Digital Intensity in Manufacturing

Trendscape Innovation Group
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Irene Petrick, Managing Director
irene.petrick@trendscapeig.com

Matt Prindible, Associate
matt.prindible@trendscapeig.com

With assistance from:
Michael Butler
Hermes Frangoudis

Introduction

This report was commissioned by the Pennsylvania Industrial Resource Center Network (IRCN) as the continuation of a series of long-term studies on the impact and opportunity of broadband connectivity and information technology in small- to medium-sized manufacturing enterprises (manufacturing SMEs). It was financed by a grant from the Federal Department of National Telecommunications and Information Administration, under the administration of the Commonwealth of Pennsylvania, Department of Community and Economic Development.

The current study included a review, update, and expansion of secondary research; the development of a graphic to illustrate the diverse role of information and manufacturing technology in the enterprise; the development and testing of a survey instrument used to explore the successful adoption of new technology; and the production of detailed case studies of leading manufacturers identified by the IRCN. Our collective goal was to highlight and share technology success stories from manufacturing SMEs across Pennsylvania. We characterize their ability to adopt new technology successfully as digital intensity. We define digital intensity as the ability for an organization to identify new technology or technology solutions for existing business and/or organizational problems; present and demonstrate said technology to the larger organization; and plan new technology-driven projects as a result of previous successful technology-driven projects. Digital intensity is not an end-state. Instead, digital intensity describes a way of thinking and acting with the intentional search for opportunities to apply technology to business challenges.

What follows is an executive summary of activities to date, reflection and analysis on the resulting primary and secondary research activities, and the project's final deliverables: secondary research, a survey instrument, an illustrative graphic, and seven detailed case studies.

Overview of Process and Methodology

To begin the process of exploring digital intensity, we reviewed, updated, and expanded an existing body of secondary research. Our goal for this deliverable is to provide many traditional and unexpected examples of manufacturing SMEs having success adopting new technology (prototypes of a digitally intense organization). We sought examples with reasonably objective measurements of investment and returns, and attempted to filter out examples that serve as a marketing piece for a particular vendor.

We created a graphic that adds organizational context to technology adoption. In our graphic, we express product development innovation and business process innovation in four generic manufacturing functions: sales, design, production, and logistics.

Each regional center within the IRCN provided Trendscape Innovation Group (TSIG) with recommendations for leading manufacturers. We targeted several specific activities which might qualify a manufacturing SME for inclusion in this study: use of an interactive website and/or social media; use of collaborative engineering, planning, and/or design tools; use of front-office applications; use of back-office applications; use of technology on the shop floor; logistics and supply chain innovation; introduction of new business models; success with transformative product development; implementation of robotics and automation; and/or use of next-generation manufacturing processes. In selecting manufacturing SMEs to include, we hoped to avoid overlapping topics so that we might explore the full range of digital intensity. TSIG notes that the participation of and the recommendations received by each regional center had a profoundly positive effect on the quality of the resulting case studies.

TSIG performed a pre-assessment of the candidates by phone. The purpose of this interview was to vet IRCN's recommendations by exploring several potential projects to be featured in a

compelling case study. By design, we limited each call to approximately 20 minutes in order to maintain a high-level discussion. In addition, we constrained potential projects to those which have been "in the making" for three to five years (or what might represent a "strategic timeline") and have been successfully implemented for at least one year in order to properly reflect on the process and outcome. Completing each of these calls before starting the development of case studies ensured a diverse set of companies, technologies, and business outcomes that respected the high quality of the initial recommendations.

From our secondary research and pre-assessment phone interviews, we developed an exhaustive list of questions to define the information requirements necessary for the interviews and case studies. We organized these questions into eight major themes that could either be identified across all case studies or perhaps only unique to one particular project: Business Analysis, Defining a Business Case, Technology and the Organization, Motivations, Identifying and Overcoming Challenges, Unexpected Outcomes, Return on Investment, and Reflections. Throughout the project, we refined and updated the instrument to reflect what we learned at each case study interview, attempting to capture more of the complexity and nuance from one project and apply it to the next.

Our final activity was the development of seven detailed case studies that individually explored each manufacturing SME's experience implementing new technology. Each interview was performed on-site after a brief tour (for context and place-setting) and averaged approximately two hours. Participants generally agreed: this was an exhaustive effort.

Also to note: in the interest of collaboration and continuous improvement, we were able to use reports and notes from peer group, vendor, and OEM forums hosted by the regional centers to inform our deliverables. We made a conscious effort to include the "voice of the manufacturer" in each deliverable in order to increase the relevance and potential impact of the final product.

Summary of Digital Intensity Graphic

The first iteration of this study's graphic was created by attaching examples from the secondary research to their respective location in the manufacturing enterprise (for example, Firewire Surfboards LLC's use of parametric models to design custom boards was attached to the design function). As more and more examples were added, various gaps and edges began to appear. These emergent geometries helped drive our exploration in secondary and primary research. *Figure 1* presents our understanding of the landscape of digital tools that might be applied to manufacturing SMEs.

It should be noted that this graphic is not intended to analyze an existing organization – it does not represent a checklist of required technologies and their implementations or an "ideal future state" for a manufacturing enterprise. Instead, this graphic could be used as a conversation starter, for example, a way to organize a conversation with a client around the immense variety of digital tools and manufacturing technologies.

Guiding Principles of Interview Process

The design of the Survey Instrument was informed primarily by our secondary research in order to create a very broad framework for uncovering what might make an equally broad portfolio of potential projects successful.

The preliminary instrument suggested an approach to eliciting information and insight about the project–breadcrumbs that helped us work backwards from present day to the project's definition and instantiation. Based on previous experience, retrospective analysis of a project generally yields a reductive project history, deceivingly strong connections between project milestones, and a story that does not respect the

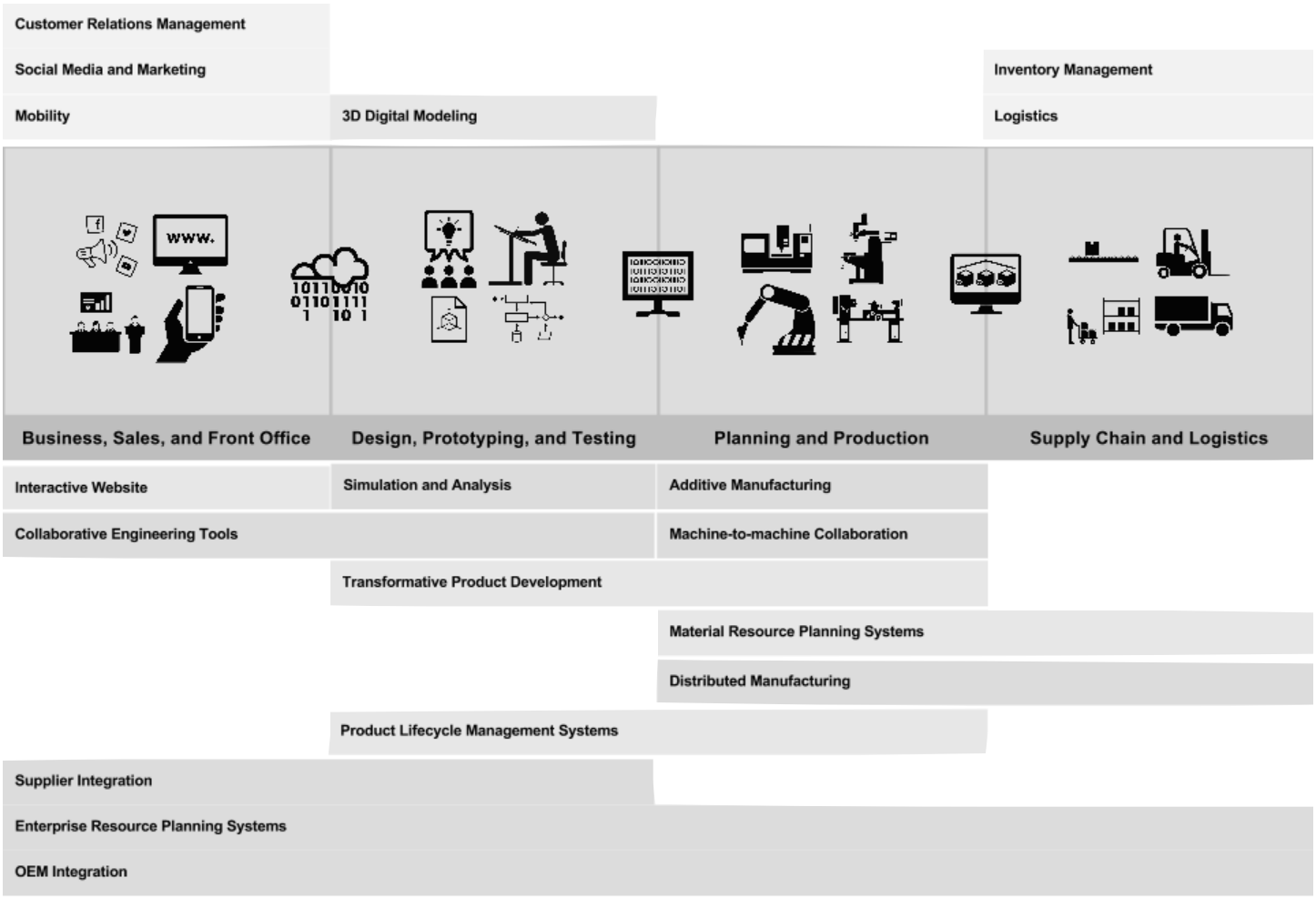

Figure 1: Digital Intensity Graphic: Technologies across the enterprise

actual experience of developing and implementing a new technology.

In an ideal sense, revealing the true nature of a project through retrospection is a bit like looking directly at the sun—direct observation without the use of specialized instruments is not possible and certainly not recommended. Instead, the questions from the survey were used to drive the larger (and often times, more chaotic) discussion, not a direct question-and-answer session.

This deliberate unpacking of the business case and its motivations, as well as a reflection on the organization's resilience and culture (and the ability to assimilate new technology and its attendants into business processes through formal and informal mechanisms of change) in the context of a successful technology project's outcomes and return on investment generates the knowledge we wish to impart on other manufacturers seeking digital intensity.

The contribution that digital intensity makes to an enterprise can only be fully appreciated if it is placed into the context of the larger organization. The story is not just about the technology. Thus, the instrument that we developed did not explicitly focus on a description of the technology. Instead, it attempted to explore and highlight the other critical elements – not unlike using a solar filter to block the sun to allow observation of sunspots, flares, and prominences, in essence, the sun's much more interesting characteristics.

Summary of Case Studies

The critical elements of each case study are highlighted below, with an expanded case study discussion contained in the Appendices.

ProtoCAM is a rapid prototyping and additive manufacturing service bureau based in Allentown, Pennsylvania. On March 6, 2013, fire completely destroyed the company's Northampton facility, its infrastructure, and production capabilities. Because of the company's existing technology and supply chain, a good insurance policy, and company culture that insists on moving forward, ProtoCAM never delayed or lost a job, and was fully operational by October—just eight months later. Ronald Belknap, President and CEO of ProtoCAM describes how the company prioritized investment in next generation manufacturing technology, how it leverages its website for ordering and education, and its strategy to move up the value chain in additive manufacturing services.

AWE Tuning is a designer and manufacturer of performance engineering products for German automobiles based in Willow Grove, Pennsylvania. As global demand for the company's products grew, production lead time stretched to 14 weeks. President Todd Sager and Marketing Vice President Jesse Kramer describe how the company acted on its strategic goal of dramatically reducing production lead time through technology, including the use of iPads on the shop floor and the digitization of its build book, and how this successful implementation and its culture has prepared the company for future success as continues to grow and move to a larger more capable facility.

L&S Machine Co. LLC is a supplier of precision-machined metal parts for the commercial nuclear industry based in Latrobe, Pennsylvania. In a supply chain governed by strict regulation, the capture, organization, and use of product and quality data is a fundamental part of the production process. The digitization of this data has not only allowed L&S Machine to evaluate its production cost and efficiency, but has become a strategic component in the company's overall business. President and CEO Rob DiNardi describes the transition to being data-driven, challenges for "big data" in his operation, and how the successful adoption of this technology has propelled L&S Machine to be the supplier of choice and created a platform for a highly scalable business.

Videon Central, Inc. is a designer and developer of commercial, industrial, and consumer media software and hardware solutions based in State College, Pennsylvania. Google approached the company to build out a consumer solution for moving personal media to the television screen based on Videon's existing working knowledge of Sony's Blu-Ray media stack, a business-to-business product. After six months of development, the company released the Avia Media Player for Google Chromecast. Rob Bargo, Vice President of Manufacturing Operations; Brandon Colton, Information Technology Specialist; Kevin Scheib, Android Developer; and Tarun Chawla, Product Engineering Manager describe the experience in building not only the company's first consumer product, but also a first-to-market consumer product.

