
# SMM Digital Transformation

## GUIDEBOOK

For the Small to Medium Sized Manufacturer (SMM)

**Advanced Manufacturing International**
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Accelerate your digital transformation with low-cost smart manufacturing solutions to compete and succeed in the global economy. Manufacturers want to produce products faster-better-cheaper. We have low-cost, easy to integrate and operate digital manufacturing technologies for small-to-medium sized manufacturers (SMMs) to help achieve those goals. Our dedicated industry experts collaborate with SMMs to find their pain points and suggest a low-cost, easy, and rapid technology solution.

Digital transformation is critical to manufacturing profitability in today's connected world to:

- Decrease Costs
- Improved Quality
- Increase Revenue
- Reduce Customer Lead Times

## *Who can I contact at AMI?*


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***AMI is part of the Manufacturing Technology Deployment Group (MTDG) that includes NCDMM, America Makes, and other programs.***


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# SMM Digital Transformation GUIDEBOOK

## How to Use This Guidebook

The ***Advanced Manufacturing International Guidebook*** is created with the business growth needs of small and medium manufacturers in mind. By utilizing the information in this chapter, you are taking the first steps to creating a competitive advantage for your company by innovating in the face of disruptive technologies.

This guidebook follows a logical flow to guide you as you learn more about transitioning to digital platforms. Review the chapters as they apply to your individual opportunities and resources, either in the order they're presented or jump around to fit your immediate needs.

This guidebook works to uplift manufacturers through increasing digital readiness; working together to accelerate the understanding and investment in emerging technologies; and foster a culture of innovation in the manufacturing industry. We encourage you to also review the future guidebooks in this series.

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## Guidebook Table of Contents (continued)





CHAPTER 1

# Additive Manufacturing

## Additive Manufacturing at a Glance

### What is "Additive Manufacturing?"

Additive Manufacturing (often referred to as simply "AM") is the process of adding layers of material (plastic, metal, concrete, etc.) upon one another to create a product. You may also hear it referred to as "3D printing" though that term only encompasses some of the processes that can be used in Additive Manufacturing.

### Why does Additive Manufacturing matter?

Additive Manufacturing has the capacity to complement and augment current manufacturing processes in the future.In three to five years, manufacturers will plan for Additive Manufacturing opportunities from product inception through design and production, in order to increase efficiencies, save money, and rapidly prototype.

### What are the biggest opportunity areas?

Traditional tooling, small weldments, low production runs, complex parts, and repair parts will see significant disruption. Learn more about opportunities on following pages.

### What are the business benefits of Additive Manufacturing?

Rapid innovation and prototyping, increased speed-to-market, lower tooling costs, unique designs, reduced partquantities, ability to embed sensors, multi-material designs, and a breadth of equipment to cover multiple applications. See more benefits in the Metrics section.

### Where can I find help to get started?

See the AMI contact information on the inside cover and visit advmfg.org. We are here to help you.

*Figure 1: Additive Manufacturing Chapter Information Flow*

CHAPTER 1
# Additive Manufacturing

## Chapter 1 Table of Contents





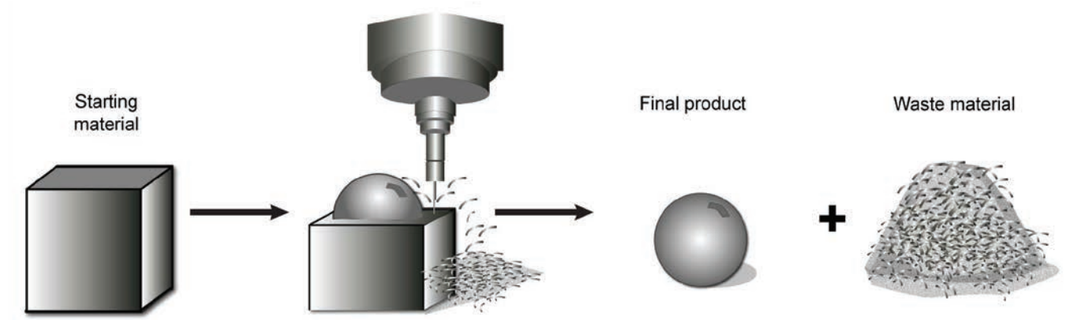
## Understand the Technology

In the first section, we take a closer look at the variety of technologies that contribute to the collective term "Additive Manufacturing." You'll gain a better understanding of how AM processes work through diagrams, frameworks, and definitions of key terms used in the AM space. This section also details additional online resources for greater understanding.

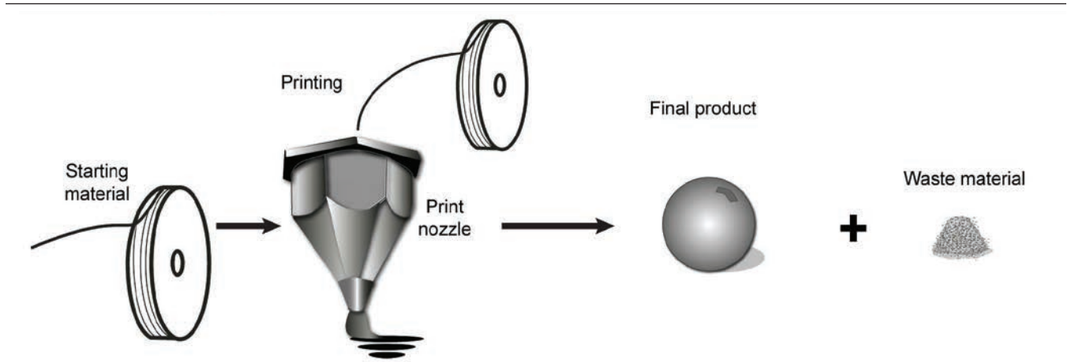
Additive Manufacturing is the process of adding layers of material (plastic, metal, concrete, etc.) upon one another to create a product. You may also hear it referred to as "3D printing," though that term only encompasses some of the processes that can be used in Additive Manufacturing.

*Figure 2. Conceptual Comparison Between Subtractive and Additive Manufacturing*[1]

**Subtractive Manufacturing**



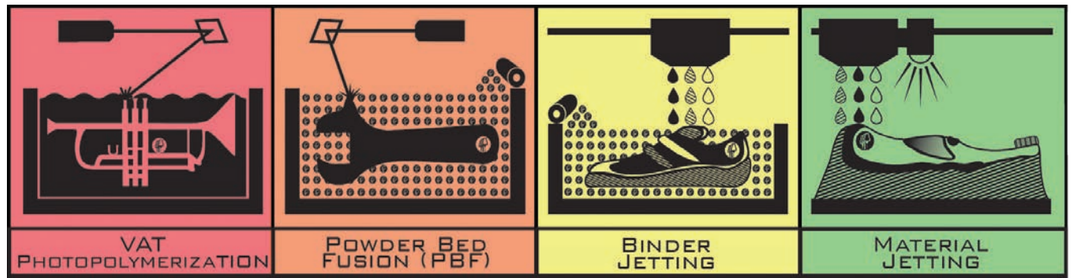

**Additive Manufacturing**




1 https://commons.wikimedia.org/wiki/File:Figure_1-_Conceptual_Comparison_between_Subtractive_and_Additive_Manufacturing_(22327379300).jpg

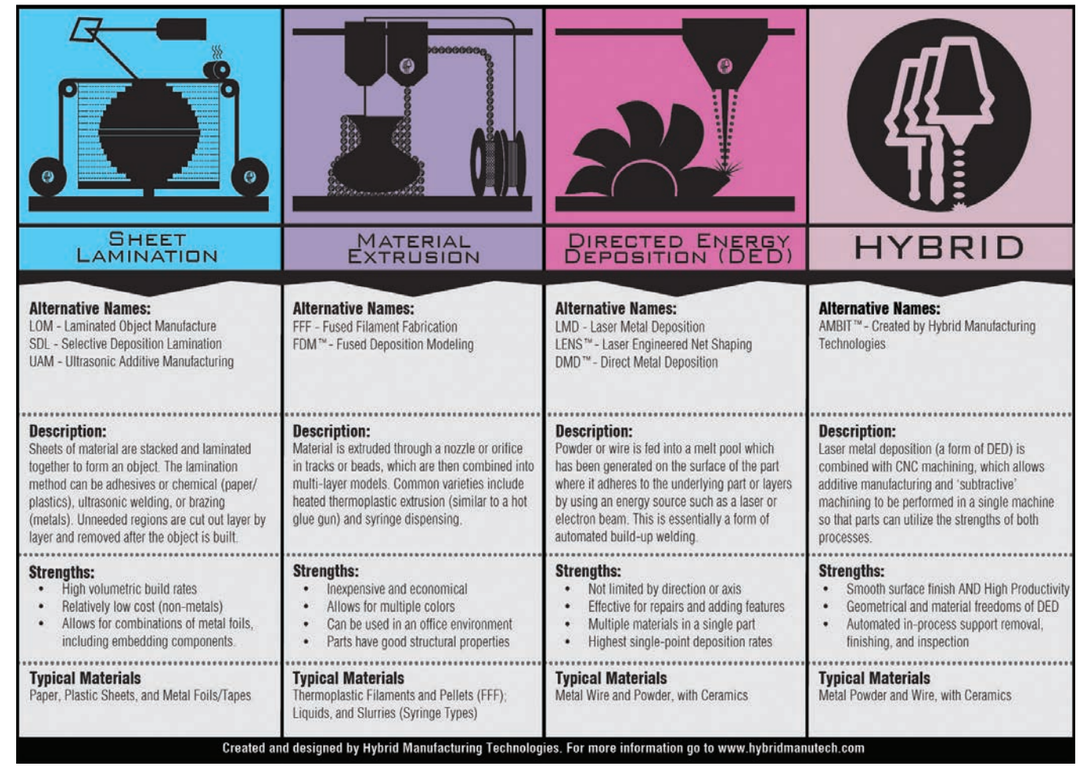
## Understand the Technology *(continued)*

*Figure 3. Seven Types of Additive Manufacturing and Hybrid, According to ASTM F2792 Standards. Diagram created by Hybrid Manufacturing Technologies.*[2]



| VAT Photopolymerization | Powder Bed Fusion (PBF) | Binder Jetting | Material Jetting |
|---|---|---|---|
| **Alternative Names:**<br>SLA™ - Stereolithography Apparatus<br>DLP™ - Digital Light Processing<br>3SP™ - Scan, Spin, and Selectively Photocure<br>CLIP™ – Continuous Liquid Interface Production | **Alternative Names:**<br>SLS™ - Selective Laser Sintering; DMLS™ - Direct Metal Laser Sintering; SLM™ - Selective Laser Melting; EBM™ - Electron Beam Melting; SHS™ - Selective Heat Sintering; MJF™ - Multi-Jet Fusion | **Alternative Names:**<br>3DP™ - 3D Printing<br>ExOne<br>Voxeljet | **Alternative Names:**<br>Polyjet™<br>SCP™ - Smooth Curvatures Printing<br>MJM - Multi-Jet Modeling<br>Projet™ |
| **Description:**<br>A vat of liquid photopolymer resin is cured through selective exposure to light (via a laser or projector) which then initiates polymerization and converts the exposed areas to a solid part. | **Description:**<br>Powdered materials is selectively consolidated by melting it together using a heat source such as a laser or electron beam. The unfused powder surrounding the consolidated part acts as a support material for overhanging features. | **Description:**<br>Liquid bonding agents are selectively applied onto thin layers of powdered material to build up parts layer by layer. The binders include organic and inorganic materials. Metal or ceramic powdered parts are typically fired in a furnace after they are printed. | **Description:**<br>Droplets of material are deposited layer by layer to make parts. Common varieties include jetting a photocurable resin and curing it with UV light, as well as jetting thermally molten materials that then solidify in ambient temperatures. |
| **Strengths:**<br>• High level of accuracy and complexity<br>• Smooth surface finish<br>• Accommodates large build areas | **Strengths:**<br>• High level of complexity<br>• Powder acts as support material<br>• Wide range of materials | **Strengths:**<br>• Allows for full color printing<br>• High productivity<br>• Uses a wide range of materials | **Strengths:**<br>• High level of accuracy<br>• Allows for full color parts<br>• Enables multiple materials in a single part |
| **Typical Materials**<br>UV-curable Photopolymer Resins (with various fillers) | **Typical Materials**<br>Plastics, Metal and Ceramic Powders, and Sand | **Typical Materials**<br>Powdered Plastic, Metal, Ceramics, Glass, and Sand. | **Typical Materials**<br>Photopolymers, Polymers, Waxes |

