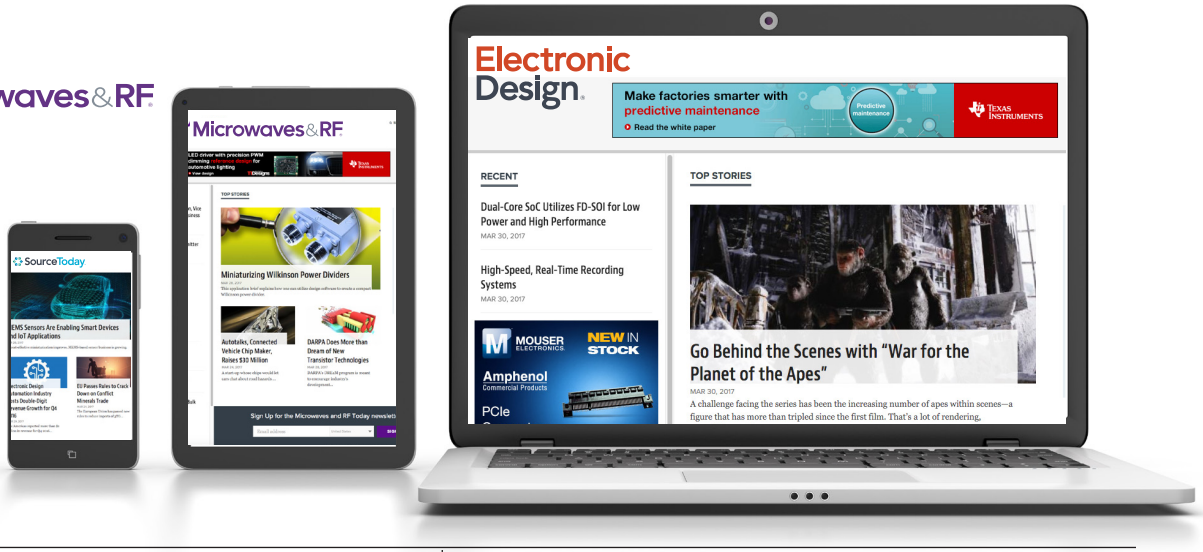

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