Drexel Metals, Inc. is custom fabricator of standing seam metal roofing and architectural products based in Levittown, Pennsylvania. The company's strategic business plan and trademark, "Metal Roofing On Demand", relies on the complete disintermediation of the traditional metal roofing supply chain. As production moves away from centralizational and into smaller, local markets, Drexel Metals must provide to its partners the information and services necessary to successfully operate in this manner. Executive Vice President of Business Development Brian Partyka describes the company's use of Box, a cloud-based enterprise storage service, microsites, and interactive services and the role they played in last year's 30 percent growth.

PoolPak International LLC is a manufacturer of industrial and commercial humidification systems for natatoriums, and large athletic and leisure pools based in York, Pennsylvania. The company's strategic business plan is the sole driver of innovation throughout the company and the successful in-house development and adoption of new technology is a primary mechanism for

meeting these goals. Phillip Landis, Director of Information Technology and Michael Shillott, Director of Operations describe how an internal incident tracking system, a million dollar laser cutter, and the company's latest cloud-enabled HVAC control and programming system align with and meet the company's strategic goals.

The ExOne Company is a designer and manufacturer of nontraditional and additive manufacturing machines, and provider of digital part materialization services based in North Huntingdon, Pennsylvania. Responding to a need to help clients at the front end of the additive manufacturing and sand casting process, the company developed internally and now provides an integrated, end-to-end service. Chief Technology Officer Rick Lucas, Contracts Manager Hilary Gilmore, and Engineering Manager Larry Voss describe the strategic intention that drives the ExCast platform and how technology played a critical role in the company's recent collaboration with a major aircraft manufacturer.

The seven case studies cover a wide range of the digital tools that might be used in a manufacturing enterprise. *Figure 2* showcases this coverage. We note, however, that time limits precluded the inclusion of a case study highlighting advanced robotics and automation.

The idea that information systems and digital tools can cross and extend organizational silos also becomes very apparent. This presents an opportunity for future research, mapping the flow of data across the enterprise. For example, historically, electronic or paper-based data has flowed linearly across the organization, from one task to the next and then out the door. Modern manufacturing enterprises are beginning to use data generated at any part of the production process to inform and improve processes at any other part of the entire enterprise. Understanding this non-linearity could be a tremendous opportunity to leverage the vast amounts of data generated by digitally intense manufacturing enterprises (see, for example: L&S Machine Co. Case Study).

A Note on the Use of the Case Studies

We believe these case studies should be the primary source of consideration and reflection for those seeking to understand the challenges of an benefits to digital intensity — perhaps, dare we say, even more so than our observations, implications, and recommendations contained in this report. Because the clients of each regional center have their own set of unique challenges and opportunities for adopting new technology, we developed the case studies not to act as best practices or a step-by-step guide to achieving digital intensity, but rather an in-depth explanation of how leading manufacturers identify opportunities for new technology, manage the implementation and work through challenges, maximize the return on their investment, and/or continue to build on previous successes.

These case studies have standalone value to a company leader or staff member struggling to understand the chaos surrounding digital intensity. While the case studies represent different areas of the enterprise, collectively they capture the need for vision, the importance of experimentation, and the impact of projects that are envisioned from the outset as a set of things to be implemented and then executed in sequence.

From an IRCN perspective, the value of the case studies is twofold. First, the stories themselves will offer insights. Second, questions for the IRCN to consider should emerge, and might include:

Can you hear the voice of your clients in these case studies? How are your client's goals similar to one or more of the case studies? How are they different? How do you suppose these similarities and differences would impact their adoption of new technology?

Would a tech-savvy employee in a risk-averse company feel inspired to "champion" a technology-

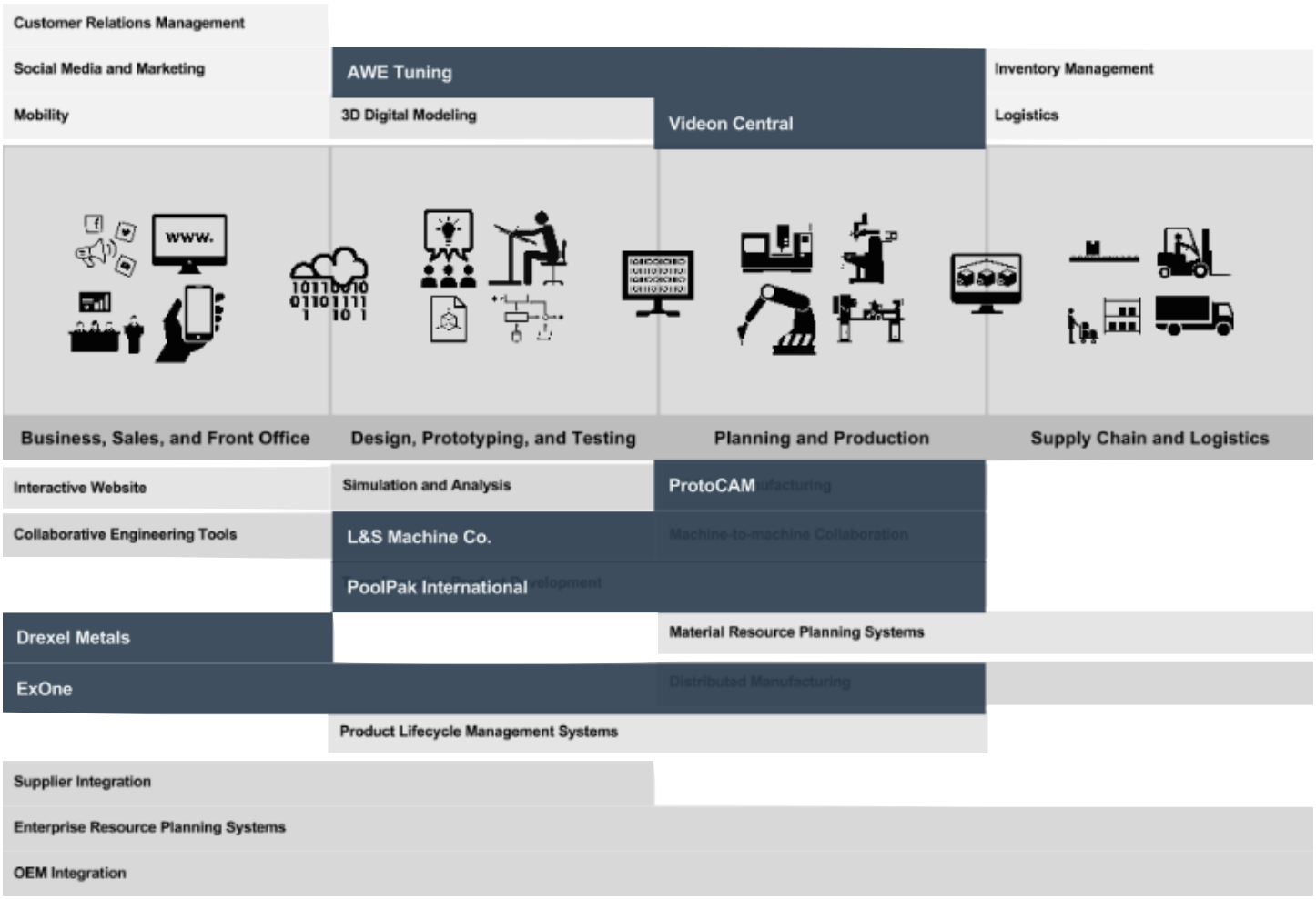

Figure 2: Digital Intensity Graphic: Case studies represented

driven project based on the success other companies have had in adopting new technology outside of a traditional or formal IT department?

Would the CEO of a company, after reading the story of a nontraditional approach to business development through the use of simple digital tools, feel more confident searching internally for alternative solutions to those pitched by external vendors?

Do these case studies, especially examples of technology aligning with business goals, motivate IRCN staff to become more familiar with technology, even though it may be well outside their area of expertise?

How can you help companies better articulate their path to success, share this information, and become leaders in their network of manufacturing peers?

Observations from Research

In our previous studies, we attempted to look at the whole of manufacturing SMEs across Pennsylvania in order to characterize its current state, identify key trends, and gauge the level of readiness for the adoption of new technology. What we found instead was a highly fragmented landscape, little to no common understanding within our sample group, and the need to identify leading organizations that would serve as the foundation for our understanding of, what we now call, digital intensity.

As a result of this most recent study, we have identified five exciting trends that could have a major impact on the IRCN and the manufacturing SMEs it serves:

1. Companies are no longer planning large, monolithic IT projects that have historically caused

disruptions throughout the organization (such as ERP systems)

2. Companies are instead acting on their business strategy by executing a series of small, exciting technology-driven projects with specific intention and direction

3. These small projects yield disproportionately large wins that continue to grow in value after the project's instantiation

4. Increasing digital intensity enables the possibility of new capabilities and capacity, instead of using new technology as a means to an end

5. Digital intensity is not an IT project, but rather results from a set of technology-driven projects, often led by champions outside traditional IT staff

If these characteristics, derived from the experiences and successes of these companies, represent digital intensity in manufacturing SMEs across Pennsylvania, and if these activities are not specific to the traditional or formal IT department and/or staff, there are major implications for other manufacturers seeking digital intensity.

Implications of Digital Intensity

For manufacturing SMEs seeking digital intensity, overcoming the challenge of strategic planning is immediate. Historically, the strategic use of technology in manufacturing SMEs has been uncommon. What is common however, are organizations using methods of lean and/or continuous improvement to increase operational efficiencies and reduce costs, putting one step in front of the other.

Digital intensity is distinct from traditional strategic planning in two ways:

1. The strategic function of digital intensity is not the end-state, but rather the long-term focus on building new capacity and capability and gaining the confidence to identify and adopt new technology with increasing returns. The means of digital intensity and its tactical execution are typically aligned with strategic business goals. Because of this relationship, there is an interesting opportunity to harness the passion for a company's product and familiarity with continuous improvement to transition from process improvement and cost-cutting measures (bottom line improvements) into new product development or customer service (top line investments).

2. Technology-driven projects can have an impact on any part of the enterprise and therefore can be introduced by any part of the business. Company leadership should no longer expect technology-driven projects to be proposed by formal IT staff or third-party vendors, but should seek innovative ideas from bottom to top, formal and informal.

Looking forward, the technologies and services that fit the scope of digital intensity – small, modular, service-oriented, cost-effective – will be offered and available through broadband connectivity (think software, platforms, and infrastructure as a service). An increasing portfolio of potential solutions accessed through the cloud also increases the opportunities for companies to identify, experiment, adopt, and implement new technologies across the enterprise.

For regional centers working with their clients, this presents a complicated arrangement. The acceleration of technology adoption in manufacturing SMEs is the core of the IRCN's identity and mission. As a fun thought experiment, assume that the list of potential new technologies for manufacturing SMEs approaches infinity. How can IRCN provide project assistance or advise on best practices for an infinite number of technologies and an infinite number of implementations? Perhaps IRCN should embrace what might seem like an exercise in futility and consider the idea of a mission-driven engagement. What does a contract between a regional center and its client look like as a mission-driven project

versus a technology-driven project? An interesting provocation.

An example of this type of opportunity might be the rising interest and increase in grants and funding for security and risk analysis. The idea of a secure enterprise with a higher awareness of risk could certainly be considered a mission (not unlike digital intensity) with a variety of attendant projects and technologies. This could open the door for broader digital intensity work that starts with a clearer purpose.

Recommendations for Future IRCN Efforts

Because of our collective success in identifying leading manufacturing SMEs across Pennsylvania and developing our primary research and case studies based on their expertise and experience, we recommend that the IRCN staff read the attached case studies. Because of the exciting and compelling examples within the case studies, we recommend reading them again. *With gusto!* A single reading tells an interesting story, but multiple readings and comparisons across case studies offer the chance for insight.

Because of the time constraints of this project, we were unable to secure participation of a company that represented robotics and automation. We believe this is a key component of digital intensity and will only continue to increase in importance as digital tools for planning the implementation of automated robotics on shop floor mature. We highly recommend further inquiry into this domain using the process from this study (supporting secondary research, identifying a leading manufacturer, interviewing, and analyzing).

Because of the success and compounding positive effect of IRCN and TSIG collaboration, we recommend the addition of a "rigorous sense making" phase to a future study. The combination of IRCN's extensive knowledge of its clients and TSIG's unmatched analytical capability, with deeper discussions around the content of our case studies could yield an even more compelling set of observations, implications, and recommendations.

As the portfolio of available technologies and services for the manufacturing enterprise continues to grow, the ability to study each offering, its implementation, and best practices will become more difficult. We recommend the IRCN or regional centers begin to prioritize specific technologies or domains for deeper investigation. We recommend this prioritization as a complement (rather than an alternative) to deeper investigations into the mindset and philosophy of new technology adoption, as this knowledge will apply to a wider range of projects.

Finally, we recommend that the IRCN and its regional centers begin the process of turning these insights into actionable steps (whether that is through internal changes or client services), specifically by adopting an attitude similar to our case study observations: small, experimental demonstrations of new technology and its business value.