*Figure 3. (continued)*

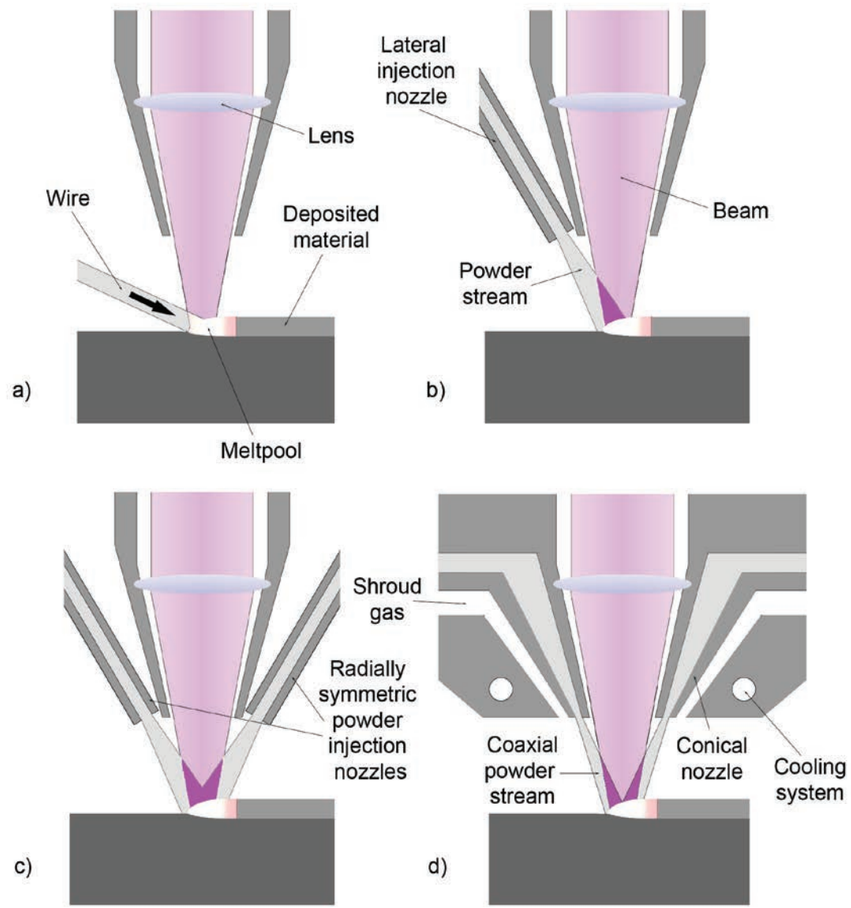


| Sheet Lamination | Material Extrusion | Directed Energy Deposition (DED) | HYBRID |
|---|---|---|---|
| **Alternative Names:**<br>LOM - Laminated Object Manufacture<br>SDL - Selective Deposition Lamination<br>UAM - Ultrasonic Additive Manufacturing | **Alternative Names:**<br>FFF - Fused Filament Fabrication<br>FDM™ - Fused Deposition Modeling | **Alternative Names:**<br>LMD - Laser Metal Deposition<br>LENS™ - Laser Engineered Net Shaping<br>DMD™ - Direct Metal Deposition | **Alternative Names:**<br>AMBIT™ - Created by Hybrid Manufacturing Technologies |
| **Description:**<br>Sheets of material are stacked and laminated together to form an object. The lamination method can be adhesives or chemical (paper/plastics), ultrasonic welding, or brazing (metals). Unneeded regions are cut out layer by layer and removed after the object is built. | **Description:**<br>Material is extruded through a nozzle or orifice in tracks or beads, which are then combined into multi-layer models. Common varieties include heated thermoplastic extrusion (similar to a hot glue gun) and syringe dispensing. | **Description:**<br>Powder or wire is fed into a melt pool which has been generated on the surface of the part where it adheres to the underlying part or layers by using an energy source such as a laser or electron beam. This is essentially a form of automated build-up welding. | **Description:**<br>Laser metal deposition (a form of DED) is combined with CNC machining, which allows additive manufacturing and 'subtractive' machining to be performed in a single machine so that parts can utilize the strengths of both processes. |
| **Strengths:**<br>• High volumetric build rates<br>• Relatively low cost (non-metals)<br>• Allows for combinations of metal foils, including embedding components. | **Strengths:**<br>• Inexpensive and economical<br>• Allows for multiple colors<br>• Can be used in an office environment<br>• Parts have good structural properties | **Strengths:**<br>• Not limited by direction or axis<br>• Effective for repairs and adding features<br>• Multiple materials in a single part<br>• Highest single-point deposition rates | **Strengths:**<br>• Smooth surface finish AND High Productivity<br>• Geometrical and material freedoms of DED<br>• Automated in-process support removal, finishing, and inspection |
| **Typical Materials**<br>Paper, Plastic Sheets, and Metal Foils/Tapes | **Typical Materials**<br>Thermoplastic Filaments and Pellets (FFF); Liquids, and Slurries (Syringe Types) | **Typical Materials**<br>Metal Wire and Powder, with Ceramics | **Typical Materials**<br>Metal Powder and Wire, with Ceramics |

Created and designed by Hybrid Manufacturing Technologies. For more information go to www.hybridmanutech.com

## Understand the Technology *(continued)*

*Figure 4. Additive Manufacturing Process: Laser Cladding Nozzle Diagram* [3]




## Understand the Technology *(continued)*

### Glossary of Key Additive Manufacturing Terms

Please refer to the glossary in the appendix for definitions of key Additive Manufacturing terminology that is utilized in this chapter. Definitions are provided for educational purposes as described by TEAMM (Technology Education in Additive Manufacturing and Materials), unless otherwise noted.

### Additional Online Resources

There are many online resources for review to deepen your understanding of Additive Manufacturing technologies, processes, opportunities, challenges, and more. We've outlined a few below:

- From MIT: "Standard Terminology for Additive Manufacturing Technologies." This terminology includes terms, definitions of terms, descriptions of terms, nomenclature, and acronyms associated with Additive Manufacturing technologies in an effort to standardize terminology used by AM users, producers, researchers, educators, press/media, and others.

  http://web.nit.edu/2.810/www/files/readings/AdditiveManufacturingTerminology.pdf

- From GE: "What is Additive Manufacturing?" (video). GE Aviation is revolutionizing the age-old rules of manufacturing and design. Learn how Additive Manufacturing, a 3D printing technology, frees engineers to design the perfect jet engine.

  https://www.youtube.com/watch?v=kKQ5KwFwW_s

- From Loughborough University's Additive Manufacturing Research Group: "The 7 Categories of Additive Manufacturing." Although the term "3D Printing" is often used as a synonym for all Additive Manufacturing processes, there are any individual processes which vary in their method of layer manufacturing. Individual processes will differ depending on the material and machine technology used. Hence, in 2010, the American Society for Testing and Materials (ASTM) group "ASTM F42 – Additive Manufacturing," formulated a set of standards that classify the range of Additive Manufacturing processes into seven categories.

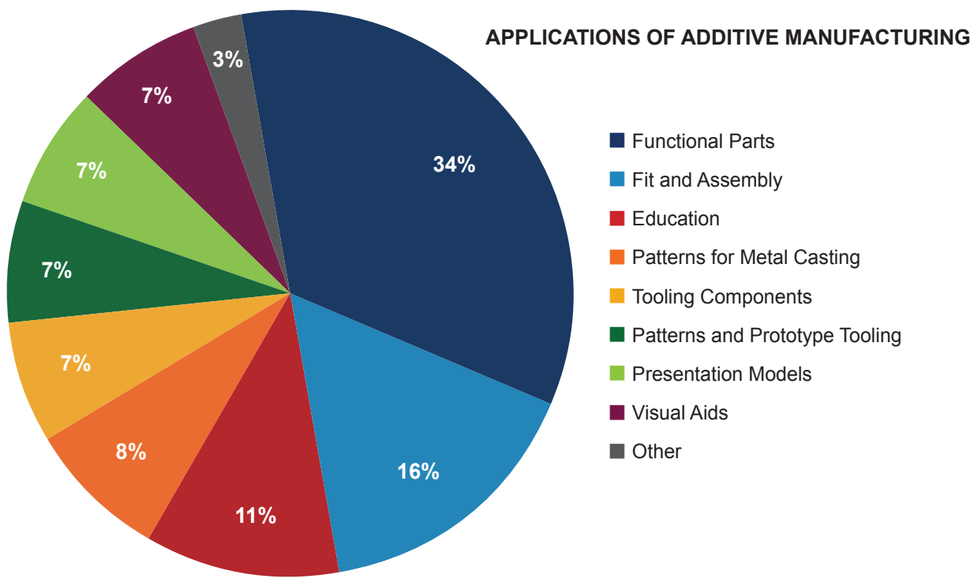
  http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/

## Identify Opportunities

Additive Manufacturing offers many opportunities to small and medium manufacturers - see figure 5 below. Of the myriad of opportunities, we have identified three key opportunity areas that will bring greatest benefit to small and medium manufacturers:

- Tooling
- Repair parts and legacy components
- Prototyping

*Figure 5. Applications of Additive Manufacturing by Use Case* [4]




### Opportunity #1: Tooling

Utilizing Additive Manufacturing, you can make tools that are either impossible to machine (complex or novel geometries) using traditional subtractive methods, or extremely expensive to machine. AM offers efficiencies in tooling production time, strength and durability in parts, higher quality finish, as well as the ability to combine multiple parts into one single print—all, of which, can positively impact return on investment over traditional manufacturing methods. Tooling with additive can be completed using a variety of materials, including nylon, fiber, and metals. Many manufacturers use AM to print one-off, custom parts to quickly solve in-house tooling issues as they arise.

### Opportunity #2: Repair Parts and Legacy Components

As Additive Manufacturing is quick and flexible in its applications, many manufacturers use it to update legacy components or efficiently replace parts in need of repair. Without Additive Manufacturing, these tasks would typically take much longer to cast a mold and print either in-house or overseas, and require more investment due to set-up costs and large batch requirements. By depositing new material using AM onto an existing part, it can not only create new use cases for tooling but also extend the lifetime of the part. If manufacturers do not have a 3D model of a legacy part or one in need of repair, there are resources that can assist in 3D-scanning solid models, as well as taking measurements in order to remodel a part (see Education section).

### Opportunity #3: Prototyping

Additive Manufacturing provides the opportunity to learn quickly, fail early, and move on to the next innovation step due to its production speed and low cost in small-batch runs. Traditionally, manufacturers become comfortable with long lead times and large runs of parts, incrementally inspiring less in-house R&D and innovation over time as it doesn't seem worth the trouble if it isn't successful. AM offers ultimate flexibility for prototyping new ideas for innovation in tooling, repair parts, fixtures, legacy equipment, and more. And, with both materials and hardware technology costs decreasing, the opportunities presented by quick and easy prototyping, and immediate problem-solving, will only continue to grow.

*Benefits and Use Cases of Additive Manufacturing Opportunities*

As the cost of international logistics continues to rise, and Additive Manufacturing become more affordable, manufacturers have the opportunity to shift facilities and production back to U.S. and local locations. This offers many benefits to small and medium manufacturers, including lower inventory levels as products are made in smaller batches and closer to "on-demand", and direct-to-consumer fulfillment opportunities.[5]

Let's examine the key benefits of utilizing Additive Manufacturing in each of the three opportunity areas previously identified. Below, you'll also find a case example for each opportunity area that shows how a manufacturer was able to utilize AM to produce better results than traditional subtractive methods.

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**Key Benefits of Opportunity #1: Tooling**

- Works best with low volume production needs, complex parts, and those that would normally be of high cost to create using traditional manufacturing methods
- Surrogate parts created using AM allows employees to practice on lightweight versions before casting is complete training aids
- Significantly cut weight of tools to increase efficiency of operator setup time
- Minimized print time and material usage while maintaining strength of tool - this can translate to high cost savings

[5] http://info.plslogistics.com/blog/6-effects-3d-printing-has-on-supply-chains

## Identify Opportunities *(continued)*

***Case Example: John Deere***

John Deere significantly cuts tooling costs by using Additive Manufacturing to create a porous support structure. See table below for cost comparisons. Fused deposition modeling (RDM) tooling proved to be more cost-effective vs. traditional aluminum and medium-density fiberboard (MDF) tooling.

| Supplier | Mold Material | Tooling Cost Quoted |
|---|---|---|
| A | Aluminum | $1,800 |
| B | Aluminum | $4,000 |
| C | Aluminum | $1,300 |
| D | Aluminum | $2,500 |
| E | MDF | ~$1,500 |
| In-House using AM | FDM | $300 |

**Key Benefits of Opportunity #2: Repair Parts and Legacy Components**

- Part repairs can be made in-place to extend lifetime and/or create new use cases and upgrades to legacy components without the need for new castings
- More efficient in-house component repair than replacing through distributor
- Reduced waste generation during the repair process
- Improved product utilization during repair and remanufacturing
- Reduced replacement parts inventory, offering cost-savings in times of low demand [6]

***Case Example: Siemens PGS***

Siemens Power Generation Services (Siemens PGS) provides support, maintenance and repair services to customers operating rotating power equipment such as gas steam and wind turbines, in gas turbines as one particular application whereby AM could improve customer value in spare parts repair and manufacturing, Siemens PGS has redesigned the burner "swirler" to make use of the design freedoms quickly and with less waste.