Acknowledgements

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Appendices

Secondary Research

As the interview process begins for our primary research and case studies, our preliminary expectations and the ability to compare and contrast Pennsylvania's leading small- to medium-sized manufacturing enterprises depends on broad secondary research. There is tremendous excitement around the nation from manufacturers, vendors, policy writers, and the general public. In the interest of delivering a sober, actionable body of research, we have decided to focus solely on specific, existing business cases for sophisticated, technology-driven manufacturing operations.

This secondary research, to the best of our efforts, represents best-in-class examples of digital intensity across small- to medium-sized manufacturing enterprises.

Our completed secondary research will serve to fill in the gaps on our Digital Intensity Graphic across business, sales, and front office; design services, prototyping, and testing; manufacturing planning and production; and supply chain and logistics. We will also add public-private partnerships to the mix – the market and political mechanisms that enable manufacturing SMEs to access to leading-edge technology.

These are the things that excite us:

Makers Row, Inc.

Founded in November 2012 and based in New York City, New York, Maker's Row, Inc. is a 10-person (plus one dog) online marketplace for opening and connecting American manufacturers to custom short run, small- and medium-sized, and product-based businesses. The site currently lists the in-depth profiles of over 5,000 factories that can be searched by product stage, industry or product category, and location. Each profile contains detailed information such as: contact information, reference samples, capabilities, hours and location, and reviews.

Currently, Maker's Row caters extensive to apparel and accessories, and furniture and home decor, but the company plans to expand to many other industries using the same model. The website, in its current form, helps businesses connect with manufacturers along each stage of the manufacturing process: ideation, pattern-making, materials, sample-making, tooling, and production. Businesses can contact manufacturers directly through the site and use the platform to maintain this relationship.

Mitch Cahn, president of Unionwear, a Newark, New Jersey-based textile services shop notes: "At first, Unionwear was very surprised at how quickly Maker's Row was generating qualified leads for our custom hat and bag cut and sew. But then we realized that there was nothing like Maker's Row in the marketplace – no way for designers to easily find domestic textile factories and filter through their capabilities and market niches to find a perfect match. We have even begun using Maker's Row to find raw materials, and an additional benefit is that we now have a place to send clients who are looking for products, materials, or quantities that are not in our wheelhouse and know that they will find a domestic source."

Make Works Ltd.

Founded in 2013 and based in Edinburgh, Scotland, Make Works Ltd. is a 12-person independent design company that facilitates, celebrates, and debates design, craftsmanship, and manufacturing. The group's first product is the Make Works Directory, an online service that opens up access to Scottish suppliers, skilled labor, and manufacturing by making sourcing factories, fabricators, workshops, and facilities easier (not unlike Maker's Row, Inc.).

Businesses can search the Make Works Directory by industry, material, processes, and location, as well as access resources such as: original articles, production guides, and case studies. Each manufacturers' profile contains: production specifics (turnaround times, starting costs, production access, and supported file types), materials, processes, machines, and production capacity (bespoke one-offs, samples, prototypes,

short run, medium run, and/or large run). The profile also has a short video showcase, client list, contact information, and related companies.

Shapeways, Inc.
Founded in 2007 as a spinoff from the lifestyle incubator of Dutch company Koninklijke Philips N.V. and based in New York City, New York and Eindhoven, The Netherlands, Shapeways, Inc. is a 140-person marketplace and production service provider for 3D printed objects. Shapeway's online platform gives designers access to the most advanced 3D printing technology, capable of manufacturing the 120,000+ designs uploaded each month by its 400,000+ community members in 40 high-quality materials. The company ships over 120,000 products each month to 119 countries.

Shapeways provides beginner designers or those new to 3D modeling tools access to TinkerCAD and Autodesk 123D, simple in-browser design tools for creating 3D models that can easily be uploaded to Shapeways' platform (any piece of software that can export a standard 3D model file can be used with Shapeways).

Once a designer has uploaded a 3D model to the platform, a series of simple tests are run on the model to ensure it is manifold and that the overall geometry and wall thickness meet the minimum requirements for a successful build (depending on material chosen). If a designer encounters any problems, the design can be modified in-browser to satisfy build constraints. Shapeways also calculates the total cost of the print as well as shipping and handling. At this point, the customer can purchase his or her design or sell it in the marketplace.

Firewire Surfboards LLC
Based in Carlsbad, California, with an office in Currumbin Waters, Australia and its major manufacturing plant located in Nonthaburi, Thailand, Firewire Surfboards LLC is a 120-person global designer and manufacturer of professional surfboards and kiteboards. Innovation and product differentiation in the high-performance and professional surfboard industry is driven primarily through new materials and construction methods which, in turn, open the door for new design possibilities. In 2009, ShapeLogic LLC, a company that had recently developed sophisticated parametric models for custom sporting equipment approached Firewire to build a web-enabled design tool that offered customers the ability to design a surfboard to meet their exact needs and specifications—the "Holy Grail of the individual surfer's relationship to his or her equipment", says Firewire CEO Mark Price.

Using Firewire's online design tool, customers can start the process with one of the company's existing designs and then alter the board's length, wide point, nose and tail width, and thickness to their exact preferences. These dimensions are fed into ShapeLogic's parametric model and analyzed against the model's rules to ensure a valid design (completely invisible to the customer) and eventually sent as a solid model directly to the machines that construct the board. What the customer does see, however, is a 3D model of their board from all angles with a variety of viewing, lighting, and rendering options. This ensures that customers fully understand their design before placing the order. Customers can also download this model to share with their social networks—this visual asset has become a tremendous viral marketing tool for Firewire which has directly increased the company's lead generation.

As a result of this bespoke design and product offering, newcomer Firewire Surfboards LLC has quickly become the second-place leader in manufacturing surfboards for competitive professional surfers.

Two Roads Brewing Company
Based in Stratford, Connecticut, Two Roads Brewing Company is a 19-person brewer of craft beer. The brewer is unique from other brewers in that not only to they produce both their own brand, but they also contract out their infrastructure to emerging brewers. They are able

to absorb costs and contract out production time within their state-of-the-art brewery using its production equipment to brew for individuals or companies who lack the capacity to maintain their own physical brewery.

Two Roads Brewing Company is able to utilize their existing infrastructure to expand their business beyond just manufacturing their own product. The company has turned their facility into a platform that smaller companies can use without having to pay the money to run their own brewery, and in turn Two Roads Brewing Company has seen a substantial increase in business. In an interview with TheVerge.com John Rehm, Director of Brewing Operations commented that,"We thought that we would be successful, but we really have exceeded our own expectations and thats why were growing at the rate that we are." He later went on to say that, "We have more than doubled production every year that I have been here."

The entire brewing process is monitored from a control station, with the majority of the actual production being accomplished through automated equipment such as their bottling assembly line. Brewers who seek to contract time with Two Roads are able to utilize equipment that would otherwise require a large capital investment. Contract partners are able to take advantage of a 100-barrel Rolec brewhouse, a Westfalia Centrifuge, 100 and 300-barrel Rolec fermenters, a 300 bottle-per-minute bottling line and 60 keg-per-hour kegging line.

Local Motors, Inc.
Founded in 2007 and located in Phoenix, Arizona, Local Motors is a 45-person manufacturer of automobiles that uses crowdsourced design and advanced manufacturing and technology to create unique, game-changing vehicles. The company's online co-creation platform enables its 36,000 enthusiasts and engineers to leverage Local Motors distributed manufacturing and supplier network to imagine and design one-of-a-kind vehicles which are then assembled by the customer and Local Motor's engineers at one of the company's three "Micro Factories." The platform is currently hosting almost 5,000 designs and 1,000 ideas across 336 active projects with contributors from over 130 countries. Local Motors first commercially available product is the Rally Fighter, an open-source, street-legal, off-road desert racing-inspired vehicle that costs $99,000. The company is currently working on a crowdsourced, open motorbike design, The Cruiser, which is a gas and electric hybrid but also complies with bike lane regulations for cities.

FirstBuild
Founded in July 2014, FirstBuild is a 22-person partnership between Local Motor's Microfactory, Inc., General Electric's appliances subsidiary (now owned by AB Electrolux), and Stratasys, Ltd. The goal of the partnership is to create a community of industrial designers, scientists, engineers, makers, and early adopters to work together on engineering challenges and innovation. The FirstBuild community is built on the processes that Local Motor's employs to develop their crowdsourced automobiles and motorbikes—ideas, projects, and design challenges, along with a variety of in-house makerspace/hackerspace-style activities.

FirstBuild showcased its vision and capabilities with the introduction of four products built at FirstBuild: an auto fill, no-spill water pitcher; a compact, under-sink food disposer with anti-clog sensors; a double-oven range with a top oven that opens like a drawer; and an oven that reads barcodes and uses custom instructions to prepare meals. Currently for sale is the $19.95 Green Bean Maker Module, a user-programmable microcontroller that extends the functionality of a range of compatible GE appliances.

Quirky, Inc.
Founded in 2009 by 23-year-old Ben Kaufman and located in New York City, Quirky is a 120- person designer and manufacturer of consumer products that is powered by an online platform for crowdsourcing and refining new product ideas. The process that Quirky has developed is that

users (of which there are currently more than 625,000) submit ideas (through the web or the company's iPhone app) for new products that are voted on by the community. The Quirky product team, along with its network of external industry experts evaluates the leading products and chooses the next product for production. Quirky engages its user base to further refine the design before it is readied for manufacturing. Currently, the company has produced 403 successful products. Because of Quirky success in quickly filling market gaps with new products, General Electric has chosen to invest $30 million in a partnership to develop "playful consumer products." The goal is to collaborate on six new projects each year for the next five years, particularly ones that leverage Quirky's WINK, a platform for developing Internet-ready devices.

M.G. Bryan Equipment Company
Located in Grand Prairie, Texas, M.G. Bryan Equipment Company is a heavy equipment and machinery OEM for the oil and gas industry. M.G. Bryan partnered with Rockwell Automation and Microsoft to create a cloud-based asset performance management system. Designed and integrated with Rockwell's sensors and devices, M.G. Bryan's new equipment control and information system leverages Microsoft's Windows Azure cloud-computing platform to help provide secure remote access to real-time information, automated maintenance alerts, and service and parts delivery requests. Along with sensor integration, Rockwell also helped M.G. Bryan design a simple, user-friendly application that can be accessed across multiple devices from the cloud in order to improve access to business information.

M.G. Bryan focused on its hydraulic fracturing vehicles in the first release of its cloud-based asset management system. Leveraging their new platform, the company can remotely track the vehicles' performance and maintenance schedule—oil filters need changed every 200 hours and engines need rebuilt every 4,000 to 5,000 hours—and optimize and increase their fleet's uptime.

Niner Bikes
Headquartered in Torrance, California and with offices in Fort Collins, Colorado; Whittier, California; Salt Lake City, Utah; Taiwan, and Vietnam, Niner Bikes is a 22-person designer and manufacturer of 29-inch wheel mountain bikes and parts (the company chose these specific locations because of, among other considerations, the availability of broadband internet speeds greater than 250 mbps).

Projects at Niner "begin with a Google Doc" for brainstorming a wishlist for new products (all employees are competitive riders, using their experiences to inform new product development). The company gathers ideas from customers through chat rooms and consolidates the ideas. The product design team uses this wishlist to create realistic specification in a Google Sheet. Engineering and design teams collaborate on Solidworks 3D models through Dropbox and do virtual testing with CATIA from Dassault Systèmes. Marketing teams have access to the final product renders through the same Dropbox, so that the team can immediately begin work on the new product materials.

Niner has recently replaced QuickBooks and Google Sheets with a more formal cloud-based system from NetSuite as they manage their 70 percent annual growth in review and doubling of product SKUs. Niner currently works with 300 domestic distributors and 38 international distributors. This system has has helped Niner Bikes increase inventory turn rates to 3.8 percent, compared to the industry average of 2 percent.

DDB Unlimited, Inc.
Based in Wynnewood, Oklahoma and with another plant in Pauls Valley, Oklahoma, DDB Unlimited is a 140-person OEM manufacturer of rugged outdoor cabinet enclosures for electrical and communications equipment. In April 2010, DDB Unlimited invested $235,000 in an in-house ERP system. The company hoped to gather information from its disparate accounting, inventory, and manufacturing departments into a central database

for a real-time view of its manufacturing processes. Unfortunately, even with a successful rollout and integration into its legacy systems, the adjustment and maintenance proved difficult and detrimental to business.

In January 2011, DDB Unlimited switched to a cloud-based ERP system from another provider, Acumatica. Acumatica handles software upgrades, patches, and backup, freeing DDB Unlimited's IT department to focus on its production facilities. Employees can use the system to track manufacturing costs, view accounts receivables, enter purchase orders, review inventory, and clear checks. The system has helped DDB Unlimited whittle its order-processing cycle from two hours down to 45 minutes. Employees can access the system from a remote computer for real-time information such as a customer's purchasing history.