It is estimated that the repair time is 10 times quicker than the previous approach. Less waste is generated as little of the burner is now discarded; only the top 18 mm edge of the burner tip is removed prior to repair. Using AM also allows for much easier upgrading to the latest design and is a step toward the business' future vision of spare parts being manufactured on-demand, closer to the customer's location.[7]

6 http://www.sciencedirect.com/science/article/pii/S0959652616304395
7 http://www.sciencedirect.com/science/article/pii/S0959652616304395



**Opportunity #3: Prototyping**

- Cost-effectively test the function of a design, geometry, and fit-up with other parts before waiting the average 20-week lead time to cast and manufacture a tool. Prototyping can be done using in-house AM equipment or partnering with an innovation lab.
- Test product markets to better understand what customer want and get in front of them faster
- Test manufacturing process, including assembly and tooling/fixtures. Print a mock-up before buying an expensive tool
- Use prototypes during discussions with suppliers as surrogates for discussion, planning, verification and sales purposes
- Prototype large parts in multiple pieces using AM to ensure each part fits into manufacturing process without error

***Case Example: DePuy Spine***

DePuy Spine uses AM to speed prototyping of complex surgical tools. DePuy Spine makes more than 70 brand-name products with more than 10,000 product codes that are distributed globally. Using a single DMLS-machine from EOS in their own shop, DePuy Spine processed 2,000 prototype parts — benders, extractors, surgical screws, clamps, reduction devices and others in the first of use alone.

This has accelerated the development of its medical instruments according to the consulting doctors' requirements rather than manufacturability using traditional methods. Delivery times for surgical prototype tools have shrunk from several months to less than one week. The flexibility of CAD designs makes it easy to adjust to new requirements, and in-house production has saved DePuy Spine time and money.[8]

*Prototype of an Expedium SFX Cross Connector measuring device, which measures the distance between rods to indicate the size implant to use.*

## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to take in implementing Additive Manufacturing within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing AM is completely different from traditional subtractive manufacturing processes that you may be accustomed to, and that the prospect of this degree of change to your business model is daunting and frightening. It is our hope that, through the following content and previous look at the benefits of AM, you'll feel more comfortable exploring how you can utilize these technologies to bring production back in-house, and create new solutions for your customers.

**Change Management:** Building the Case Requires Data and a "Test-and-Learn" Approach for most small and medium manufacturers, the prospect of adopting AM seems risky, as it bucks the status quo and requires learning new equipment, technologies, and procedures to remain profitable. Only through experimentation, learning, and failing fast, can you quickly gain new expertise and experience that will benefit your company in years to come.

It's tempting to allow your self-defense mechanism to take over when faced with new technologies. It's natural for leaders to practice self-preservation to protect their role, team, and the future of the company at-large. However, it is new technologies, like Additive Manufacturing, that are shifting the very structure of the manufacturing industry. New business models are emerging, and the only way to survive is to be proactive in your adoption of AM in ways that fit your production methods.

There are many ways for you to get started along the path to utilizing AM. Use the change management tips below to make the case for change and immediately begin proving results:

- Understand the business value of Additive Manufacturing and set goals accordingly. Use our metrics outlined on Pg.19 as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating AM into your existing manufacturing processes. This will help in resource planning if you're measuring the right benchmarks out of the .. gate. Focus on one or two main use cases first before adding complexity to your production process and supply chain.

- Focus on getting every employee on board with the benefits of AM through peer education. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of AM initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaborate between disparate generations and team members. In reverse mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with AM technologies and benefits.

- Keep communication lines open during the trial-and-error portion of AM experimentation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to prototyping successful equipment, product, and tooling runs. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies in AM. Breed risk-taking early.



**Change Management:** Building the Case Requires Data and a "Test-and-Learn" Approach (continued) Part of change management also lies in understanding and planning for the challenges you will encounter in integrating AM into your existing operations. Below are three challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

- Longer print times: Depending on your application of AM, it may take longer to print an entire run of parts or tools due to the speed of the 3D-printer. For this reason, AM is best suited for small-batch runs and prototyping for many manufacturers.

- Frequent firmware updates: The software utilized to communicate with AM machinery requires regular updates in order to perform correctly. You'll need to plan for hardware and software resource allocation accordingly within your facilities.

- Costly metal printing filaments and powders: Though the cost of smaller 3D-printers that output plastic or other polymer parts is declining, the cost of utilizing AM for metal parts is still quite steep. Manufacturers must conduct a cost/benefits analysis of printing efficiency, cost, labor, batch size, and delivery against traditional methods (either internally or outsourced). The feasibility of using AM for metal materials will vary by project and is dependent on cost structure.

**Processes and Frameworks for Implementing Additive Manufacturing:**
Integrating AM into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks below to jumpstart your efforts.

***Workflow 1: Additive Manufacturing Planning and Deployment Strategy*** [9]

1. Diagnose: Assess your current state of AM knowledge and create a vision for where your company should be in its use of AM in three to five years.

2. Define: Define your strategy and timeline for achieving your vision. Include resource planning and goals and metrics to define success.

3. Deploy: Develop and pilot priority initiatives to test AM capabilities and use cases. Embed new capabilities, and upgrade necessary technologies and infrastructure.

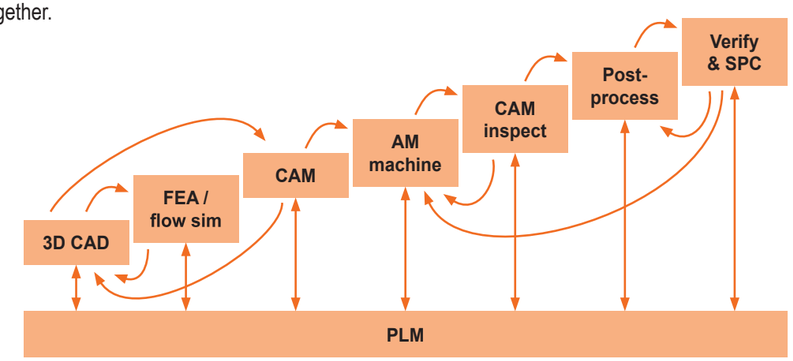
4. Determine: Measure impact against predefined benchmarks and iterate on future AM uses. Continue this process iteratively.

9 Workflow adopted from Altimeter Group, a Prophet Company's approach to jumpstart digital transformation.

## Build the Business Case & Begin Implementation *(continued)*

***Workflow 2: Tools Chain to Create a Process for Additive Manufacturing*** [10]

From Reinshaw: AM must be underpinned by an effective process chain with user-friendly design tools and a range of post-processing and metrology before the parts it makes can be used. Information must flow up and down the chain to link processes together.




**Resources Needed: Technology & Staffing**
Resources required to implement AM within your manufacturing facility will vary by the use cases you've established for the technology. For example, utilizing AM for rapid prototyping will yield a different cost structure for hardware, software, and staffing than planning to use AM as a replacement for all tool casting. As previously outlined, you must create a strategic plan for how AM will augment or replace your current manufacturing processes in the recommended opportunity areas of tooling, repair and legacy parts, and prototyping before jumping the gun and purchasing a series of 3D printers, updating software, and hiring unnecessary talent.

Use this general checklist to assist in the process of planning for your hard and soft costs in AM:

- **Hardware:** The machinery you purchase will depend on how you plan to use AM within your manufacturing facility. Refer to the glossary on Pg. 22 to review the types of AM that are best suited for various use cases. Once you have decided on how you will utilize the machine, and what type of AM is best suited for your needs, begin the research process of purchasing one or more machines.

  America Makes also offers the Senvol Database, a comprehensive database of industrial Additive Manufacturing machines and materials. Users are able to search the database by more than 30 fields, such as machine build size, material type, and material tensile strength. Access the database here to aid in your selection process: http://senvol.com/database/.

10 http://www.renishaw.com/en/blog-post-chain-of-tools-creating-a-process-chain-for-additive-manufacturing--37533



**Resources Needed: Technology & Staffing** *(continued)*

- Software: AM begins with a CAD model, which often means there will be a small learning curve for engineers and designers in transitioning into the software specific to your AM machine. There are many modeling programs that can be used for AM and feature sets depend on your intended use. Use the framework below to begin deciding which software is right for your application(s) and continue research online.

- *Figure 6: Seven sub-categories of AM software*[11]

| Basic Requirements | Scanning & File Transfer | Improving Performance Through Analysis | | | Process R&D |
|---|---|---|---|---|---|
| 1. Design Modeler<br>SOLIDWORKS<br>AUTODESK<br>SPACECLAIM | 3. Geometry Repair<br>Geomagic Design X<br>SPACECLAIM<br>Materialise 3-matic<br>netFabb | 4. Topology Optimization<br>Altair OptiStruct<br>solidThinking<br>VR&D | 5. Lattice Generation<br>WITHIN<br>Altair OptiStruct<br>simpleware<br>SPACECLAIM | 6. Part Analysis<br>ANSYS<br>ABAQUS<br>Altair<br>MSC Software | 7. Process Simulation<br>AUTODESK<br>FLEX<br>Lawrence Livermore National Laboratory<br>ANSYS |
| 2. Build Preparation<br>Magics by Materialise<br>exaSIM | | | | | |

*Note: Not a complete list*

- Employees and Hiring: Assess your current employees for skill-sets in CAD/CAM to determine if expertise is applicable and transferable to your AM software choices. Most manufacturers have in-house talent that is ready and able to augment their urrent skills. However, some small and medium manufacturers have opted to hire new employees with engineer and design expertise specific to AM in order to speed up the implementation process, as well as inject new, passionate approaches to innovation within the company. Work with education partners to find inexpensive design and engineering talent either freshly graduated or as a temporary intern (with, ideally, intent to hire).

11 http://www.padtinc.com/blog/the-focus/the-additive-manufacturing-software-conundrum

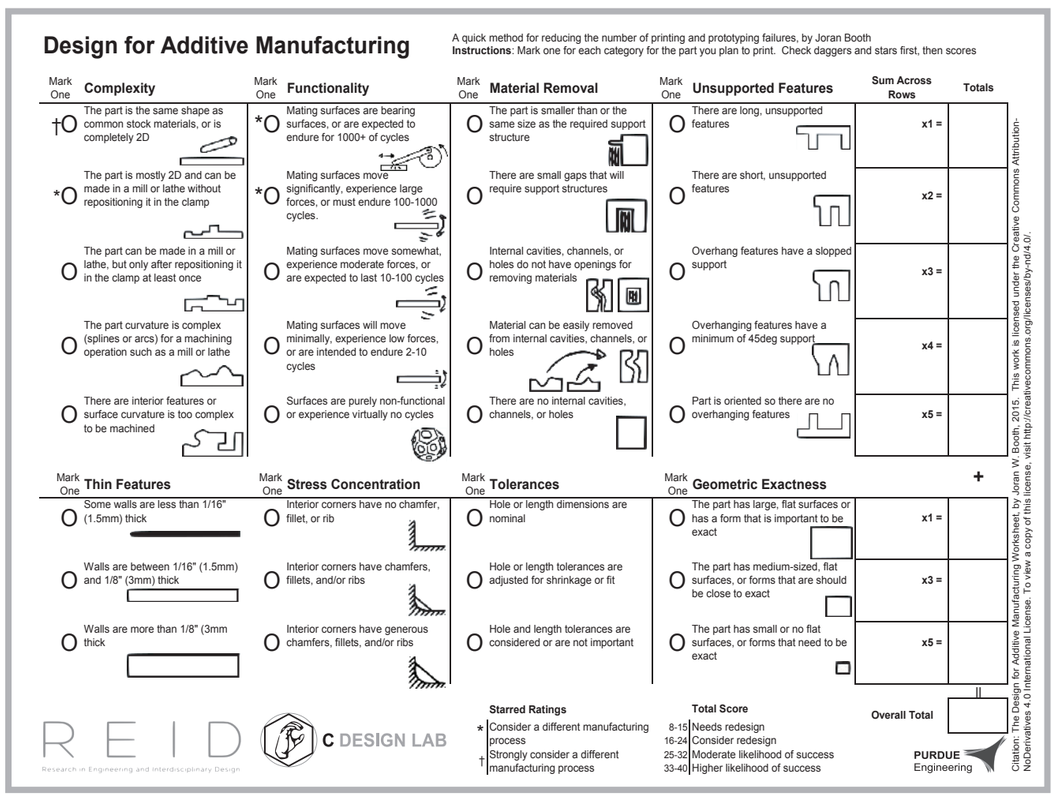
**Resources Needed: Technology & Staffing** *(continued)*

**"Quick Wins" to Get Started with Additive Manufacturing**

Take a page from the guidebooks of manufacturers like John Deere, Trackside Solutions, Ossian, and more that are already up-and-running with AM by following a few of their tips to jumpstart your use of the technology:

- Start with brainstorming potential applications in tooling. What can you make that's low volume, and expensive to make traditionally? Also, consider what would require otherwise complicated or impossible geometry using traditional methods—those are your immediate opportunity areas! Utilize the worksheet below in Figure 7 (available for high resolution download at: https://joranbooth.files.wordpress.com/2015/10/dfam1.pdf) from Joran Booth to guide you through the process of designing parts for achieve your goals. It was created to quickly reduce the number of printing and prototyping failures.