It cost DDB Unlimited about $100,000 to transfer data and take the other steps necessary to implement Acumatica's cloud-based ERP system, which costs $35,000 per year. However, the transition from an in-house ERP system to a cloud-based ERP solution will cut $80,000 in annual expenses.

Hiawatha Rubber Company

Based in Minneapolis, Minnesota, the Hiawatha Rubber Company is a family-owned designer and manufacturer of custom-molded rubber parts and assemblies for OEMs. Hiawatha recently replaced an aging, in-house ERP system with a cloud-based ERP solution from Plex Systems, an independent software vendor specializing in cloud-based manufacturing software. While their old system could provide basic information, it lacked the ability to provide the detailed, real-time and accurate financial and manufacturing information that company decision makers needed. This was particularly challenging when they were trying to integrate production data with costing and quality data.

Following a three-month implementation—about half the time it took to install the original in- house system—Hiawatha managers were able to see the value of real-time visibility. According to Tim Carlson, a company manufacturing manager, "the plant-floor employees now see upcoming jobs and where materials are located in real time, enabling them to make quicker and better decisions. Now when a customer calls for a rush order, we can tell them in minutes when their order will be ready, compared with several hours and a significant amount of manual effort when we had our previous system in place." The company's website proudly advertises this capability, saying: "Our extensive and sophisticated enterprise resource planning system lives in the cloud, giving us a platform that's typically only found at Fortune 500 companies."

Spring Dynamics, Inc.

Based in Almont, Michigan with a second facility in Harlingen, Texas, Spring Dynamics, Inc is a 49-person manufacturer of custom precision springs for the automotive, aerospace, appliance, military, and defense industries. Spring Dynamics recently replaced an in-house ERP system that was limited to accounting functions and standard reports on inventory, accounts receivable, and accounts payable. Management demanded a more comprehensive system that would also integrate shop floor operations in order to generate more detailed reports and maximize performance across the entire enterprise.

After settling on an appropriate solution, Spring Dynamics successfully implemented Plex Cloud ERP across both of its facilities in just four months without any system downtime. With the addition of Plex to the company's existing processes, Spring Dynamics now had a complete enterprise resource planning and manufacturing execution systems, along with product quality management, customer relationship management, and shop floor integration—the system enables employees to access and create real-time reports from filtered data generated across the entire enterprise.

As a result, the company no longer needs to invest internal resources to manually tracking inventory. Jessica Marco, president of Spring Dynamics notes: "We had two people in the Materials Department who had to run around and pull cartons, manually enter part numbers, and print and compare paper reports in order to try to figure out what was missing and where it was." Today, the company scans barcodes to identify and track all products with nearly 100 percent accuracy (the only variation since implementing Plex was an existing carton not properly entered into the new system before launch), compared previously to a costly 5 percent variation in actual and recorded product inventory.

Industrial Control Associates, Inc.
Located in Lagrange, Georgia, Industrial Control Associates, Inc. (ICA) is an eight-person systems integrator and machine builder specializing in programmable logic control system machines. The company relies on its software and networked systems to "present a large company image" to larger customers such as Cooper Tire & Rubber Co., DuPont Chemical, Procter & Gamble Paper Products, and Tyson Foods. ICA accomplishes this through product lifecycle management software, specifically Siemens' Teamcenter software, that has been specifically configured for web-based development and implementation and quick return on investment—a boon for small-medium manufacturing enterprises. CEO Brian Hare notes that prospective customers from large organizations are "surprised to see that we have the same type of technology they're using. It inspires confidence right from the start.

As a result, the company is better able to manage product revisions, drawings and models, PDFs, quote documents, conceptual drawings, pictures, and other background material and immediately notice the improved quality of drawings and bills of material that it can provide to customers. The time it takes to search inventory has decreased from 10 minutes to 30 seconds, improving the quality of customer service that ICA is able to offer. The company can also collaborate with customers on assemblies with a web-based communication process that takes about 30 seconds to initiate versus 30 minutes in a previous system which allows more frequent "mini design reviews".

Videon Central, Inc.
Based in State College, Pennsylvania, Videon Central, Inc. is a 65-person developer and producer of high-performance digital video solutions and consumer electronics goods. Videon uses managed infrastructure and many cloud-based applications for resource planning and project tracking.

In a recent interview, Videon CTO Jim Condon cited one of the biggest advantages to employing a cloud-based solution is being able to expose critical business information to its customers and suppliers. Because Videon is a small manufacturer, it is often [in the eyes of a large OEM] grouped in with other small companies that in some cases supply or sell things as simple as a screw. Videon, which sells much more sophisticated software and/or hardware would like more control over the pace of communication and project development and stand its ground against large bureaucracies. By using a hosted instance of Jira by Atlassian Software Systems, Videon's suppliers and customers can integrate their project tracking systems with Videon's for real-time project and product updates.

Die-Tech, Inc.
Based in York Haven, Pennsylvania, Die-Tech, Inc. is a 50-person precision metal stamper for a variety of industries. In a recent interview, Director Ronay Wolaver described the productivity gains in tool and die development (historically the costliest—in terms of time and money—process for the business) from the use of digital simulation and analysis. In the past year, Die-Tech has invested in four workstation PCs (total hardware investment of about $32,000) running high-performance technical computing software (total software investment of about $15,000) in order to be able to digitally design a new tool or die and digitally test its performance over an expected lifetime. Before

the addition of workstation PCs and simulation and analysis software, Wolaver estimated that the time to design, test, and create a tool or die took about 18 to 20 months - mostly due to costly and time-consuming physical prototyping and destructive testing. In February 2013, Die-Tech began development of four new dies and had completed two of them at the time of the interview (June 2013). She estimates that because of the strategic advantage created by shorter time-to-market and the money saved in tool and die development, Die-Tech has saved "hundreds of thousands of dollars".

JECO Plastic Products LLC

Based in Plainfield, Indiana, JECO Plastic Products is a 25-person custom-mold manufacturer of large, complex and high-tolerance products for large OEMs in the automotive, aerospace, printing and defense industries. The company uses rotational molding and twin-sheet pressure-forming processes and employs materials ranging from commodity thermoplastic resins to highly complex resins with continuous unidirectional carbon fibers.

Recently, JECO received a last-minute design change for a custom pallet that it was designing for a large German automobile manufacturer—part of a multimillion dollar export contract. JECO was able to access high-performance computing resources through a partnership between Purdue University's Manufacturing Extension Program and the Ohio Supercomputer Center through the National Digital Engineering and Manufacturing Consortium (NDEMC). Using an instance of Ohio Supercomputer Center's SIMULIA Abaqus Unified Finite Element Analysis software suite from Dassault Systèmes and the knowledge, expertise, and training from Purdue University, JECO performed rigorous simulation and analysis, and was able to quickly validate the last-minute design changes.

Because of the success of JECO's custom pallet, the client has signed an additional contract worth $2.5 million annually for the next five to ten years. Along with the increased revenue, Jeco plans to hire 15 additional employees for these new advanced manufacturing capabilities. JECO also plans to spend an additional $500,000 on building out their simulation and analysis competency after their success with the NDEMC help the company secure additional projects with major aerospace and automobile clientele.

Rosenboom Machine & Tool, Inc.

Based in Sheldon, Iowa, and with plants in Spirit Lake, Iowa and Bowling Green, Ohio, Rosenboom Machine & Tool, Inc. is a designer and manufacturer of custom hydraulic cylinders. Across these three locations, Rosenboom produces about 2,500 hydraulic cylinders each day. As part of a partnership with NDEMC and global agricultural machine manufacturer Deere and Company, Rosenboom would leverage Deere's high-performance computing resources and engineering expertise to solve complex design and engineering problems.

In its current operations and given its current technical computing capacity, if simulations took more than a week to complete, Rosenboom opted for the more expensive and time-consuming physical prototyping and testing. Rosenboom's optimal design cycle is between three and seven days. If a project cannot be completed in this timeframe, Rosenboom must move on to other projects.

The first problem Deere experts helped Rosenboom solve was with a high-pressure weld joint on a cylinder product that had been experiencing root cracks and failure that could not be reliably or consistently explained by Rosenboom's engineers. Using Deere's resources and expertise, Rosenboom engineers could use finer meshes to reliably solve the problem and correct the design. The knowledge obtained in this exercise was also quickly applied to another cylinder in an entirely different product line that was also experiencing premature failure. After redesigning and optimizing the joint, the product's lifetime expectancy grew 20-fold.

The second problem Rosenboom was interested in solving was testing large hydraulic shock absorbers, a problem plaguing Rosenboom engineers because without sufficient in-house computing capacity, engineers were forced to build physical prototypes, test, and iterate—not only an expensive and time-consuming process but also extremely challenging as each cylinder is about 30 feet long. Deere's engineers trained and assisted Rosenboom engineers in creating a digital model of the prototype that engineers could then simulate, test, and validate before building a physical prototype. Based on these successes, Rosenboom's next step is leveraging more powerful systems and software to run full assembly simulation of its cylinders and move away from its current practice of physical assembly tests.

Flexcon Industries, Inc.
Based in Randolph, Massachusetts, Flexcon Industries, Inc. is a 130-person international manufacturer and distributor of well water tanks. In order to remain competitive in an industry with many global players, Flexcon sought to improve the ergonomics and efficiency of its production lines while also increasing quality. The company worked with Motion Controls Robotics, Inc. of Fremont, Ohio to plan and develop cost-effective automated production system that integrated with Flexcon's existing robotics and machines. The first system implemented performed a pick-and-place maneuver with a grinder for 24-inch by 5.5-foot, 40-pound assemblies (normally requiring six or seven workers). The second system unloads completed tanks from an overhead conveyor belt, measures the length and diameter of the tank, and feeds it into a test rig.

Immediately, as a result, Flexcon improved its shop floor ergonomic conditions by reducing instances of workers lifting and moving heavy and/or awkward products and minimizing the potential for injuries. The company has also seen a dramatic improvement in cost and efficiency as these machines can run uninterrupted for up to 20 hours each day. Quality has also been improved by using sensors to measure and check inputs to particular machines that could break down if fed improperly.

Based on these successes, Flexcon has increased the number of automated systems implemented by Motion Controls Robotics to four and has seen a return on their initial investment in less than three years.

Imperial Machine & Tool Company
Based in Columbia, New Jersey, the Imperial Machine & Tool Company is a 49-person provider of advanced machining, fabrication, and assembly services. Imperial prides itself on its ability to develop long-term relationships with its customers, but must also stay at the forefront of new manufacturing technology and creative solutions. Imperial often finds itself finding solutions for: rapid prototyping, lightweight structures, machining of complex geometries, refractory metals manufacturing, new materials development and testing, and delivering and exhausting coolants and gasses—projects that are the perfect candidates for realizing the benefits of additive manufacturing.

In order to provide innovative and creative solutions in these spaces, Imperial evaluated a variety of process technologies and settled on powder bed fusion (direct metal laser sintering). The benefits of this process are the ability to create shapes and internal features, reducing the costs in refractory metal applications, and a completed build precision equal to their current offerings.

Humtown Products
Located in Columbiana, Ohio, Humtown Products is a family-owned, 12-person provider of foundry and pattern services. The company recently engaged with the Youngstown Business Incubator to begin introducing additive manufacturing technology to the domestic foundry industry with the goal of increasing the demand of additively manufactured sand core prototypes. Humtown recognized the growing demand for these prototypes, but was unable to afford the high upfront costs associated with new machines.

Through this partnership however, the company's design staff was able to leverage manufacturing resources at the University of Northern Iowa to develop complex and precision sand core prototypes for their clients.

As a result, Humtown is now able to complete sand core castings in as little as three weeks—as compared to tooling that can take up to a year to complete. the company can now approach clients and offer quicker turnaround on prototypes, complex geometries, and low-volume production runs.

America Makes

The first pilot institute within the National Institute for Manufacturing Innovation is America Makes, formerly the National Additive Manufacturing Innovation Institute, based in Youngstown, Ohio and lead by the National Center for Defense Manufacturing in Blairsville, Pennsylvania. America Makes' mission is to accelerate the adoption of additive manufacturing processes and technologies within the domestic manufacturing sector. The Institute fosters open collaboration amongst its members, facilitates the development, evaluation, and deployment of additive manufacturing technologies, as well as designs programs for educating students and training the existing workforce.

DMDII

The Digital Manufacturing and Design Innovation Institute (DMDII), based in Chicago, Illinois, is the third of four current Institutes for Manufacturing Innovation within the Nation Institute for Manufacturing Innovation. This partnership includes 73 companies, universities, nonprofits, and research labs, funded by a partners-matching $70 million federal investment. This particular institute is working to enable interoperability across supply chains, develop enhanced digital capabilities to design and test new products, and reduce costs in manufacturing process across multiple industries. There are currently three project calls: Integrated Design and Manufacturing Models with Metrology (Advanced Analysis), Plug-and-Play Toolkit for Geometric-adaptive Machining (Intelligent Machines), and Model Based Enterprise Data and Infrastructure (Advanced Manufacturing Enterprise).