*Figure 7. Design for Additive Manufacturing Worksheet from Joran Booth*



**Design for Additive Manufacturing**

A quick method for reducing the number of printing and prototyping failures, by Joran Booth
**Instructions**: Mark one for each category for the part you plan to print. Check daggers and stars first, then scores

| Mark One | Complexity | Mark One | Functionality | Mark One | Material Removal | Mark One | Unsupported Features | Sum Across Rows | Totals |
|---|---|---|---|---|---|---|---|---|---|
| †O | The part is the same shape as common stock materials, or is completely 2D | *O | Mating surfaces are bearing surfaces, or are expected to endure for 1000+ of cycles | O | The part is smaller than or the same size as the required support structure | O | There are long, unsupported features | x1 = | |
| *O | The part is mostly 2D and can be made in a mill or lathe without repositioning it in the clamp | *O | Mating surfaces move significantly, experience large forces, or must endure 100-1000 cycles. | O | There are small gaps that will require support structures | O | There are short, unsupported features | x2 = | |
| O | The part can be made in a mill or lathe, but only after repositioning it in the clamp at least once | O | Mating surfaces move somewhat, experience moderate forces, or are expected to last 10-100 cycles | O | Internal cavities, channels, or holes do not have openings for removing materials | O | Overhang features have a slopped support | x3 = | |
| O | The part curvature is complex (splines or arcs) for a machining operation such as a mill or lathe | O | Mating surfaces will move minimally, experience low forces, or are intended to endure 2-10 cycles | O | Material can be easily removed from internal cavities, channels, or holes | O | Overhanging features have a minimum of 45deg support | x4 = | |
| O | There are interior features or surface curvature is too complex to be machined | O | Surfaces are purely non-functional or experience virtually no cycles | O | There are no internal cavities, channels, or holes | O | Part is oriented so there are no overhanging features | x5 = | |

| Mark One | Thin Features | Mark One | Stress Concentration | Mark One | Tolerances | Mark One | Geometric Exactness | + |
|---|---|---|---|---|---|---|---|---|
| O | Some walls are less than 1/16" (1.5mm) thick | O | Interior corners have no chamfer, fillet, or rib | O | Hole or length dimensions are nominal | O | The part has large, flat surfaces or has a form that is important to be exact | x1 = |
| O | Walls are between 1/16" (1.5mm) and 1/8" (3mm) thick | O | Interior corners have chamfers, fillets, and/or ribs | O | Hole or length tolerances are adjusted for shrinkage or fit | O | The part has medium-sized, flat surfaces, or forms that are should be close to exact | x3 = |
| O | Walls are more than 1/8" (3mm thick | O | Interior corners have generous chamfers, fillets, and/or ribs | O | Hole and length tolerances are considered or are not important | O | The part has small or no flat surfaces, or forms that need to be exact | x5 = |

REID Research in Engineering and Interdisciplinary Design

C DESIGN LAB

| Starred Ratings | |
|---|---|
| * | Consider a different manufacturing process |
| † | Strongly consider a different manufacturing process |

| Total Score | |
|---|---|
| 8-15 | Needs redesign |
| 16-24 | Consider redesign |
| 25-32 | Moderate likelihood of success |
| 33-40 | Higher likelihood of success |

Overall Total =

PURDUE Engineering





**Resources Needed: Technology & Staffing** *(continued)*

- Gain experience through service bureaus. Turn to Pg. 21 for educational and partnership resources. Depending on your AM applications, it's likely you'll be able to make use of others' assets during your planning and consideration phases. This will help you build the business case if you need to "sell" the idea of AM to leadership within your company.

- Talk to machine resellers to better understand the pros and cons of each machine you're considering purchasing. They'll be able to tell you the ideal applications for each machine, material needs and tolerances, and if it fits with your production needs. Before making a large purchase, experiment with a cheaper 3D plastic printer. Get them in the hands of your engineers to begin rapidly innovating in real-time.

**Metrics for Success: How to Measure Impact**
When setting your objectives for AM, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance of AM against traditional manufacturing, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

- More efficient and rapid prototyping
- Production time reduction
- Higher precision and more uniform cooling patterns
- Decreased production and output time
- Reduced post-processing time and resources
- Increased component stability
- Greater accuracy and repeatability
- Decreased materials costs
- Increased customer value
- Increased product sales in either volume or price-point
- Competitive advantage in innovation
- ... and more, depending on your specific AM application

**Resources Needed: Technology & Staffing** *(continued)*

*Figure 8: Additive Manufacturing Occupational Profile. Foundation for EICC curriculum.*

| Categories | Tasks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Promote Job Safety** | A | Follow PPE procedures | Participate in safety training | Perform Lockout / Tagout | Perform material storage procedures | Perform matieral use procedures | Perform material disposal procedures | |
| **Perform CAD File Procedures** | B | Generate CAD file | Evaluate CAD file | Process CAD file | | | | |
| **Perform AM Machine Setup** | C | Clean AM machine | Prepare AM materials | Install AM materials into machine | Load CAD file into machine | Level AM machine | | |
| **Build AM Part** | D | Start build cycle | Monitor build cycle | Remove AM part from machine | Evaluate AM part quality | | | |
| **Perform Part Post-Processing** | E | Remove part support structure | Perform post-build operation (e.g., heating, coating, hot isostatic pressing) | Evaluate post-processed part | | | | |
| **Perform Troubleshooting / Maintenance Duties** | F | Troubleshoot AM build prob - lems. | Troubleshoot AM equipment problems. | Perform machine diagnostics. | Communicate problems to: • customers • electricians • engineers • equipment manufacturers • management | Implement recommended solutions | Evaluate implemented solutions | Perform AM equipment preventative maintenance |
| **Perform Administrative Duties** | G | Schedule AM builds (I.e. logistics) | Supervise shop floor tasks | Supervise AM technicians | Supervise AM processes | Participate in equipment / technology training | Participate in equipment acquisition | Perform recordkeeping tasks |

### General Knowledge & Skills

- Ability and willingness to follow directions
- Ability to lift up to 50 lbs.
- Ability to read a print
- Ability to use respirator
- Algebra
- AM machine software (e.g., Magic 19, Materialise, Netfabb)
- Basic arithmetic
- Basic regulations knowledge
- Basic understanding of electricity and electrical schematics
- Basic understanding of materials
- Basic understanding of quality assurance and quality control
- CAD skills
- Communication
- Ethics
- General employability skills
- Geometric Dimensioning and Tolerancing
- Keep up with rapidly changing technology
- Lockout / tagout
- Machine limitations
- Multitasking
- Problem solving
- Recordkeeping accuracy
- Specific machine knowledge

### Tools & Equipment

- Bandsaws
- Basic hand tools (e.g. wrenches, screwdrivers, hammers)
- Caliper
- Computers
- Dial indicators
- Electrical Discharge Machine
- Heat treating equipment
- High-pressure cylinders
- Lockout / tagout equipment
- Micrometer
- Mils and lathes
- MS Office programs
- Multimeter
- Professional camera
- Safety equipment
- Scales (e.g. precision, density, measurements)
- Tablets



## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to-implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**America Makes:** America Makes is the nation's leading and collaborative partner in Additive Manufacturing (AM) and 3D printing (3DP) technology research, discovery, creation, and innovation. Structured as a public-private partnership, they innovate and accelerate AM/3DP to increase our nation's global manufacturing competitiveness.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse highlighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing Extension Partnership:** MEP is a public / private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**ThomasNet.com:** ThomasNet.com is a search engine to discover certified suppliers to the supply chain, identify local job shops, find specific products or accelerate the design process.

## Appendix

**Glossary of Key Additive Manufacturing Terms**
*Definitions provided for educational purposes as described by TEAMM (Technology Education in Additive Manufacturing and Materials), unless otherwise noted.*

**3D Printer:** Machine used for 3D printing.

**3D Scanning:** Method of acquiring the shape and size of an object as a 3-dimensional representation by recording x,y,z coordinates on the object's surface and through software the collection of points is converted into digital data.

**Build Cycle:** Single cycle in which one or more components are built up in layers in the process chamber of the machine.

**Build Platform:** Of a machine, any base which provides a surface upon which the build is started and supported throughout the build process.

**Build Surface:** Area where material is added, normally on the last deposited layer which becomes the foundation upon which the next layer is formed.

**Computer Aided Design (CAD):** The use of computers for the design of real or virtual objects.

**Computer Aided Manufacturing (CAM):** Typically refers to systems that use surface data to drive CNC machines, such as digitally-driven mills and lathes, to produce parts, molds, and dies.

**Fused Deposition Modeling (FDM):** Making of thermoplastic parts through heated extrusion and deposition of materials layer by layer. A plastic filament is unwound from a coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be turned on and off. The nozzle is mounted to a mechanical stage which can be moved in both horizontal and vertical directions. As the nozzle is moved over the table in the required geometry, it deposits a thin bead of extruded plastic to form each layer. The plastic hardens immediately after being squirted from the nozzle and bonds to the layer below. The entire system is contained within a chamber which is held at a temperature just below the melting point of the plastic.

**Prototype Tooling:** Molds, dies, and other devices used to produce prototypes; sometimes referred to as bridge tooling or soft tooling.

**Rapid Tooling:** In machining processes, the production of tools or tooling quickly by subtractive manufacturing methods, such as CNC milling, etc.

**Selective Layer Sintering (SLS):** Thermoplastic powder is spread by a roller over the surface of a build cylinder. The piston in the cylinder moves down one object layer thickness to accommodate the new layer of powder. Here, a piston moves upward incrementally to supply a measured quantity of powder for each layer. A laser beam is then traced over the surface of this tightly compacted powder to selectively melt and bond it to form a layer of the object. The fabrication chamber is maintained at a temperature just below the melting point of the powder so that heat from the laser need only elevate the temperature slightly to cause sintering. The process is repeated until the entire object is fabricated. After the object is fully formed, the piston is raised to elevate it. Excess powder is brushed away and final manual finishing may be carried out.



## Appendix *(continued)*

**Stereolithography (SL):** Process used to produce parts from photopolymer materials in a liquid state using one or more lasers to selectively cure to a predetermined thickness and harden the material into shape layer upon layer. Once one layer is completely traced, it's lowered a small distance into the vat and a second layer is traced right on top of the first. The self-adhesive property of the material causes the layers to bond to one another and eventually for a complete, three-dimensional object after many such layers are formed. Stereolithography is the most widely used rapid prototyping technology.

**STL:** A file format native to the stereolithography computer-aided drafting (CAD) software that is supported by many software packages; it is widely used for rapid prototyping and computer-aided manufacturing.

**Subtractive Manufacturing:** Making objects by removing of material (for example, milling, drilling, grinding, carving, etc,) from a bulk solid to leave a desired shape, as opposed to Additive Manufacturing.

**Tool, Tooling:** A mold, die, or other device used in various manufacturing and fabricating processes such as plastic injection molding, thermoforming, blow molding, vacuum casting, die casting, sheet metal stamping, hydroforming, forging, composite lay-up tools, machining and assembly fixtures, etc.

CHAPTER 2

# Virtual Reality & Augmented Reality

## VR & AR at a Glance

**What are "Virtual Reality" and "Augmented Reality?"**
Virtual Reality, most commonly referred to as simply "VR," utilizes computer-generated simulations of three-dimensional images or environments that users can interact with in a seemingly "real" way through wearing special equipment such as VR headsets and hand-held sensors or stepping into immersive multi-screen physical environments. Augmented Reality, or "AR," is less immersive than VR, overlaying computer-generated images on real-world objects and environments, viewed through technology-enabled glasses or with a mobile-device application.

**Why do Virtual Reality & Augmented Reality matter?**
Manufacturers can achieve greater cost and time efficiencies by utilizing virtual and augmented reality technology to simulate real-world scenarios. These technologies are critical to compete and achieve scale in a global economy of larger and greater-resourced manufacturers. Many manufacturers are already utilizing and experimenting with VR & AR to better equip their technicians for machine repairs, employee training, architectural development, equipment sales, and more.