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Survey Instrument

This survey will not help analyze organizations seeking digital intensity. Our goal with this survey is to dig deep into a particular manufacturer's success story and provide insight into what enabled its adoption and return on investment.

Inventory and Business Analysis

What process, system, or technology did this new project improve or replace?

If the project created an entirely new capacity: how was this unmet need identified?

Describe, in detail, the new process, system, and/or technology.

Work together on a 5-minute napkin sketch of the new process, system, and/or technology.

Defining a Business Case

Is there a formal mechanism within the organization for defining a new project's business case and goals?

How was this particular project framed and justified?

Was the entire project scoped out before presenting it to the business?

Did you envision the total solution from the start (strategic) or was it a series of smaller, successful projects (tactical)?

How was this project budgeted? Special project budget, capital expenditure, routine department budget, etc? Probe for investment characteristics (time, people, money).

Technology and the Organization

Which parts of organization was involved in this project (touch points) and how would you describe their attitude toward new technology?

Before this project, what was the most highly regarded project or technology within the organization?

What was/is the most loathed project or technology within the organization?

When this project began, who or where were the project and/or technology champions or drivers?

Was there a formal project ownership, stakeholders, or project management office?

What external infrastructure existed (broadband internet access) that enables the organization and/or this particular project?

Are there, are you aware of, or have you identified any informal mechanisms for innovation (peer groups, hobbyists, tinkerers, hackers, etc.)?

Motivations

Is there a intrinsic motivation [in the overall organization or in a specific department] to test and evaluate new technology even before a need or business case arises?

Which internal forces drove the adoption of new technology?

What external forces drove the need for change or adoption of new technology?

Which projects occurred from the bottom-up?

Which projects occurred from the top-down?

Identifying and Overcoming Challenges

After the project began, what was the first challenge to overcome? Others?

How was this (and further) challenge(s) identified?

Looking back, did you learn enough from that challenge to know what you would do differently (having the opportunity to do it again)?

Were there any areas of organizational or technological inertia before the project began? Barriers to change (during) or opposition (holdouts)?

Has the organization or any specific department become more inert during or after this project? (On the flip-side, has the organization or any specific department become more welcoming to change after the success of this project?)—rephrase

If a vendor was assisting with the implementation, how was the relationship? Were there any points of contention?

Were there any unmet expectations? Looking back, were your expectations unrealistic? How was this mitigated?

Unexpected Outcomes
Either during or after the project, were there any unexpected outcomes?

Has this project allowed you to consider or re-consider other existing technologies or business processes?

Was there anything surprising about this project? Positive or negative.

Return on Investment
Were key performance indicators, metrics, or targeted outcomes (either business or technological) defined before the project began?

Did this change during and after the project? If so, how?

What were the internal (business, bottom-line, new capabilities, etc) returns on investment?

What were the external (what suppliers and customers see) returns on the investment?

What tangible value was created? How is it measured?

What intangible value was created? How is it measured?

Has this project affected your ability to think strategically about technology? Explain.

Has this project affected your ability to remain innovative (with either one-off or game-changing developments).

Based on this project's success, what is newly possible in your organization (something not considered possible before the success of this project)?

Reflection
What lessons did you personally learn during this project?

What lessons did the organization learn during this project?

What would you do differently next time? Provoke/listen for: a different vendor with broader capabilities or smaller vendor with less pushing their own solutions, bringing in experts (internal/external), "I wish I had anticipated…", time, unpreparedness, analog versus digital processes, similar tools but different results, "I didn't realize how many other processes would need changed with a particular project…"

ProtoCAM Case Study

Less than eight months after fire destroyed their facility, ProtoCAM, an additive manufacturing service bureau located in Allentown, PA, was back online with an array of production technology and services to meet the growing demand for next-generation advanced manufacturing. ProtoCAM's existing expertise with design and production tools, a strong focus on education through its interactive website, and a dynamic company culture that promotes both resilience and innovation has prepared the company for its strategic move from rapid prototyping services to the manufacture of sophisticated, production-quality parts through additive processes.

The Fire

At 7:30pm, on Wednesday March 6th, 2013, firefighters responded to an industrial fire on Cherryville Road in Allen Township, PA. Less than an hour later, after multiple fire companies extinguished the blaze, ProtoCAM had lost its entire office and production facility. The next morning, it was business as usual. Kind of.

"We immediately reconvened the next day at a restaurant in downtown Northampton", recalled President and CEO Ron Belknap. The company met the next morning in the banquet room of a local restaurant. Armed with nothing more than TracFones and the password for the WiFi, the team began the process of moving its current workload to their existing network of subcontractors and securing the location for its new office.

Meanwhile, a team at the site of the accident negotiated with state police and fire investigators to have access to the building and recover their servers. Hours later, the servers were up and running in the basement of a local business partner. "We really didn't skip a beat. Our website may have been down for a day, while we were doing that."

At this moment, no more than 24 hours after fire destroyed the company's facilities, ProtoCAM was virtually back up on its feet. Less than eight months later in early October, ProtoCAM began bringing its new facility online and just three months later, was fully operational. "A good friend of mine, he makes custom keyboards. I saw him about six months later – after we did several jobs for him – and I told him about the fire and he goes: 'Oh my gosh… but you did work for me! I didn't see any difference in your deliveries, in your… anything!'"

While history and the odds certainly didn't favor ProtoCAM (according to the company's insurance agent, of the five percent of companies that survive a fire, half of that group will fail after the first year), this is not the story of an underdog. This, instead, is a story of a company whose leadership and employees refuse to do anything but look forward. That this case study could even be written is a testament to good planning and resilience, not just luck and good fortune (well… maybe a little bit).

Clean Slate

"It is because of the systems we had in place, is how we were able to survive, quite honestly." The three pieces of infrastructure that allowed ProtoCAM to keep its business running after a disaster were a phone system that could handle the forwarding of calls, an existing network of subcontractors for production, fulfillment, and logistics, and a website as the primary interface with the company – three distinct systems with one common characteristic: they were able to quickly virtualize each.

ProtoCAM had much to consider while planning out their entire new operation – things that most companies spend their entire existence implementing and perfecting. ProtoCAM had only a couple months to do this. "We knew about all of this stuff (referring to all the changes they have wanted to make to the business)… but we couldn't do it [in the old facility]. Now we could take advantage of it."

On the business and operations side, ProtoCAM sought minor changes: upgrading their existing phone system to a hosted VoIP system; and planning for the eventual implementation of a

system that could monitor and manage production, fulfillment, and logistics. On the production side, however, ProtoCAM sought radical changes.

With complete control over the layout of their new shop floor, ProtoCAM used an existing compilation of desired improvements to plan their ideal production flow. Separate rooms for each technology, bigger build areas, proper paint booths, and a dock area for loading and unloading all promised obvious efficiency gains. "We've taken a good hard look at safety within the [new] facility." A dust collector was highly prioritized, and one of the first features added to the shop to ensure a safer environment for workers.

ProtoCAM also had a blank slate for production machines to consider, the most expensive part of the rebuilding process. ProtoCAM currently fulfills its orders with four additive process technologies: material extrusion, vat photopolymerization, powder bed fusion, and multi-color multi-material jetting (one of the industry's newest and most sophisticated processes).

Projects that required the material jetting process and machine had historically been contracted out, but sales were reaching a point that necessitated bringing the machine in-house. The initial hesitation wasn't so much the capital expenditure as it was the assumption that it would be difficult to operate. After ProtoCAM's engineers participated in offsite advanced training, the company is finding ways to push the new technology to its absolute limits. "I should've brought this in a year ago… it's working out so well."

Modern Customer Service

ProtoCAM also took the opportunity to revamp its virtual presence. The new website serves two primary purposes: quoting and education. "People don't typically understand the steps it takes to get a true prototype from a 3D printing facility. We want to create videos of that and get it on the web." There is much more to the production of a part than the actual printing. Not only might a part take an entire day to print in the machine, but then there are myriad steps to the finishing process that are unique to each build. "If I put these processes on the website, [a customer] can see it and say, 'okay now I know exactly why I can't get my part in one day.'" ProtoCAM is very diligent when it comes to using this technology to create realistic expectations regarding its production processes.

"Once a customer starts trusting the technology, then they will start designing around the technology. But that's going to be a process (referring to education)." ProtoCAM's engineers routinely push their machines "to the limits". One of the newer possibilities is the manufacture of a "living hinge" – functional hinges that are created with a blend of photopolymers that mimic rubber-like materials. Once this production is matured and formalized, ProtoCAM can impart this knowledge to customers via the educational material on their website.

Additionally, these videos (and other educational content) serve as marketing for the company. ProtoCAM matches its online advertising campaigns against various industrial and process terms, hoping that it can not only fulfill the information needs of the browser, but also convert them into a customer. "Our goal is to be on the first page of search results for all terms related to what [our] business does."

Building for the Future

Speed has always been a key differentiator for additive manufacturing, and that has many implications. "One of the things I've noticed being in business for 21 years is that if you don't go forward with new technology and processes and procedures, you go backwards. You can actually go out of business standing still. Everyone else goes by and you just stand there."

That's not overstated. The average fulfillment time for ProtoCAM is just two days. In some instances, a customer can approve their design for production, call back within hours to submit a change request, and have that change rejected because the part

has already been printed. “We run at such a fast pace, a lot of times we’re ahead of the customer.”

To meet the demands of this business environment, ProtoCAM has worked consciously to remove any barriers to innovation. Recommendations for new technology or ideas for improvement come from the people with the experience and expertise. “It goes both ways (referring to decision-making driven by leadership and new ideas filtering up from operational levels). My people here are always looking around and reading. If they identify something and bring it to my attention, we talk about it. If it makes sense, we go forward with it.” ProtoCAM is currently using this mindset to explore and test new software packages to automate various business processes. This exploration is solution-driven (as opposed to vendor-driven) – finding the right software to address the right business needs.

ProtoCAM is committed to embracing new technology through non-traditional ways of learning and growing, most notably through Twitter, where news and new technology is constantly promoted, and online additive manufacturing user groups. “One of the things we are committed to here is investigating any new technology out there to stay on top of the latest and the greatest so we can keep moving forward.”

Embracing and adopting new technology can range from cheap and easy to prohibitively complex and expensive. The machines that ProtoCAM uses for production are long-term, expensive investments. “Constantly buying new machines is not possible due to costs, so utilizing existing machine technology with existing and new software technology will help us make the transition. Relying on new software and material systems will help us make the transition to production manufacturing.” Remember the living hinge?

This type of applied research and development is advantageous for ProtoCAM’s business. “About 30 percent of our business is healthcare. It’s an extremely dynamic industry. Everyday is different.”

ProtoCAM also sees its ability to quickly mimic production-quality injection molding as a huge opportunity. “We’re able to produce parts with no tooling (which can cost up to $40,000). These parts can be produced in a week. That would normally take eight to ten weeks, traditionally.”

Takeaway

Each of these stories of people, process, and technology has a compounding effect that has prepared ProtoCAM to move up the value chain toward production-quality additively manufactured parts. ProtoCAM recognizes the growth of new service bureaus as a credible threat to their prototyping processes. “Workshop 3D printing – even at home – should not be dismissed. Any machine that can mimic our processes can disrupt the industry.” What a machine cannot disrupt, however, is ProtoCAM’s ability to apply design skills, new technology, and materials knowledge to new challenges.

AWE Tuning Case Study

As worldwide demand for products from AWE Tuning, a designer and manufacturer of high performance engineering products for German automobiles based in Willow Grove, PA soared, average lead time for production grew to 14 weeks. Identified as a competitive disadvantage and a threat to future growth, the company made the reduction of its lead time the primary business initiative for 2012. Realizing there would be no silver bullet to the problem, the company identified and tested various apps and processes as a digital build book running on Apple's iPad. AWE Tuning's current lead time is less than two weeks.

Fourteen Weeks

"What have you ever waited three months for in your life?!" asked Jesse Kramer, Vice President of Marketing. Interpreted one way, it speaks highly of the world-renowned quality and growing demand of AWE Tuning's product design and performance engineering. This is true. Interpreted another way, it's a looming threat to the company's business and continued growth. This is also true. "In our competitive landscape, nobody took anywhere near that long to get products out," added Todd Sager, President. "We were putting the company at risk. There was no way we were going to grow the company if we didn't get the lead time down."

"The catalyst for change was a leadership recognition that if our lead times didn't come down, we were going to have bigger problems on our hands", said Kramer. That bigger problem was the risk of losing significant market share. "There was an all-hands-on-deck meeting, like 'let's all get together and figure this one out.'" Sager described the purpose of this meeting as "not necessarily a crowdsourcing of the solution, but the identification of the real problems and prioritizing which one to hit first."

Problem Identification

Incorrect and often confusing build books, the paper-based blueprints for product assembly, was identified as a key inefficiency during the manufacturing process. During the product prototyping phase, engineers or shop floor personnel would record the build plans as a series of sketches, handwritten notes, and digital photos. These unstandardized plans were (sometimes weeks after the initial prototyping) manually gathered, organized, and consolidated into a master copy hosted on a single PC, then printed and presented to the shop floor. "The point of capture was very fragmented – handwritten notes and digital photos – and disjointed because it didn't all happen immediately. So there was a paper build book when all was said and done, but inevitably, because of the capture, it was filled with errors."

That wasn't the only problem. "Then when you would go to build the product, all these errors would surface." If shop floor personnel identified an error or needed a clarification, they would quickly make a note in the margin of the book (or place in Post-It Notes when space ran out), then return the build book to management for review and revision. Given the high number of product SKUs at AWE Tuning, there was always a backlog, piles of build books sitting on management's desk, waiting for revisions. These same books, waiting to be corrected, were still needed for production on the shop floor – slowing down production time, increasing material waste, and driving up costs. Once a particular book was able to be reviewed and revised, the error-prone process began again, compounding the problem.

"The only silver bullet was realizing that there wasn't a silver bullet. It really was a combination of leadership, of processes, and – yeah – of technology. But none of those could have functioned independently," said Kramer. "Everybody knew it was the lead times. That was obvious. How to solve it was not obvious," added Sager.

The Digital Build Book

A single device to capture build book content, such as a tablet, was identified as a potential solution. Much of AWE Tuning's shop and office

technology infrastructure runs exclusively on Windows-based PCs and a Sharepoint server. In the interest of compatibility, Windows-based tablets were initially evaluated. Apple's iPad, instead, was quickly adopted because of its robust App Store ecosystem. "We were able to link together a collection of apps from the App Store to allow us to edit and publish the build books directly from an iPad."

The company first focused on the process of creating the build book. "The lead time on build book creation was cut to hours instead of weeks, and the accuracy of the first draft was exponentially improved." Instead of disparate handwritten notes and digital photos, the entire process could be captured in one place with the on-screen keyboard, touch screen, and rear-facing camera.

Building on this success, the shop floor was soon outfitted with iPads in ruggedized cases. When an order was issued for manufacture, a paper traveler was printed and accompanied the prepared job materials as it moved across the shop floor. On this traveler was a QR code that could be scanned with the iPad's rear-facing camera, and an app would automatically call up the most up-to-date build book in digital format. This also allowed multiple copies of the same build book to be used at the same time.

Another set of apps on the iPad was used to correct the inefficiencies in reporting errors. Engineers and shop floor personnel used an app to annotate the current build plan, then emailed it directly back to management without ever leaving the production site. The same person who created that build book was then notified and tasked with correcting the mistake and updating the book. These updates reflected immediately in the Sharepoint server, thus ensuring all iPads had the updated copy.

Over time though, this revision process had become less and less important because the need for annotations and changes to each build dropped to almost zero. "It's really amazing because we put that [process] in there since the last paper documents needed so much correction. But it's amazing how few times that gets used now. We can now create documents with no problems to begin with."

No longer burdened by the creation, review, or revision processes, engineers and shop floor personnel have moved on to finding other ways to use the iPad, such as tracking time, updating inventory, and reporting waste – all within minimal customization or IT overhead. One app, after scanning the same QR code on a traveler, triggers a timer that writes time study data to a cloud database. The same QR code, when scanned by another app, calls up a Google Doc that is used for waste tracking. Counting inventory is done with another app by scanning QR codes on inventory locations and entering a product count. "The digital capture of data with automated report creation has given us tremendous visibility into all facets of our manufacturing process."

With the exception of the inventory reporting tool, which was contracted out, the apps AWE Tuning uses are readily available from Apple's App Store. The iPad also had little impact on the company's budget. "The budget didn't even play a role because it was ultimately pennies in the grand scheme of things – as far as the return."

Results

Reducing production lead time was like "changing the wheels on the bus as it was moving", said Sager. We didn't stop the bus – which would have been 'okay, we lost all our market share, now we can fix everything and start the bus again'". Kramer added that "demand never went away, but our ability to fulfill it went up." AWE Tuning currently fulfills orders within its original goal of two weeks.

The company executed its strategic goal "by taking it in bites", said Sager. "It may have taken you five hours to build something that now will take you two hours to build. So this digital build book really did have a tangible return: taking this finite

resource of time and making it much more efficient."

Toward the Future

The App Store itself has become a prototyping platform for AWE Tuning – employees can try different apps for different processes and adopt the ones that are easiest and work best. Special expertise and training for specific software packages is replaced with the willingness to try new apps. "How do we make this device do what we want? The App Store has all the apps we need."

AWE Tuning is also currently in the process of moving to a larger facility which will allow them to design a more efficient shop floor, utilizing the most cutting edge technologies. "If we didn't know what we know now from integrating new technology into the actual business process, we wouldn't necessarily be looking at the class of machine that we are now."

The company now has confidence, capability, and expertise to do work with complex automated machinery. "Robots on our shop floor. That's not just something you can casually wander into. You need to have that kind of technology foundation to be able to integrate those things into the production line."

L&S Machine Co. Case Study

In a supply chain governed by regulations, the capture, organization, and use of product and quality data is a fundamental part of the production process for L&S Machine Company, a supplier of precision-machined metal parts for the commercial nuclear industry based in Latrobe, PA. The ability to generate and use this data has not only allowed the company to create a highly scalable platform for manufacturing, but also become the supplier of choice for a major OEM. The company's current focus is creating the ability to use big data in a strategic manner, a unique technical and personnel challenge.

Generating Data

L&S Machine Company's capability for data generation begins directly at the point of production – with the Direct Numerical Control interface between computer and machine. "What that pulls out of the machine is efficiency and probing data, and can be used [to inform] any program that it's running," said Rob DiNardi, President and CEO. In its current state, this is a closed loop. However, in order to extend the data's value across the organization, the company has invested in an off-the-shelf software package that only required a minimal amount of customization and integration called Q-Pulse. "It stores our drawings, documentation, programs, inspection plans, as-built records, route sheets, any data that is required by the nuclear industry… these are our two big systems."

The software gives the company the flexibility to store any data, organize it, and describe its relationship to other documents and data. "It's almost comparable to a SQL or Access database, but it is also compliant with [the nuclear industry's] NQA-1 regulatory specification and [the aerospace industry's] AS9100 specification, as well as ISO-9001." These two systems are part of a significant, long-term investment in data-driven projects that has come together "over the course of five years."

Beyond production improvements however, DiNardi also sees how these systems have empowered the machine operators. He sees operators approaching the employees typically in charge of generating reports and asking if they can get more and more details. "They're *always* asking for more stuff."

Using Data

They way data is consumed throughout the organization varies, depending on the role. Digital signage throughout the shop displays ambient, high-level information. Individually, all operators are able to identify potential problems and solve issues as they happen. Data about these problems is stored in Q-Pulse and the company is now able to look back at historical data and recognize patterns and trends in these issues – long term views that help with continuous improvement.

Each supervisor on the shop floor has an iPad, but the goal is to put a device at every work cell. On that device, operators will have immediate access to not only efficiency and probe data, but also insights into the larger business. DiNardi wants the operators to have even more insight into the business – not necessarily financials, but the ability to see the incoming workload, where orders are in the production process, and current inventory.

"Another plan for that device is to display procedures – because we have to train all the time – employees will be able to immediately call up a procedure."

Prior to Q-Pulse, many of the company's production or process changes were implemented outside of a formal process and were often unstructured – but well within the constraints of nuclear regulation. "Looking back, we did a lot of things by the seat of our pants." The company looks to Q-Pulse and its data to help structure and drive the improvement process.

The Problem

"That data never goes away. We just keep generating and generating." DiNardi estimates that

the company is only effectively using about 10 percent of the data it generates. Looking back on one year's worth of production data, the company can see where it has identified and resolved issues, but "we're not solving the root cause, and I think we have the data to discover and correct it."

"All machinists are good at seat-of-the-pants problem solving – they have a problem, they know what to adjust, and the problem is solved. Now, when that same problem occurs two weeks later, they attempt the same fix and now the problem doesn't go away. They try a new, but similar adjustment, and the problem goes away. When you look back at all those events, you see you've had the same problem all year and never truly addressed the root cause of the problem. Yeah, we fixed it all the time, but we never really knew what the problem was."

"I want to be a data-driven company. I want to develop a process where we're looking at that data and moving forward instead of just reacting to what has already happened."

As an example, data compiled in noncompliance reporting showed the majority of production issues stemmed from only three or four parts. "[With Q-Pulse], we know what part is the problem and what the problem was, we have all that data. We know all the answers are [in the data], but we don't currently have the talent or the time to look for the answers."

DiNardi's desire to solve problems with data doesn't stop at production and operation issues. Instead, he sees a much larger opportunity.

"We want to grow. What's preventing us from growing is that we're not looking at all of this data at the supervisor level to help us out. We're making the same mistakes and I don't want to do that in 2015. I want us to move ahead."

The Opportunity

His strategic approach to data begins with asking questions. "We have all this data now. How do we sift through all of it? What can we gain from it? Obviously there's something in there to tell us more about our process. What do we need to fix?" The company has no problems extracting and organizing its data, but now needs to understand "how do we make it meaningful to somebody?"

L&S Machine Company has previously tried to work with an OEM on root cause discovery and analysis. The company once sent an employee to attend a workshop, but most likely did not have the proper background to fully apply the lessons from the training. The company has also evaluated various software tools for analytics, but remains "overloaded and undermanned on the data side – so much so that we haven't been able to get our feet firmly on the ground."

As the company puts together its strategic plan for big data, it has already identified the talent gap it must overcome. The company is currently working toward defining the requirements, qualifications, and experience necessary for this role. "It is a mathematician? An industrial engineer? An expert in computer science? Who is best to look at this?"

The Challenge

The company has the money and the business case to hire for this position. It is currently a matter of finding the right talent. In addition to who this person might be, the company is also trying to figure out where they might come from. "[An OEM] has recently gone through layoffs, is that a place to find them? [The OEM] was good at training their people to do root cause analysis – could I hire them as a consultant?"

Helping to guide the company through these questions and unknowns is the knowledge and experience of building out professional strategic roles within the company. The role of Chief Financial Officer was created to "move away from accounting and bookkeeping, and become a place for improvement and new ideas." The company's Quality Assurance Manager has most recently taken on a similar role, becoming the person "people gravitate toward as the be-all-end-all guy

for quality." DiNardi is going for a three-peat, this time with data.

The company has also attempted to develop specifications for the role through a variety of in-house projects and, most recently, a university partnership on a capstone project. The project highlighted the unique multidisciplinary nature of big data, as challenges arose from the team's industrial engineering focus. "We needed an industrial engineer *and* someone in computer science — I think you need that software development experience."

Applying Big Data

In the meantime, L&S Machine Company has also used its technology expertise to build and scale a platform for manufacturing. Along with its shop in Latrobe, the company also operates a plant in nearby Marion Center.

"About five years ago, we made a scale model. We put five machines in a different building about a quarter-mile from this building. Just to try it. Can this work?" The company was trying to prove that if, for example, it were to expand, could it integrate and remotely operate the new production facility "closer to the OEM, without moving things back to Pittsburgh".

Using Latrobe as the central office, the team there can prototype and write new programs that can be run in any facility, anywhere in the world, now and in the future.

"[That test] allowed us to learn all the little stuff — all the stuff that you forget that you need."

Because of L&S Machine Company's sophisticated capabilities, a major OEM uses its Latrobe plant as a model shop, showing off their operational and production capabilities to potential and existing customers. "We *always* want to be that. So that drives us to be new and innovative."

"Right now, it seems the only way to compete is based on price," but the company is investing in and hoping that it will soon be able to compete on data and speed, "because that's all that's left".

Videon Central Case Study

Building off existing expertise and experience developing commercial solutions for the Blu-ray software stack, Videon Central, Inc., a designer and developer of commercial, industrial, and consumer media software and hardware solutions based in State College, PA launched its first consumer facing media product, the Avia Media Player. Supporting Google's Chromecast as a first-to-market solution for playing local media on a TV, Avia now supports Apple TV, Roku, WebOS, and DLNA devices. In addition to the software and support, Videon also developed the Avia brand to market and promote its media products.

Manufacturer as Software Developer

"We didn't necessarily just transition into software development, that's been part of us from day one", said Brandon Colton, Information Technology Specialist. On the outside, the release of a product targeted directly to consumers might seem like a radical departure from Videon Central's core business of commercial and industrial media solutions. Internally, however, there was very little talk of it being different from any of their current business offerings. In fact, the company's first consumer facing product has its roots deep in commercial product development.

"The project began [around 2010] as a partnership with a leading CE manufacturer to bring our Blu-ray player software stack to Google TV", recalled Tarun Chawla, Product Manager. Videon integrated the Blu-ray middleware, the software that works between other software, hardware and the Google TV user interface. "There's been a Blu-ray player stack, around the DVD player stack that was meant for airline and private aircraft [inflight entertainment]. So we had an existing core competency with the DVD player hardware and software", added Kevin Scheib, Development Lead for Avia.