**What are the biggest opportunity areas?**
We have identified four key opportunity areas in VR & AR for manufacturers:

- Opportunity #1: Immersive Training and Education. Manufacturers have the opportunity to use VR to train employees in virtual, simulated worksite environments.
- Opportunity #2: Operating and Repair Guidance. Augmented reality shines in its facilitation of efficient employee guidance while operating or repairing equipment.
- Opportunity #3: Site, Machine, and Parts Planning. VR gives manufacturers the opportunity to understand machinery and tooling before it hits the manufacturing floor.
- Opportunity #4: Sales Engagement. Virtual reality can also be used as a technical sales tool, offering the ability to view intricacies of machinery before a purchase order is signed.

More information can be found in the Identify Opportunities section, page 9.

**What are the business benefits of utilizing VR & AR?**
Though dependent on the VR & AR opportunity area(s) you pursue, manufacturers witness many benefits from implementing these technologies. These include decreased onsite and field accidents, more efficient repairs, reduced maintenance and rework costs, increased profitability and sales, and more efficient troubleshooting. For a full list of metrics, turn to the Build the Business Case and Begin Implementation section.

**Where can I find help to get started?**
There are agencies that can assist you with the development and implementation of VR & AR solutions, hardware, and applications. There are also many free online resources, as well as educational courses offered by universities and colleges. Go to Find Help for a list of resources to help jump start your use of VR & AR to grow your business. See the AMI contact information on the inside cover and visit advmfg.org. We are here to help you.



*Figure 1: Virtual Reality & Augmented Reality Chapter Information Flow*


## VR & AR Table of Contents

## Understand the Technology

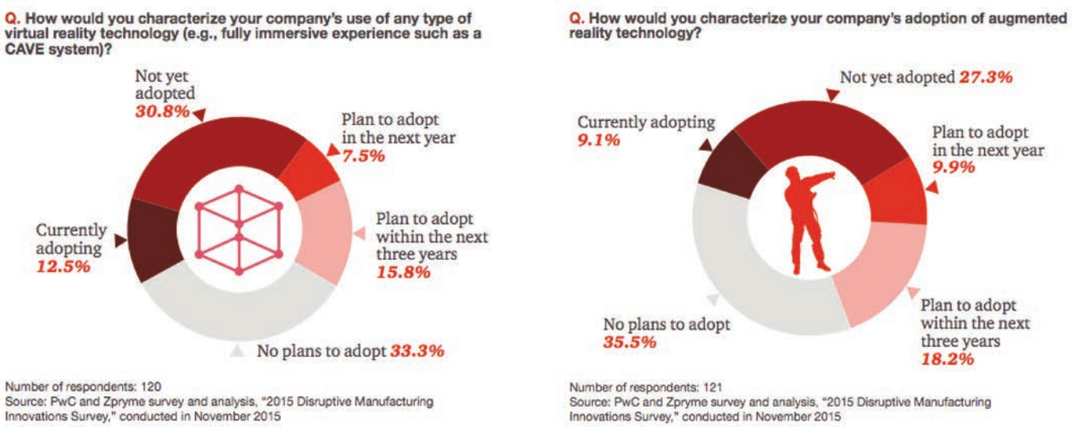
In the first section, we take a closer look at the technologies that enable virtual reality (VR) and augmented reality (AR). You'll gain a better understanding of how VR & AR contribute to your company's digital technology and innovation strategy through diagrams, frameworks, and definitions of key terms uses in the space. This section also details additional online resources for greater understanding.

Virtual Reality, most commonly referred to as simply "VR," utilizes computer-generated simulations of three-dimensional images or environments that users can interact with in a seemingly "real" way through wearing special equipment such as VR headsets and hand-held sensors or stepping into immersive multi-screen physical environments.

Augmented Reality, or "AR," is less immersive than VR, overlaying computer-generated images on real-world objects and environments, viewed through technology-enabled glasses or with a mobile-device application. You may also come across the term "mixed/merged reality," which refers to a combination of VR & AR.

**Glossary: VR & AR Terms**
Please refer to the glossary in the appendix on pg. 20 for definitions of key VR & AR terminology that is utilized in this chapter. Definitions provided for educational purposes as described by Gearbrain unless otherwise noted.

*Figure 2: More than one in three manufacturers expect to adopt VR & AR technologies by 2018, via PwC* [1]






## Understand the Technology *(continued)*

*Figure 3. Virtual Reality Simulations: Headsets vs. On-screen* [2]

**Virtual Reality Headset:** Using a VR headset to interact with an immersive manufacturing simulation. Photograph (right) showcases what the headset wearer sees within the virtual environment at scale. VR headsets are used individually to create immersive experiences.

**Virtual Reality On-Screen:** The photograph (right) showcases the experience of interacting with virtual reality through a series of screens in an immersive "cube" environment that scale to the desired dimensions. These environments do not require specialty headsets, but often utilize 3D-glasses to achieve desired effects. They can also be used in group settings with multiple people viewing the same simulation.

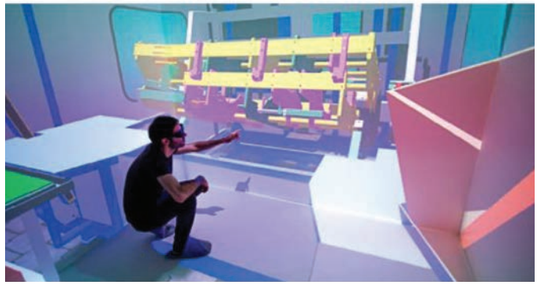
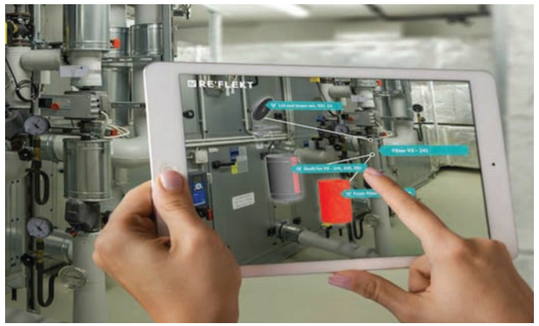


*Figure 4. Augmented Reality via Mobile Device/Tablet*

The photo (right) showcases an augmented reality application being used on a tablet to overlay important repair and parts information on a piece of equipment. Augmented reality applications are often interactive, allowing operators to see procedures, additional specs, and more.



2 http://www.advice-manufacturing.com/Virtual-and-Augmented-Reality.html

## Understand the Technology *(continued)*

*Figure 5. Mixed Reality on the Factory Floor, via Deloitte* [3]

**Maintenance & operations**

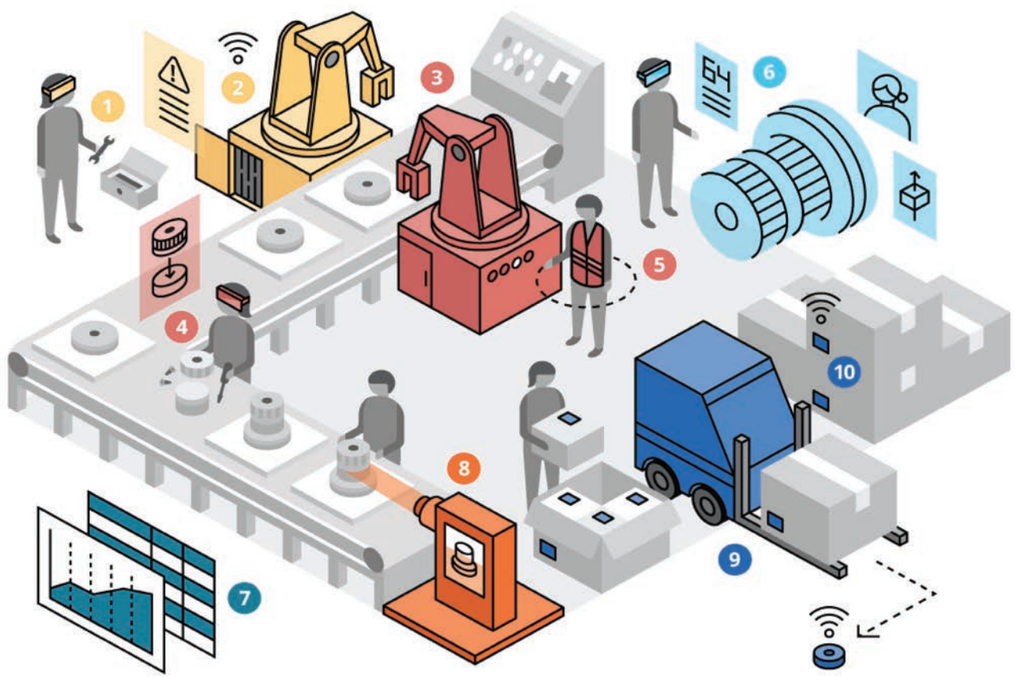
1 Smart goggles provide metrics, instruction, and remote support to maintenance workers. 2 Sensors on machines generate diagnostic data and machine learning helps predict failures and improve productivity.

**Production**

3 Smart robots automate production. 4 Smart goggles with cameras and motion sensors help train workers and overlay assembly instructions. 5 Smart equipment like safety vests and hard hats monitor surroundings.

**Design & development**

6 Virtual prototypes allow rapid iteration, assembly simulation, advanced testing, and remote collaboration. Full-body motion tracking informs ergonomic design of workspaces and assembly lines.




**Reporting & analytics**

7 All devices are connected to a data management system, which digitally documents each step of the process. Advanced analytics predict demand patterns to optimize production.

**Quality control**

8 Machines use sensors, computer vision, and photogrammetry to evaluate products against standards. 3D models give inspectors access to all product specs during production.

**Distribution**

9 Beacons and smart goggles guide operators through the warehouse. Autonomous vehicles manage inventory. 10 Product sensors provide visibility into the entire supply chain.

Deloitte University Press | dupress.deloitte.com

3 https://dupress.deloitte.com/dup-us-en/focus/tech-trends/2017/mixed-reality-applications-potential.html



## Understand the Technology *(continued)*

**Additional Online Resources**

There are many online resources for review to deepen your understanding of VR & AR applications, technologies, use cases, opportunities, challenges, and more. We've outlined a few below:

- ***"For US manufacturing, Virtual Reality is for real"*** from PwC: Read the whitepaper at: https://www.pwc.com/us/en/industrial-products/publications/assets/augmented-virtual-reality-next-manufacturing-pwc.pdf

  This whitepaper explains how virtual and augmented reality technologies are reimagining America's factory floors. Based on manufacturer survey data, this report reveals a snapshot of how these technological tools are being used by manufacturers and suggests how their adoption could change in the future. Topics covered include VR & AR adoption, popular applications, and challenges faced.

- ***"VR Process Simulation"*** by Ant Automation: Watch the video at: https://www.youtube.com/watch?v=xvyKIOdhrX4

  In this video, you'll see live examples of VR in action in a manufacturing environment, used for process and physics simulation, 3D visualization, virtual commissioning, and operator training.

- ***"Virtual and Augmented Reality: Understanding the Race for the Next Computing Platform"*** (an excerpt), from Goldman Sachs. Download the report at: http://www.goldmansachs.com/our-thinking/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf

  This report outlines the current state of VR & AR and potential for its growth, highlighting key technologies in the ecosystem (hardware and software); forecasted adoption; future potential of the market; and – most importantly – uses cases for a variety of industries, including education, military, and engineering. All, of which, are relevant and complementary to manufacturing use cases.

## Identify Opportunities

Virtual and augmented reality offers many opportunities to small and medium manufacturers. We have identified four key areas that can bring greatest benefit to small and medium manufacturers: expanding reach, deepening engagement, closing sales, and collaboration with peers.

### Opportunity #1: Immersive Training and Education

Manufacturers have the opportunity to use VR to train employees – either onsite or remotely – in virtual, simulated worksite environments. Consider your options in scaling your complex equipment, repair, or other training programs to multiple employees at various locations. VR training is also effective in immersing trainees in high-pressure or otherwise dangerous scenarios where they must choose the correct course of action 100% of the time in order to avoid injury or damages to expensive equipment. In a virtual training environment, such risks are mitigated while also delivering a "hands-on" training environment. There are also AR education opportunities to train employees on-the-job using visual informational assists via augmented reality glasses or similar technologies.

### Opportunity #2: Operating and Repair Guidance

Augmented reality shines in its facilitation of efficient employee guidance while operating or repairing equipment. Viewed as a visual overlay to the real world via AR glasses, mobile phones, or tablets, AR expands information about physical equipment that is useful to employees. This includes machine models, serial numbers, repair procedures, operating manuals, and more. AR is especially useful for field technicians when servicing older equipment or unfamiliar equipment among manufacturing facilities or multiple sites, as all needed information is readily accessible and in eyesight. This eliminates the need to carry a parts catalog or training manual.