Work on this project opened the door to new opportunities. In late summer of 2013, a small team at Videon visited Google engineers at their headquarters in Mountain View to discuss ways to "cast" media to a TV through their Chromecast device.

Avia

The Avia Media Player for Chromecast launched on December 10th, 2013. "We're one of the few – in fact, we're one of two apps that can play local media on your TV. [The other app] actually requires users to install a server on your home network to house the content. The unique thing about Avia is that we don't have that requirement. We can connect to any [supported] device on your server and play any content that the device allows", said Scheib.

Avia makes it simple. Avia lets you play, manage and share your personal media. You get seamless access to photos, videos and music from social media sites, your home network, and your device's local storage. The fun part is sharing it on the big screen. With Apple TV, Chromecast, DLNA, Roku or WebOS it is even easier. Share the moments that matter most with the people who matter most. – from aviatheapp.com

"When you're one of the first ten apps released on a device that no one knows what it can and can't do – there are a lot of things that you don't know that could happen."

In its first month supporting Chromecast, Avia had about 35,000 new customers. As of January 2015, the Google Play Store estimates that the app has been downloaded and installed between one and five million times.

Development of Avia, for its release on Chromecast, took roughly six months and was the result of successfully integrating many moving pieces from many different partners. "The biggest challenge was that the [Chromecast] API was changing as we were working on it." Recognizing this would be an ongoing challenge, Videon used it as an opportunity to provide feedback and collaborate on its development.

Working with Giants

As a small- to medium-sized manufacturing enterprise, Videon Central has a history of very successful interactions with much larger OEMs in the media landscape.

A few trips were made to Google's headquarters in California to meet with engineers and learn the various development libraries, but interactions, for the most part were virtual.

Google shared the initial development libraries with Videon, and from there, the teams used tools such as Android Studio for development, Jira for project management and issue tracking, and wikis for documentation. "We have wikis for every project and for all the documentation that we have on each project." The Avia team changed from five members initially to currently three members and these documentation practices and software help greatly with knowledge transfer during transitions.

"My job, I feel, is more or less to make sure everything is available for people to use the tools as they see fit, not necessarily as IT might dictate them", said Colton regarding Videon's unique freedoms for design and development tools. "We're not a typical company in that regard: where we do give employees the ability to make decisions with their workstations and the software they install and everything like that. It's more freedom for them to be able to accomplish what they need to accomplish."

Consumer Product Development

Traditionally, Videon's commercial and industrial products are unbranded. Avia is the first branded product released directly to the consumer, and an entirely new endeavor for the company.

"This all has to do with branding ourselves – to get out there and give Videon a slogan or brand", said Chawla. Videon worked with a local company to research and develop everything from the new logo and slogan ("Simply Moving Media"), down to the particular colors they use. "Avia ties into that slogan very well – we gather your media, your content and move it to a display, whether that's a TV or computer or whatever that might be."

As part of its marketing and promotional efforts, Videon also created an entirely separate website for the app: http://aviatheapp.com/. "The website is an introduction to the app, with some basic troubleshooting and setting up the receiver properly", said Colton. "It all came together right at the product's launch, right at that time."

Users first interact with Avia either through Videon's website or the Google Play Store (on the web or Android devices). A unique piece of the Play Store experience is the ability for customers to publicly rate and publish reviews of the app. Currently, over 13,500 people have provided feedback and helped Avia earn a respectable rating of three-and-a-half stars out of five (in what can sometimes be a very unforgiving environment).

"We get a lot of our feedback from Google Play, from the people who download and use it. So we have to balance those comments with the addition of new functionality that is being proposed from other company partnerships and other business-to-business requests. It's a balance that we're trying to get right", said Scheib.

Moving Forward

Beyond the app, Avia and "Simply Moving Media" represent a major ongoing research and development effort for Videon. Its future product development roadmap is a composite of a variety of interdependent activities: customer feedback and market research and business partnerships. "You can imagine, with full-time developers, that's a significant amount of money, time, and resources for a small company like ours", said Chawla regarding the need to identify the best opportunities, and balance consumer and commercial needs.

The company is moving quickly with its consumer media solutions and, only in the last two months, has added support for Roku, Apple TV, and WebOS devices.

"[Future development] is much more complicated than coming up with something the business wants – there's market research, business-to-business – so we're always in the process of figuring out what comes next."

When preparing to launch new functionality, Videon "has to line up an OEM or partner, someone who builds [the platform we want to target] and convince them to install Avia on their product." This type of partnership and collaboration determines the product roadmap and where Avia goes next. It works both ways too: "[a company] can contact our business development group and say, 'we really want to be able to do this' and then we will have to consider whether or not it's a viable option", added Scheib.

If there is no market demand, there is no use for the company to devote these resources.

The success of Avia and Videon's consumer facing media product is not simply the result of quality software development, but also the ability to scan for and be open to new opportunities and collaborations with a variety of partners and businesses.

Drexel Metals Case Study

Creating and delivering the digital and information services that enable their customers' businesses is critical to the continued growth of Drexel Metals, a custom fabricator of standing seam metal roofing and architectural products based in Levittown, PA. The company's trademark "Metal Roofing On Demand" requires the decentralization and diffusion of production into smaller, regional markets and the ability to support these activities with a cloud-based document storage and collaboration service, marketing microsites, and a visualization tool. There's little doubt these played an important role in last year's 30 percent growth.

Passion for the Product

Brian Partyka loves metal roofs. "My wife took an assignment in Paris. And at the time, I was about five years into Drexel Metals; I started in 1995. So we're at the top of Notre-Dame Cathedral in Paris, and the sun is setting, the Eiffel Tower is out here, and the Sacré-Cœur is over there. It's just beautiful – gargoyles all around us. We're at the very top of the Cathedral, looking all over the city – hundreds of narrow steps to get up there. And my wife is standing behind me and puts her arms around me, and she asked me what I was thinking about. I mean… a really romantic setting. And I said, 'I wonder how old that metal roof is over there.' It was one of the oldest metal roofs in the world! But that's when I knew I found the niche that I enjoy. It's about finding a passion."

As the Executive Vice President of Business Development, it's his responsibility to translate that passion into a successful business. This same spirit exists throughout the entire organization: "Our sales guys are former roofing guys, so they've walked a mile in their moccasins. I think that's been a key to our success: the fact that [our] guys know what these guys [in the field] deal with everyday."

Disintermediation

"The way we go to market, compared to our competitors is certainly a competitive advantage for us." The company has positioned itself to take advantage of an industry-wide trend: that products are moving from being produced centrally in a factory to being produced on-demand in the local market. "And that's really helped us dramatically grow – 30 percent last year – and take the share away from the big boys."

Drexel metals supports a metal roofing project in one of two ways: selling material and leasing remote fabrication machines, and providing the pull-through marketing for local projects and businesses. "There's thousands of these machines out there – the assets are already on the ground. Our job is to support what is already existing. And the machine makes one component of the entire roof assembly. So it's getting the contractor, the building owner, or the architect to think, 'Alright, if I have this piece of equipment, I'm going to need all these other tools to go with it'. That's where we become the back office for these guys."

"We have a guy in Pittsburgh who started a business in Sarasota, Florida to make metal roofing panels who would not be able to do that without the tools that we gave him." The person running this local business has access to Drexel's entire product catalog, marketing materials, and various other assets and collateral. "We're doing this together with them."

Mr. Roof, the third largest residential roofing contractor in the country owns one of the company's machines and does nothing but promote Drexel Metals' Residential Metal Roof System primarily because of its warranty.

These two examples are emblematic of the types of relationships that Drexel Metals can have with its customers. "They have access to all these tools and can go through and pick and choose whatever they want [to offer]. We live in an on-demand world and nobody has the attention span to spend a lot of time looking for something. So we try to make it as easy as possible."

Box

"We were just trying to figure out a way to get information here – a three-and-a-half inch screen

and without having to always access it through the web (in contrast to their current wiki-based solution)." Instead of creating an entire application to support this, Drexel Metals opted to use Box.com, an enterprise-grade, cloud-based document storage service. "Why should I go out and try to recreate the wheel when there's already something out there that I can use… that's cheap." An article in Inc. Magazine, profiling Box.com as a rapidly growing company was the inspiration for its use. "When I was reading it, I was thinking 'wow, this could be a really big problem-solver for us.'"

Having this information readily accessible lead to the development of ArchitectBinder.com. "ArchitectBinder.com is nothing more than a Box folder. That's all it is."

The first project launched with ArchitectBinder.com was a barn project for the Bucks County Audubon Society. "I really wanted to test the waters with an architect. So I took one of our Box folders and created a new [copy] for the architect. I took everything [online] – his initial estimates, our initial pricing worksheets, the sets of plans we drew up, our shop drawings, everything I thought he would need – and immediately we got the project."

This success became a blueprint for future engagements, using Box folders as the primary point of contact and collaboration for architects and general contractors (each with their own unique set of information requirements – which Drexel Metals understands). All new projects start and end with Box. "It's really a very simple thing. It's just keeping it simple."

Based on successes with static documents, the company would like to move toward making things like spreadsheets available in much the same way. These could be turned into a webpage that customers can use to perform their own estimating and quoting.

Box also has a basic set of analytic tools that enable decision-making. It provides the business just enough insight into what is and isn't being viewed by their customers and potential customers. For example, if the business is selling a lot of systems, but not a lot of the components for those systems, it can use Box's analytics to see how many people are viewing individual products versus the entire system into to target the company's marketing.

There are many things Drexel Metals can and wants to do with Box, but the primary focus is meeting customer needs. "Metal roofing is growing, so let's make it easy for these guys to get into it. You do what you're good at – which is selling roofs, installing roofs. Let us do all the back office stuff that nobody really wants to deal with."

Microsites

Another tool in Drexel Metals' arsenal is the development of locally-targeted microsites. These microsites help generate quality leads and more marketing pull-through for the business. "These are going to help us generate the buzz that we need for customers to pick our product." These sites rank highly within the search engine results of common terms for the company's products.

CommercialRoofEdges.com is one example of this tactic. The keyword 'commercial edge metal' is something an architect might be searching for in a roofing project. "We're trying to nail the Google search results for commercial roof edges. All the different products are listed here: coping, gravel stops… all the different types. So if they go into 'gravel stops', for example, it's going to pull it up and it gives you the information you need. If you go to the specifications – because we want to be able to track this, who's coming along – it's going to go right out to our Box account."

Commercial and residential roofing is a technology-intensive industry, full of specifications, codes, data, etc. Access to this information is a key differentiator for Drexel Metals and having a common backend like Dropbox – used by internal sales, independent sales, architects, general contractors, etc. – keeps the very latest information at their fingertips.

In one month, with minimal promotion or marketing campaigns, Drexel Metals was able to pull in 267 new leads in locations such as Cherry Hill, NJ; Bonita Springs, FL; Rutland, VT; Pueblo, CO; and Wilmington, DE. Partyka attributes the success of these microsites to the company's ability to listen to their customers and provide them valuable information. "For every ten pitches (referring to the microsites), six of them are hits."

Visualizer Tool

One tool that appears on the microsites is a tool that helps customers visualize the appearance of a new metal roof on an existing building. Launched in February 2014, customers can now upload a picture of their home or building, and test Drexel Metals' entire product catalog in over 30 colors, sizes, and gauges.

As part of the registration, users are asked to provide an email address, and this contact information gets added to the company's newsletter and becomes a new business lead. In a typical month, over 400 unique users will fully engage with this tool (register a new account, upload a picture, and customize a new metal roof).

The company is currently working with a local design and development studio to develop a visualizer tool for the iPad. This will allow contractors to work directly with clients on visualizing roofing and siding projects. They can take pictures at the site with iPad's camera and work remotely without an internet connection.

"Nothing is more rewarding for us than to grow our business more than 30 percent last year and see our customers' businesses grow exponentially as a result of the things we're doing. It's pretty cool."

PoolPak International Case Study

Strategic planning is the primary driver of innovation at PoolPak International, a manufacturer of industrial and commercial dehumidification systems for indoor pools for universities, school systems, municipal recreation centers, medical centers, and private facilities based in York, PA. The successful adoption of new technology for both business process, in the form of an incident tracking system built in-house, and product development innovation, in the form of a smart HVAC controller, has been the mechanism for meeting one particular strategic goal: the reduction of warranty repair costs.

Strategic Planning and New Technology

The 2008 economic recession created a challenging climate for manufacturers of industrial equipment. "Some technologies that were already implemented, such as a Customer Relations Management system, paid huge dividends in seeking out and securing business opportunities", said Phil Landis, Director of Information Technology. This enabled the company to maintain market share and revenue levels during the recession. As the economy improved, the company was positioned to begin investing more heavily in technology for its operations. "All of our engineering stations are on the latest software. We went with new workstations and dual screens. We updated our whole 3D modeling workflow because our newer, state-of-the-art products increased the complexity of the requirements for our CNC programming."