### Opportunity #3: Site, Machine, and Parts Planning

VR gives manufacturers the opportunity to understand machinery and tooling before it hits the manufacturing floor. By creating 3D models that can be explored via virtual reality software and hardware, engineers are able to better predict potential collisions among other equipment, plan for ergonomics of employee operations, and steer clear of potential safety concerns. This lends to cost efficiencies during 3D-mockups in quickly identifying potential problems and course-correcting, vs. creating a part, tool, or bringing in a machine that doesn't align with existing operations. Using VR, manufacturing design and engineering transforms from reactive to proactive, allowing for entire teams to easily weigh in on the process before any real-world applications are implemented.

### Opportunity #4: Sales Engagement

Virtual reality can also be used as a technical sales tool, offering the ability to view intricacies of machinery before a purchase order is signed. In a virtual environment, sales and engineering teams can showcase advantages at any scale. This builds bridges between those designing the technologies and equipment with less technical buyers. By creating proofs-of-concept in VR, sales prospects are immersed and influenced in a deeper way during design reviews. This also decreases risk throughout projects, as all requirements are clearly articulated and tested in a virtual space that mirrors that of a manufacturing floor.



## Identify Opportunities *(continued)*

**Benefits and Use Cases of VR & AR Opportunities**

In this section, we'll examine the key benefits of utilizing VR &AR in each of the four opportunity areas on page 9. Below, you'll also find a case example for each opportunity area that shows how a manufacturer was able to utilize VR or AR to produce results throughout the purchase funnel.

### Opportunity #1: Immersive Training and Education

- Train for workplace scenarios that rarely occur without the need for real-world resource allocation or waste. Recreate those environments virtually to help employees learn by doing vs. looking at training manuals or PowerPoint slides.

- Knowledge transfer among outgoing and incoming generations of workers is made simple with VR, as no information is lost with employee churn. By documenting all tasks and creating training scenarios in VR, complicated equipment processes are easily and efficiently passed among operators and technicians. Refresher training in VR is accessible on-demand, too.

- Train employees and teams together that would have to work together in complex day-to-day or emergency scenarios. VR allows for the connection of multiple training environments and participants to act out situations where teamwork is critical.

**Case Example: ExxonMobil Partners with EON for Holistic Virtual Reality Training Program**

ExxonMobil wanted a holistic training approach that combined effective field training using 3D immersive environments with panel operator training using advanced dynamic process simulators. Partnering with EON Virtual Reality for training development and utilizing its Icube portable VR display screens, ExxonMobil is able to offer interactive field training to employees. ExxonMobil simulates a variety of plant scenarios, such as routine operations, emergency response, abnormal operations, upset scenarios, integrity critical procedures, and low probability-high consequence events in a safe and controlled environment. Employees, either individually or in teams, are repeatedly trained on how to respond to these situations in VR until their actions become second-nature.[4]

*ExxonMobil employees in virtual training environments.*

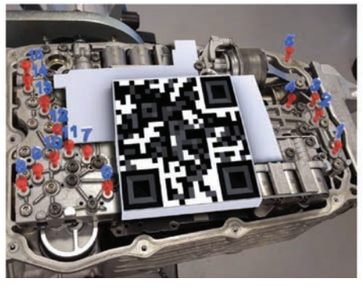
[4] Example provided by Frank Botdorf, EON Virtual Reality.

## Identify Opportunities *(continued)*

### Opportunity #2: Operating and Repair Guidance

- Manufacturers no longer need to rely on employee memories post-training, as AR clears confusion by helping technicians identify problems, models, parts, and repair procedures on-demand. Variability among sites is no longer a challenge.
- Although AR glasses (e.g. Google Glass, Microsoft Hololens) are convenient for your employees using AR in the field or on the manufacturing floor, many companies are taking advantage of this technology using common devices like smart-phones and tablets. Using the cameras on these devices, employees can scan the parts or equipment for repair needs and pull up contextual information to proceed, outlined step-by-step in a virtual task list. This offers tremendous cost efficiencies in completing repairs and installations the first time around.
- As machines become "smarter," embedded with sensors and connected through the "Internet of Things" network, employees armed with AR will also become smarter. Analytics and data shared among machinery and equipment will be delivered simultaneously to operators, allowing them to simply download the prescription and carry out recommended actions through AR guidance.

**Case Example: Mercedes Benz Uses AR Overlays for Maintenance and Repair Procedures**
Mercedes Benz has deployed a first-of-its-kind AR training experience that allows mechanical technicians to operate repair and maintenance procedures using AR overlays displayed directly to the viewer's eyes through a pair of specially engineered AR glasses (see image at right). Voice and visual overlays guide the technicians through each step and allow for a hands-free process of repairing a transmission.[5]



### Opportunity #3: Site, Machine, and Parts Planning

- Utilizing 3D-modeling and VR helps manufacturers understand machinery, equipment, and parts before they hit the shop floor. Quickly mock up different proofs-of-concept without paying for a new build each time. VR can also be used in entire site planning in the architectural design phase.
- VR is accessible 24/7 for planning purposes, without having to be inside the facility. Engineers and planners have clear view and influence on the design process from the start, rather than reactively catching up (and increasing project time and investment).
- Increases safety when detecting potential collisions, overlay, ergonomics, or employee accidents ahead of time. It's hard to detect such issues – especially when equipment, robots, and humans are interacting closely within the same space – when looking at a 2D drawing.
- View sites, machines, and parts on a 1:1 scale individually or as a team, or zoom in to see intricate details. This allows manufacturers to view how tight tooling will fit together, how sensors will work, and other potential issues in programming and design. Overall, VR can help in "de-risking" a project from start to finish.

5 Example provided by Frank Botdorf, EON Virtual Reality.

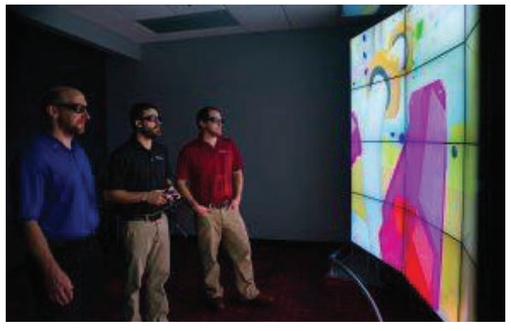


## Identify Opportunities *(continued)*

**Case Example: Quad Cities De-icing Chemical Manufacturer Ossian Inc. Plans for New Facility in VR**
Prior to breaking ground at its new facility in Walcott, Iowa, Ossian Inc. began building layouts in VR in order to find the best work-paths for equipment and employees. VR simulations of the new facility helped Ossian understand not only where equipment would be placed, but also how to get it into the building and maneuver machinery amongst other objects and employees. The flexibility of VR allowed Ossian to mock up many variations efficiently as layout needs shifted, including simulating catwalks, equipment access points for maintenance, and forklift motion paths and height restrictions. VR allowed Ossian to put their eyes on a real-world scenario at scale before pouring concrete, beyond imagining the feasibility of a facility layout on paper.

### Opportunity #4: Engaging Sales Experience

- Display machinery and tooling proof-of-concept details via VR, highlighting advantages to build bridges among engineering, sales staff, buyers, and senior leadership with varying understanding of technology. Answer questions in real time, zooming in on specific parts and inner workings.
- Decrease the risk of conceptualizing during a project, allowing the buyer input and interactivity at multiple phases. This eliminates drastic changes during final designs or, worse, after the machine, tool, or part is built and in-use.
- Get in front of your customers with proactive solutions using VR modeling. Showcase your commitment and accountability by fleshing out 3D prototype models that simulate reach analysis, weld distortion, and other design concerns that may otherwise derail a sale if not addressed efficiently or accurately.



**Case Example: Genesis Systems Optimizes Designs and Smooths Sales Process with VR Visualization**
Davenport Iowa's Genesis Systems Group is utilizing VR, presented on a Mechdyne grid of curved screens (see image above), to improve both how they work with their customers and their internal collaboration. Through VR modeling and prototyping, Genesis customers review robotic designs and dive deeper into their concepts. This gives Genesis the ability to answer insightful questions, and address design requests before product development ever begins. Through using VR, Genesis has found that customer solutions are uncovered and implemented much more efficiently as trust and confidence are boosted through every stage of the sales and development process. Additional benefits witnessed include process streamlining, decreased product development costs, and more cohesive teamwork internally.[6]

6 http://advancedmanufacturing.org/genesis-systems-teams-with-virtual-reality/

## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to take in implementing VR & AR strategies and tactics within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing VR & AR technology is very different from traditional training/education, site planning, repair and maintenance, and sales processes that you may be accustomed to. We understand that the prospect of this degree of change to your manufacturing floor and employee experience is daunting! It is our hope that, through the following content and previous look at the benefits of VR &AR, you'll feel more comfortable exploring how you can utilize these technologies achieves efficiencies throughout your company.

**Change Management: Building the Case Requires Data and a "Test-and-Learn" Approach**
For most small and medium manufacturers, the prospect of adopting VR or AR seems risky, as it bucks the status quo and requires learning new technologies and procedures to remain relevant in a digital age. Only through experimentation, learning, and failing fast, can you quickly gain new expertise and experience that will benefit your company in years to come.

It is new technologies, like VR & AR, that are shifting the manufacturing industry. New strategies and tactics are emerging, and the only way to survive is to be proactive in your adoption of VR & AR in ways that fit into your current culture and align with your business growth goals.

There are many ways for you to get started along the path to utilizing VR & AR. Use the change management tips below to make the case for change and immediately begin proving results:

- Understand the business value of each VR &AR separately, and set goals accordingly. Use our metrics outlined in this section, as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating VR &AR into your existing funnels. This will help in resource planning if you're measuring the right benchmarks out of the gate. Focus on one or two main use cases first before building complexity.

- Focus on getting every employee on board with the benefits of VR & AR through peer education. Get all stake-holders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of digital platform initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse-mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with digital technologies and benefits. Turn to Find Help on pg. 19 for more education resources and tips.

- Keep communication lines open during the trial-and-error portion of experimentation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to successfully implementing new VR & AR strategies. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies. Breed risk-taking early.



## Build the Business Case & Begin Implementation *(continued)*

Part of change management also lies in understanding and planning for the challenges you will encounter in integrating VR & AR into your existing operations. Below are three challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

- **Challenge 1: Misunderstanding technology needs.** For many manufacturers, it is unclear if implementing VR & AR solutions requires specialty applications, software, hardware, code-readers, etc. Start small, and refer to the Resources Needed section on p. 15. Keep it simple and conceptually easy to start with, focusing on a single piece of equipment or process use case. Also, consider the types of hardware you'll need, and how they'll work with your facility conditions. For example, Ossian Inc. recognized that the Microsoft Hololens could not withstand the dust in their facilities, so they are exploring other AR hardhat options.

- **Challenge 2: Budgeting for hardware/software set-up costs.** Even if starting small and understanding your minimum technology requirements, bringing VR & AR into your facility requires costs in computers (that can handle operating load of VR & AR), the actual hardware (headsets, glasses, immersive cubes, screen panels, etc.), and software. Plan your entire budget out for the course of your VR projects, and investigate your ability to do mock-ups in existing CAD/CAM programs to cut initial costs.

- **Challenge 3: VR & AR technology is viewed as a novelty.** Some manufacturers receive mixed reception from customers and prospects as to the viability of VR & AR as an engineering/design tool. They're intrigued by the possibility but not convinced of its value or capabilities. For those customers (or your own organization!) on the edge, revisit the possibility of using VR & AR at quarterly intervals as new use cases are presented with concrete results, and as hardware costs decrease over time. Feel free to repurpose the case examples from this chapter, or contact us if you have more specific needs!

**Processes and Frameworks for Implementing VR &AR**
Integrating VR & AR into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks below to jumpstart your efforts. The frameworks in this section are to aid in your high-level strategic prioritization of VR & AR, and we recommend you search out specific frameworks for each technology and use case chosen to guide your implementation.[7]

*Framework 1: VR, AR, and MR Use Cases in Manufacturing, via Zuehlke* [7]


Possible use cases. (Zuehlke)

[7] https://www.zuehlke.com/blog/en/augmentes-virtual-and-mixed-reality-in-the-manufacturing-industry/

## Build the Business Case & Begin Implementation *(continued)*

| Enterprise category | What | Where | Potential results |
|---|---|---|---|
| **Guidance and collaboration** | Provide a worker with visual cues to help her perform tasks such as maintenance, repair, or assembly | Aerospace and defense, automotive, construction, health care providers, industrial products, oil and gas, power and utilities, technology | Improved productivity, streamlined work processes, reduced risk, cross-geographic collaboration |
| **Immersive learning** | Immerse the user in realistic training environments that are normally either high-cost or high-risk to personnel; variations include addressing PTSD, phobias, and other medical issues | Consumer products, health care providers, higher education, and industrial products | Stronger retention of material, reduced risk, cost savings, improved therapeutic outcomes |
| **Enhanced consumer experience** | Enhance customers' experience by providing customized or unique methods to interact with the company, brand, or its products | Automotive, banking and securities, consumer products, health care providers, industrial products, media and entertainment, and travel, hospitality, and services | Better customer engagement, increased marketing opportunities, increased sales, enhanced brand positioning |
| **Design and analysis** | Enable knowledge workers to assess design ideas virtually and/or analyze data in new formats | Aerospace and defense, automotive, construction, higher education, industrial products, real estate, and technology | Cost savings, increased efficiency, earlier detection of design flaws, new methods to analyze data and generate insights |

Source: Deloitte analysis. **Deloitte University Press | dupress.deloitte.com**

*Framework 2: Applications of AR/VR Technologies, via Deloitte* [8]

**Resources Needed: Technology & Staffing**

Resources required to manage and implement VR & AR strategies will vary by the use cases you've established and which technologies you've prioritized. For example, utilizing VR for immersive training to work better with remote employees will yield a different cost structure than planning to use AR for more efficient and accurate machine repairs. As previously outlined, you must create a strategic plan for how VR & AR will augment or replace your current processes in the recommended opportunity areas before jumping the gun and investing in the latest "bright, shiny technology" or hiring unnecessary talent.