Changes and updates were also happening on the shop floor. "Down here we were dealing with antiquated software that forced you to take more steps than you needed," added Michael Shillott, Director of Operations. Planning for the installation of about $1 million in capital equipment, including a brand new fiber laser and other sheet metal production equipment, Shillott took the first step and updated the CAM software. "In consideration of the current production level and in anticipation of what was coming down the road, I had to look seriously at increasing our output and decreasing our lead times. In order to deal these dual demands, we need to have equipment that's state-of-the-art."

"You don't turn on a dime," said Shillott, referring to planning each of these upgrades. "You have to actually plan, say where you want to be in two years. You have to have a strategic plan. And then a tactical plan to implement it."

PoolPak has a formal strategic planning group that meets, as a whole, twice each year and smaller task groups that meet regularly as needed, on tactical projects. The company has used this process for well over a decade. In this latest round of strategic planning, the reduction of warranty costs was identified as one of the strategic goals. "We put this one together about a year and a half ago, when we started looking at what our capabilities were, what our equipment was capable of, what kind of downtime we had, and where we wanted to be."

According to PoolPak, most returns on investments are expected in two to three years, but ideally they would like to see a return within the first year. "If you try to justify the return over five years, you're probably going to get turned down. If you want to survive in today's economy, you have to be quick."

"What we're during today, our competitors will be doing tomorrow. Which means we have to be another step ahead. We have to be planning what we're going to do next, now." There is a sense of urgency within PoolPak's business. "We want to get moving. Fast," added Landis.

Company leadership prioritizes the tactical projects of the strategic plan based on which ones have the most immediate and biggest return on investment. Even though there are day-to-day demands for improvement, the driving force over the long-term comes through strategic planning. "Those five or six things basically drive the entire company, directly or indirectly."

PoolPak has approached achieving its goal of reducing warranty costs through both business process improvement and new product development.

Incident Tracking System

What initially began as a system developed in-house to report defects has become one of the most important business systems running at PoolPak. Prior to ITS (Incident Tracking System), there was no central system to track defects in production or out in the field, making it tough (and costly) to identify the source of problems.

"We once had a particular problem with a valve. One of our vendors made a change internally, replacing a previous component with ferrous metal. This became magnetized in operation and caused the solenoid to malfunction. And this caused us all sorts of problems. Lots of money." The only information PoolPak had available was how many service calls a machine had and how much money those repairs cost the company – with little insight into the root cause.

"It took about a year to develop the basic capabilities." The system for centrally reporting and tracking defects for quality purposes was developed in 2013 and fully implemented for all of 2014.

"It started as a defect tracking system. Now it's a reporting system for quality, for service, for our parts department, for customers, [and for] technicians in the field – basically it's a closed loop system," said Shillott, referring to how the ITS has grown into a full-service system that tracks the production process end-to-end. By the end of 2014, ITS was being used in almost every department in the business and across production.

"The proof is in the pudding with the ITS stuff. Our warranty costs are going down. Significantly. That's the end result." PoolPak's warranty costs have gone down roughly 50 percent since beginning these programs.

Smart HVAC Controller

The new product development approach to reducing warranty costs comes in the form a smart, connected HVAC controller for its dehumidification units – think Internet of Things. "It's a smart controller that is able to connect to the internet. It gives us an advantage for updating the control sequences in our equipment. It allows us to receive alarms from bad situations or equipment and sensor failures. It sends us [diagnostic information] and allows us to remotely monitor – to check in and see how things are going from anywhere at any time. And it has data logging capabilities, so we can see what's happening over a period of time."

PoolPak has previous experience in building connected devices dating back to the days of modems that could dial out to report a problem. For early adopters ("probably seven or eight years ago") who requested a remote control capability, the company was able to provide a connected solution using an existing controller connected to an Access Point Name Service from AT&T called I2GOLD, essentially a device with a SIM card and a public static IP address. "We had to track down this product. You probably won't see it in any literature. In fact our last account rep, when we mentioned I2GOLD, said 'how the heck did you guys find that?!' I said 'because we needed it!'"

The new controller has obvious, tangible benefits. Landis explained: "Suppose our service guy is two hours away from a unit and something happens. A customer calls up with a problem and we'll send the service guy out there. So he drives two hours, looks in and says 'the janitor propped the door open', closes the door, drives back – warranty charge to PoolPak for four hours on the road, an hour on-site, truck charges… and what are we supposed to do? This will allow us to see those kinds of anomalies without having to send a guy out there, reducing our costs, making the customer happier. It pays off in so many ways."

"We were able to tell, on one of our installation systems, that a chiller was down. We knew it before

[the customer] knew it. And we called them", added Shillott, referring to cases where PoolPak is able to identify and correct a problem before the customer even knows.

Landis said that "this [new package] will replace anything we've done as a custom build, or as a temporary or stopgap measure", but agreed that everything they've learned through earlier projects has led to this. "There are 200 separate points - something like that - that we measure within the machine and in its environment." At least one of PoolPak's competitors is working on a similar solution, however, [the competitor] cannot compete with PoolPak's internal expertise and development. "Our engineers write those programs that make the unit do what the customer wants. That is what separates us from our competitors," said Shillott.

PoolPak introduced this technology with its new products at the AHR Expo in Chicago, the industry's largest show held annually and presented by ASHRAE, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Alignment

PoolPak's leadership has long supported technology as the mechanism for driving change. "I really feel like we get a lot for the dollar that we spend on IT. I don't think we're frivolous," said Landis. PoolPak considers the technical abilities of its employees to be the key competitive advantage. Looking holistically at the company's system of innovation, PoolPak's management identifies strategic goals in a top-down fashion, but tactical plans are developed with a bottom-up philosophy. These plans are implemented and enhanced with feedback through employee involvement at all levels of the company.

"[Our employees] bring a certain wealth of knowledge and experience of what actually works in a company and in a particular marketplace." PoolPak is not only able to successfully apply that knowledge and expertise to projects like the ITS and smart HVAC controller, but is also able to serve the larger strategic goals of the company, sharing and maximizing company resources.

"One of the important things that I see about my role is not to get too far from what is a core requirement for the company and what's just some cool stuff. We do cool stuff, but it's always with an eye on 'what's it going to do for us?'"

ExOne Case Study

After securing a key partnership with a major aircraft manufacturer for a technology demonstration of its next-generation aircraft, The ExOne Company, a designer and manufacturer of nontraditional and additive manufacturing machines and equipment, and provider of digital part materialization services based in North Huntingdon, PA, integrated a number of previously decentralized casting activities and technologies into a single centralized service. ExCast leverages the company's extensive knowledge and experience of using binder jetting technology to design and create molds and cores, and to take end-to-end ownership of the casting process in order to design and deliver the highest quality parts.

Manufacturing as Capability

The ExOne Company has been researching, developing, and commercializing binder jetting technology ever since acquiring the patents from MIT almost 30 years ago. The company's experience supporting other non-traditional manufacturing processes goes back even further, over 50 years to Extrude Hone's abrasive flow machining process. Today, ExOne provides not only industry-leading machines and equipment for additive manufacturing, but also advanced design and production services.

The company's business revolves around powder metallurgy – that is, making things out of tiny bits of metal powder through a binder jetting process. The company provides equipment and support for a variety of direct and indirect metal fabrication activities. Historically, stainless steel infiltrated with bronze has been its primary material system. However, ExOne's latest machine, M-Flex, is a machine built to handle a variety of traditional, modern, and future material systems.

"It has the flexibility to be more than one thing. For a customer that runs three different material systems, they would mostly likely still require three different machines. But the advantage is that their operators only need to be trained once, there's a common software platform," said Larry Voss, Engineering Manager. M-Flex can now serve as a platform for companies buying the machines.

ExOne works tirelessly to make available new materials for their customers' applications. "A company isn't going to change the material of a component just because it can be 3D printed. They need to make it in titanium, make it in aluminum. So we are working to develop materials [that can be 3D printed] that would be incorporated into those [existing] components," said Hilary Gilmore, Contracts Manager.

"We're constantly looking at different technologies and mechanisms for dispensing and spreading material and how to handle different classes of materials, whether they're spherical or angular, high density or low density, flowable or not flowable," added Voss. ExOne is able to apply a tremendous amount of its research activities to the development and commercialization of new materials, processes, and technology to continue to meet the needs of its customers now and tomorrow.

Design for Additive Manufacturing

"Conventional designs are made for conventional manufacturing, said Gilmore. "If you're no longer constrained by the manufacturability of the design [through additive processes], you can make any design – within reason. Overhangs, undercuts, and complex internal passages, for example – you can't make those any other way. So now design is wide open. You're designing for functionality, rather than manufacturability."

This philosophy, designing for additive manufacturing, has been slow to catch up with the technological advancements of the industry. "Things are typically made to be manufactured in a cost-effective way. Now, for example, you can design for things such as weight reduction while maintaining strength by using a lattice fill pattern, instead of a solid part."

"We say: we can print things that you could never manufacture through traditional means. That's true and that's great. But usually – unless you get out there and educate them – these designers are designing parts that can be made with normal fabrication techniques," added Voss. The business case for education and design services is obvious in this situation. Parts that are not optimized for additive manufacture are not priced competitively against traditional machining or fabrication.

"However if they come in and work with us on the process – once they see it, then they go back and understand exactly [how to design for additive manufacturing]."

The company is currently working with a large list of clients on new projects because of their interest in ExOne's technology. "Fortunately for us, our technology is perceived to have both immediate and long term benefits for a large number of industries and large OEMs," said Rick Lucas, Chief Technology Officer. The belief in what this technology has to offer opens the door to major innovation through strategic partnerships.

Strategic Partnerships

A recent key partnership for ExOne is with a major aircraft manufacturer for an ongoing technology demonstration of the OEM's next generation aircraft. ExOne began its partnership by supplying the printed molds to the OEM's qualified foundries, where they would be poured and casted.

Soon after, the OEM asked ExOne to "take ownership of the casting process itself". ExOne was now responsible for the design of the molds and cores, including solidification and finite element analysis, printing the mold, and overseeing the final casting. As part of its new responsibilities within the casting process, ExOne provided services such as x-ray analysis, post production processes such as etching, heat treating, and hot isostatic pressing, and finally machining off the cast part's gates and risers – the entire backend of the casting process.

Traditionally, ExOne had not been directly involved with these activities, but given their expertise, they integrated the new processes to provide the OEM "with the finished part – that's what they care about."

"We got our noses bloodied a bit. We knew how to print molds and cores, yet managing the whole downstream part of the process was kind of new territory for us. But we've learned a tremendous amount."

The OEM is thrilled with ExOne's technology and services. The faster design times and transparent design discussions that come along with moving an entire process to one vendor are huge wins for both companies. "We've completely changed the casting market for [the OEM] and how they go out to procure castings."

ExOne values its strategic partnerships as a way to demonstrate the tremendous value of their newest products and services. "We have to focus our resources and capital in the most efficient way we can."

"Now the goal is to get this technology into the hands of as many people as we can. It's exciting what we're doing here. We're expecting some pretty sizable contracts in 2015 to demonstrate this."

It is not ExOne's intention to begin competing with its customers or foundries. The company, along with its partners are instead focused on developing and maturing this new integrated process. For example, when a new customer or foundry buys an ExOne printer, they have access to the very best and proven industrial practices. "There's an unmet need in the industry that we believe our process fulfills, and it's our goal to go out there and demonstrate it."

Manufacturing as Service

As global demand for casting grows to 115 million tons in 2015, there is a need to identify leaders to help shed the industry's fragmented, dirty, and

dangerous legacy. ExOne plans to lead this transformation by using additive manufacturing and advanced simulation, modeling, and analysis for the design and production of complex molds and cores. This is the strategic intention behind ExCast, the company's integrated process for sand casting.

"The whole goal of all of this is to get the value of 3D printing cores and molds adopted into the foundry industry because it has the ability to revolutionize the way castings are done. It allows you to create certain parts that cannot be done with any other manufacturing method."

Demand for more efficient, environmentally friendly parts is also growing. Any increase in performance and/or efficiency is directly associated with an increase in complexity. These gains are created and delivered through the production of optimized designs with advanced simulation and analysis, and testing and inspection – processes native to additive manufacturing. These digital processes are also highly scalable in that computer models can be tested and iterated endlessly, which is much cheaper than the destructive testing of physical prototypes.

Using this advanced simulation and modeling, ExOne can significantly reduce the production time of a cast part from an industry average of four to six months to their target of four to six weeks. At the time metal is ready to be poured, other than that particular mold, not a single other physical piece has been created. Not only does digital testing save time and money, but it dramatically increases the chances of a successful pour on the very first attempt, opening the door to successfully using a variety of materials such as magnesium, aluminum, iron, and steel.

Digital design also reduces or eliminates the need to store physical patterns. Because the design and testing is done digitally, ownership of both the pattern and mold returns to the supplier or OEM, not the foundry. "Even though it may be *your* part, [the foundry] currently owns the ability to produce that part," said Gilmore. This has a dramatic effect on production lead times.

ExOne's larger vision includes establishing the Global Casting Center of Excellence, distributed across specific strategic geographic markets for customer base and partnerships with local foundries.


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