Use this general checklist to assist in the process of planning for your hard and soft costs:

✓ **Hardware:** A significant investment in hardware (and, software as outlined in the following sub-section) is needed to implement VR & AR solutions within a manufacturing environment. Luckily, there are many options of varying price ranges for both headset hardware (ambient Google Glass starts at $12.99 for example, while immersive HTC Vive at $600 at time of writing), as well as on-screen simulated environments. Use the table below to begin your decision-making process. Always consider your use case first, tying your goal back to one or more of the four opportunity areas (Identify Opportunities, pg. 9). Also, take into account if you plan to use this on an individual basis or in a group environment, as well as if it needs to be mobile/portable, as that will greatly impact your hardware choice(s).



**Resources Needed: Technology & Staffing** *(continued)*

In addition to the VR & AR headset and/or on-screen set-up, you will likely need a computer with high processing power, retailing from $900-$3,000, if choosing to go the route of immersive headsets like HTC Vive, Oculus Rift, or Microsoft Holo-Lens. Some manufacturers will already have this processing power and memory readily available on their office PCs if running high-usage CAD/CAM programs. Also, consider your needs for motion trackers, mounted displays, sensors, and cameras, depending on your setup and desired hardware.


*Figure 6. VR & AR Hardware Categorization, via Digi-Capital* [9]

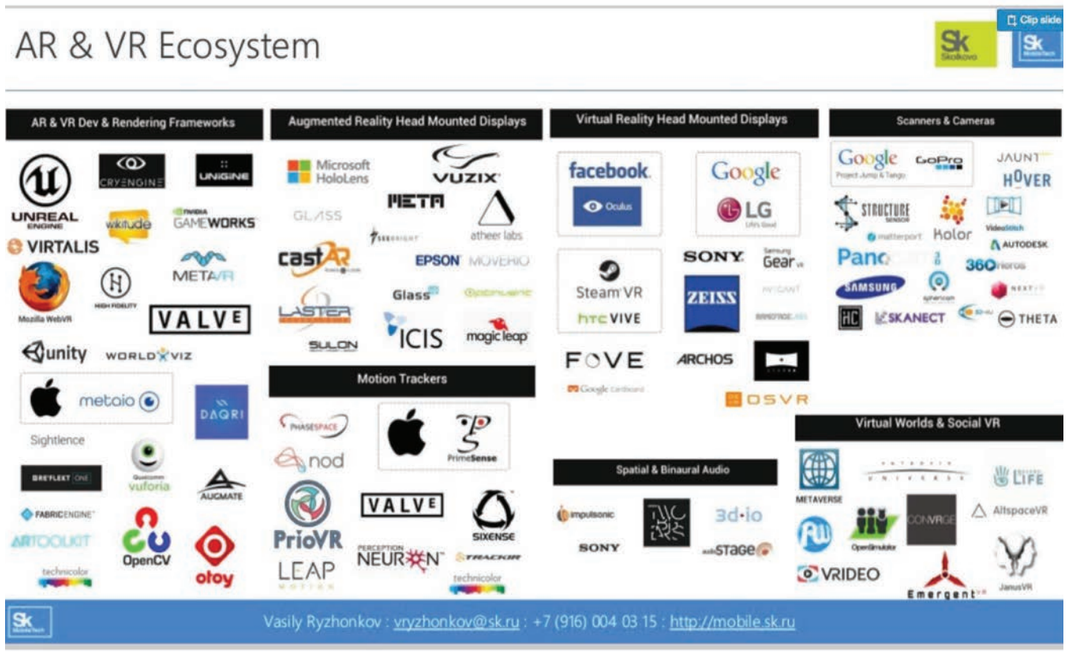
✓ **Software:** You will need two types of software, at a minimum, to program and execute your VR & AR projects. The first type coincides with the hardware, e.g. if you are utilizing an Oculus Rift, you will need the software pack that accompanies it. The second type is the software you will use for the actual 3D programming in a virtual space. The most commonly used software for this purpose is Unity 3D, though EON and Unreal Engine (Steam/Valve) are also popular among VR developers. We recommend you research the exact software needed per your device, computing system, and use case.

[9] Image provided by Digi-Capital's Tim Merel

**Resources Needed: Technology & Staffing** *(continued)*

Use the figure below to jumpstart your hardware and software decision process:

*Figure 7. AR & VR Ecosystem. High-resolution available at*
https://www.slideshare.net/VRyzhonkov/the-rise-of-vr-ar-era-why-this-time-is-different




✓ **Employees and Hiring:** Assess your current employees for skillsets in each opportunity area, as well as in individual platforms, to determine if expertise and interest exists. Most manufacturers have in-house talent skilled in CAD/CAM who understand how to work in a 3D space and are ready and able to augment their current skills. However, some small and medium manufacturers have opted to hire new employees with VR & AR expertise to speed up the implementation process, as well as inject new approaches to innovation within the company. Work with the education and hiring partners to find VR & AR with experience, freshly graduated, or as a temporary intern (with, ideally, intent to hire). You may also choose to outsource content development initially as a cost-saver until you have an established, proven use case for VR & AR.

**"Quick Wins" to Get Started with VR & AR**
Take a page from the guidebooks of manufacturers like Ossian Inc., Genesis Systems, and John Deere that are already up-and-running with VR & AR by following a few of their tips to jumpstart your use of these technologies:

- Tip 1: Look to other industries for various use cases in AR/VR &how to scale. Manufacturing tends to be a laggard in adoption of technologies early on, so you may need to find inspiration and guidance in other verticals. Look to health-care, automotive, gaming, and advertising/marketing as starters.

- Tip 2: Brainstorm potential use cases of VR that could eliminate or decrease risk and/or avoid rework and redesign. These are likely the most obvious and simplest ways to implement VR with 3D modeling within your company to save money and time. Also, consider using safety data from your company to pinpoint what VR & AR training and educational guidance would be most useful in the near-term.

- Tip 3: Test and learn with quick pilots. ExxonMobil takes baby steps in small changes to VR proofs-of-concept in order to determine what level of detail was needed in their training program. The bottom line: just do it, and start experimenting!

- Tip 4: Work with VR labs to brainstorm potential applications of VR & AR, including the use of already existing CAD/CAM files to get your feet wet on virtual product tours. They may recommend partnering with students at their educational lab, or train your current employees to learn new skills.

- Tip 5: Gain experience through events and free online resources. Go to Find Help on pg. 19 for educational and partnership resources, and talk with others actively involved in the VR & AR within your community. There are many free webinars and reasonably priced online courses to get you up-to-speed with your technologies of choice. These resources all help to build the business case if you need to "sell" the idea of using VR or AR to leadership within your company.

**Metrics for Success: How to Measure Impact**
When setting your objectives for VR & AR, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance against traditional strategies, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

- Decrease in accidents on trained scenarios (VR)
- More efficient repairs and installations (VR & AR)
- Reduced maintenance costs and shop-floor collisions (VR & AR)
- Reduced rework on jobs over time (VR)
- Increased profitability on programming tools and fixtures (VR)
- More efficient use of time on redesigns (less total redesigns) (VR)
- More efficient troubleshooting (VR & AR)
- More complete design back-ups (VR)
- Increased sales and more satisfied customers due to involvement in VR process (VR)

## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to-implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**America Makes:** America Makes is the nation's leading and collaborative partner in additive manufacturing (AM) and 3D printing (3DP) technology research, discovery, creation, and innovation. Structured as a public-private partnership, they innovate and accelerate AM/3DP to increase our nation's global manufacturing competitiveness.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Hiring Solutions:** Robert Half Technology; https://www.roberthalf.com/technology. Robert Half Technology specializes in placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**ThomasNet.com:** ThomasNet.com is a search engine to discover certified suppliers to the supply chain, identify job shops, find specific products or accelerate the design process.

**Udacity:**
- VR Software Development Course: https://www.udacity.com/course/vr-software-development--ud1014
- VR Developer Nanodegree: https://www.udacity.com/course/vr-developer-nanodegree--nd017

A national online skills marketplace for technology education, dependent on student skill level and timeline (see links above). Udacity offers two programs for VR developers in-training, In the software development course, students will learn how to make VR experiences more dynamic and responsive to users. They will be exposed to C# programming and use it in the Unity interface. Upon completing this course, students will have learned basic programming constructs such as methods, loops, variables, and using events and how to apply them in a VR environment. In the nanodegree program, students will master the core principles of VR development and design, learn to turn creative ideas into high-performance VR applications, and pursue an advanced concentration.

**Victory VR:** https://www.victoryenterprises.com/services/virtual-reality-vr/ From fully customized VR apps (iPhone and Android) to 360-degree virtual videos, Victory Enterprises can help your company explore the world of VR &its capabilities. Victory VR has special experience in educational applications and training, as well as showroom modeling that may be attractive to manufacturers and OEMs.



## Appendix

**Glossary of Key Virtual Reality & Augmented Reality Terms**
*Definitions provided for educational purposes by Gearbrain.*

**360-degree VR view:** A 360-degree view is the simulation of an altered or augmented environment that surrounds the VR user, allowing them to look around in every direction as they'd be able to in real life.

**Aspect ratio:** The proportion of the width of your viewing screen to its height is the aspect ratio. This can affect how the images from the VR world appear and whether or not they become distorted. It's all about the proper pixels for the ultimate view.

**Augmented reality (AR):** Virtual reality creates a whole new and artificial environment, but augmented reality uses the existing environment the user is already in and overlays digital information in the form of a computer-generated image on top of it in real time. This provides a composite view.

**Cave:** A cave is a virtual reality world projected onto the walls and the ceiling of the room of the user to give the illusion of total immersion.

**Cinematic VR:** This type of virtual reality utilizes real images from cameras rather than computer-generated graphics for a super-realistic VR experience for the user.

**Data glove:** Also known as a 'wired glove', this glove is filled with delicate sensors that connect to your computer as you play VR games. The hand movements and gestures lead you through a VR environment.

**Directional sound:** Oftentimes in VR games or movies, there's an overall background sound, but when the sound seems to come from a specific area, it's called directional sound.

**Dollhouse view:** A view from above allowing the user to see their entire artificial space to better make decisions regarding their next moves.

**Eye tracking:** While your eyes are on the VR experience, the sensors in the HMD (head mounted display) are carefully tracking eye positioning. If you're playing a VR game, the software will guide your view into a specific direction or use eye motions for other perks the game offers.

**Field of view:** Abbreviated as FOV, field of view is the number of degrees in the VR visual area. The more degrees in the field, the greater and more realistic the VR experience will be.

**Haptics:** You know that cool feeling in VR where it seems like you're actually reaching out and touching or feeling something in the scene? That's haptics. While what you see seems like it's at the tips of your fingertips, it's all an illusion.

**Head mounted display:** Head mounted display or HMD is the hardware that gives the user his or her VR experience. You'll find HMDs in the form of a headpiece, helmet, glasses, or goggles. You will enjoy your VR experience through what you see in the HMD.

**Head tracking:** Head tracking is akin to eye tracking, but uses the positioning of the entire head to help you look in any direction during your VR experience. It's just like looking around in the real world, but through the more advanced technology of VR.

## Appendix *(continued)*

**Glossary of Key Virtual Reality & Augmented Reality Terms**

**Immersion:** Placing users in an artificial environment yet making them feel like they're right in with the action is considered immersion. VR creates this immersive playground where the sights, sounds, and perceived feelings surround the user with the perception that they are really there.

**Latency:** Latency feels like the VR is a step behind your head or eye movements. This lag is a glitch that will hopefully be eliminated as VR becomes more and more updated.

**Locomotion:** The movement of the user from one place to another in the VR world – the mechanics to process their navigation.

**Mixed reality:** Mixed reality (MR), is also known as hybrid reality which is the merging of the real and virtual worlds to create completely new environments where the physical and digital objects interact and co-exist in real time.

**Refresh rate:** The series of images and how quickly they get updated in VR is considered the refresh rate. 60+ frames per second is ideal for the best experience with little lag time between frames.

**Simulator sickness:** Sometimes VR can produce a feeling of being ill. When the brain doesn't match up to what the eyes think they're taking in, people can get nauseated. The feeling of spinning, falling, and the like have been known to make users feel anything sick.

**Stitching:** Taking bits of footage from a number of different cameras, stitching combines and edits them together to create a continuous view rather than a patched-together framework.

**Tethered headset:** A tethered VR headset requires a connection to a computer with a high processing power. This strong computing power is needed in order to provide the most life-like VR experiences for the user. Without them, the view will be more pixelated and graphics may lag.





# Robotics & Automation

## Robotics & Automation at a Glance

**What does "Robotics & Automation" for manufacturing encompass?**
Robotics incorporates multiple engineering disciplines to design, build, program, and use robots to complete tasks – in our focus, manufacturing tasks. The purpose of industrial robots varies, and can include movement of products, materials, parts, and tools, as well as completing a wide variety of programmed tasks.[1] Industrial automation involves using machines, robots, and control systems to automate tasks within a manufacturing process. Automation uses a variety of technologies, including computer hardware, software, and machines, to perform tasks usually done by human workers.[2]

**Why do Robotics & Automation matter to the manufacturing community?**
Robotics & Automation has the capacity to augment and replace current manufacturing processes in the future. Workers now are producing 47% more than 20 years ago. Through the development of automation, robotics, and advanced manufacturing, the sector has bounced back along with the overall economy.[3] In three to five years, manufacturers will plan for Robotics & Automation opportunities when designing factory layouts, engineering and designing products, and upskilling current employees to increase efficiencies, save money, and remain competitive.

**What are the biggest opportunity areas?**
Three key opportunity areas in Robotics & Automation for manufacturers:

- **Opportunity #1: Production efficiencies and cost savings.** Most manufacturers experience ROI in 12 to 18 months after adding robotic automation.[4]
- **Opportunity #2: Increased onsite safety.** Robots are designed with built-in safety functionality and are not prone to the same human errors.
- **Opportunity #3: Employee development.** Employees can develop their careers in new ways, stepping out of low skill-level tasks to explore other fields that benefit the company.

More information can be found in the Identify Opportunities section on page.[9]

**What are the business benefits of utilizing Robotics & Automation?**
Though dependent on the Robotics & Automation opportunity area(s) you pursue, manufacturers witness many benefits from implementing these technologies, including lower production costs, reduced time to complete tasks, labor cost savings, increased onsite safety, and higher skilled employees. For a full list of metrics, turn to Build the Business Case and Begin Implementation on page.[13]

**Where can I find help to get started?**
There are resources who can assist you with the development and implementation of Robotics & Automation solutions, hardware, machinery, software, and applications. There are also many free online resources, as well as educational courses offered by universities and colleges. Go to Find Help on page 20 for a list of resources to jump start your use of Robotics & Automation to grow your business.

[1] https://www.robots.com/faq/show/what-is-an-industrial-robot
[2] http://blog.robotiq.com/whats-the-difference-between-automation-and-robotics
[3] https://www.brookings.edu/blog/techtank/2016/06/02/how-technology-is-changing-manufacturing/
[4] http://www.boschpackaging.com/doboy/eng/pdf/bosch-delta-robot-white-paper1.pd

CHAPTER 3

# Robotics & Automation

*Figure 1: Robotics & Automation Chapter Information Flow*


## Robotics & Automation Table of Contents





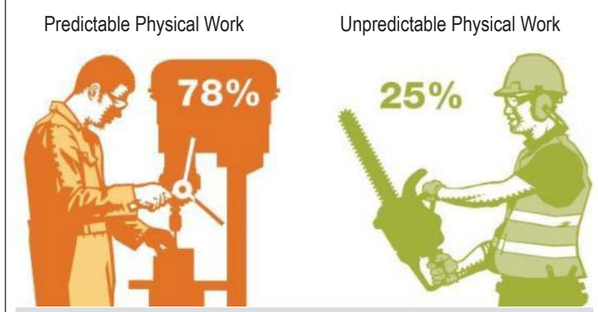
## Understand the Technology

In the first section, we take a closer look at the technologies that enable Robotics & Automation. You'll gain a better understanding of how Robotics & Automation contribute to your company's digital technology and innovation strategy through diagrams, frameworks, and definitions of key terms used in the space. This section also details additional online resources for greater understanding.

Robotics incorporates multiple engineering and design disciplines to build, program, and use robots for task completion—in our focus, manufacturing tasks. Industrial robots are used by manufacturers to move products, parts, and tools, and perform many other programmed tasks.[5] A subset of industrial robots, collaborative robots (or "cobots") are designed to safely work alongside humans to perform manufacturing tasks that benefit from automation but cannot yet be fully automated.

Industrial Automation involves using machines, robots, and control systems to automate tasks within a manufacturing process. Automation uses computer software, machines, and other technologies to carry out tasks that would otherwise be done by human workers.[6] Various levels of automation, when combined with robotics, can complete tasks on a manufacturing floor.

*Figure 2: Technical Feasibility of Automation / Percentage of Time*




Percentage of time spent on activities that can be automated by adapting currently demonstrated technology. Image: McKinsey & Co.

Both Robotics & Automation achieve their greatest value and traction as they're integrated with other technologies in advanced manufacturing environments to deliver greater efficiencies. Whether integrating with traditional tasks such as welding and picking/sorting; or with new technologies like additive manufacturing, machine sensors, and artificial intelligence (AI); many manufacturers are finding additional value from utilizing Robotics & Automation to augment and improve existing processes that have historically required human involvement. This is especially true when considering the capabilities of collaborative robots that are more flexible and safer than traditional industrial robotic applications.

**Glossary: Robotics and Automation Terms**
Please refer to the glossary in the Appendix for definitions of key Robotics & Automation terminology that is utilized in this chapter. Definitions provided for educational purposes as described by Robots.com unless otherwise noted.

[5] https://www.robots.com/faq/show/what-is-an-industrial-robot
[6] http://blog.robotiq.com/whats-the-difference-between-automation-and-robotics

## Understand the Technology *(continued)*

*Figure 3: Types of Industrial Automation Systems. Approved for reuse by ElectricalTechnology.org* [7]

| Automation Type | Description | Uses |
|---|---|---|
| **Fixed or Hard Automation** | This type of automation is employed to perform fixed and repetitive operations in order to achieve high production rates. It uses special purpose or dedicated equipment to automate the fixed sequence assembling or processing operations. | Once it is employed, it is relatively hard to change or vary the product design. Therefore, it is inflexible in providing product variety but increases the efficiency with higher production rate and reduces unit cost. Some of these automated systems are distilled process, paint shops and conveyors. |
| **Programmable Automation** | In this automation, a specific class of product changes and also assembling or processing operations can be changed with the modification of control program in the automated equipment. | This automation is best suited for batch production process where product volume is medium to high. But in this, it is hard to change and reconfigure the system for a new product or sequence of operations. It requires a long setup. Examples of this automation system are numerically controlled machines, paper mills, steel rolling mills, and industrial robots. |
| **Flexible or Soft Automation** | This automation system provides the automatic control equipment that offers a great flexibility for making changes in the product design. These changes can be performed quickly through the commands given in the form of codes by the human operators. | This automation allows the manufacturers to produce multiple products with different ranges as a combined combination process rather than separate. Some of the examples of this automation system are automatic guided vehicles, automobiles, and multipurpose CNC machines. |

7 https://www.electricaltechnology.org/2015/09/what-is-industrial-automation.html



## Understand the Technology *(continued)*

*Figure 4: Types and Classifications of Robots Via OSHA* [8]

Industrial robots are available commercially in a wide range of sizes, shapes, and configurations. They are designed and fabricated with different design configurations and a different number of axes or degrees of freedom. These factors of a robot's design influence its working envelope (the volume of working or reaching space). Diagrams of different robot design configurations are shown.

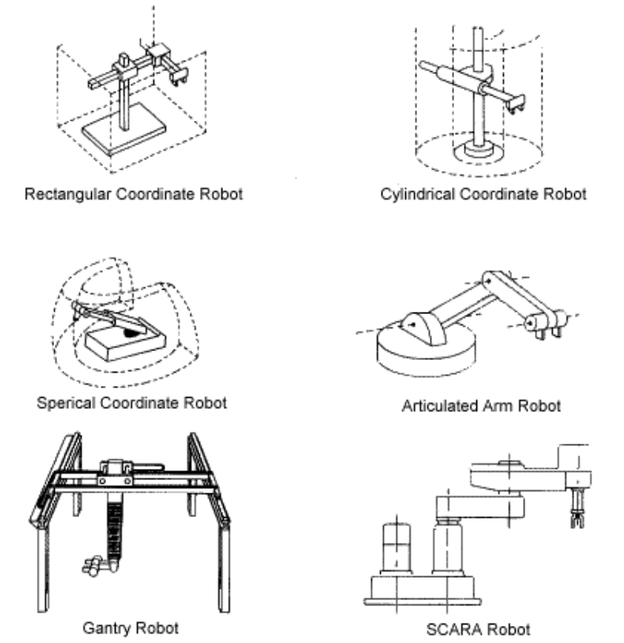
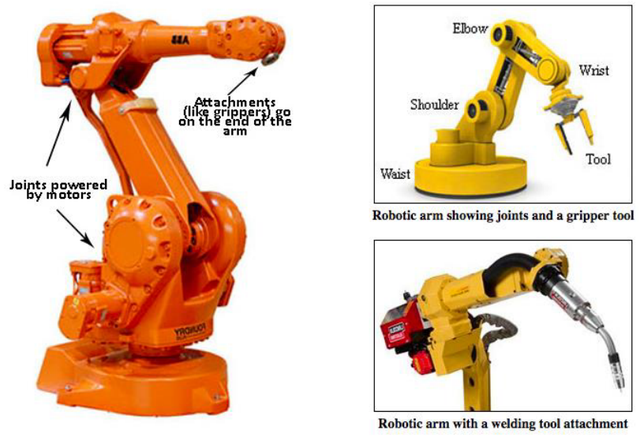



*Figure 3.1 A closer look at articulated arm robot anatomy. Approved for reuse by ICT Lounge* [9]




8 https://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_4.htm
9 https://www.ictlounge.com/html/applications_in_manufacturing.htm

## Understand the Technology *(continued)*

*Figure 5: Capabilities of Traditional Robots vs. Collaborative Robots ("Cobots")*
Collaborative robots are designed to work alongside human workers, in operations that cannot be fully automated.
Approved for reuse by Universal Robots.[10]

| If you need... | ...consider a traditional industrial robot | ...consider a collaborative robot ("cobot") |
|---|---|---|
| High-volume, high-speed production | ✔ | |
| Similar throughput as a human worker | | ✔ |
| High payload or very long reach, especially at high speed | ✔ | |
| Ability to program and set robot up in-house | | ✔ |
| Ability to easily redeploy robot to different processes/tasks | | ✔ |
| Extremely high accuracy, including at high speed | ✔ | |
| Minimal changes to existing production layout | | ✔ |
| Human workers to enter the robot cell to complete their tasks | | ✔ |
| Integration options with other machines and robots | ✔ | ✔ |
| Low initial cost and payback in under a year | | ✔ |
| Ability to run processes with few or no employees | ✔ | ✔ |
| Automation of processes or products that won't change over time | ✔ | ✔ |

Additional Online Resources
There are many online resources for review to deepen your understanding of Robotics & Automation machinery, software, applications, technologies, use cases, opportunities, challenges, and more. We've outlined a few below:

- *Automate This:* The business leader's guide to robotic and intelligent automation, via Deloitte.[10a] In this guide, you'll find the nuts and bolts of process and enterprise automation in man manufacturing. Additionally, find common myths debunked related to intelligent automation, ways to get started step-by-step with robotics, as well as a glimpse into the future of manufacturing automation.
- *The New Hire:* How a new generation of robots is transforming manufacturing, via PWC. This report delves into how the rise of robots in manufacturing has created new jobs in new industries, how current workers can interact with robots, and how the collaboration creates a new workforce. You'll also find outlines of the benefits of flexibility and competitiveness, definitions of barriers to widespread adoption, cost breakdowns, and a handy self-assessment of your readiness for robotics.[10b]

10 https://info.universal-robots.com/cobots-vs-traditional-industrial-robots
10a https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf
10b https://www.pwc.com/us/en/industrial-products/assets/industrial-robot-trends-in-manufacturing-report.pdf



## Identify Opportunities

Robotics & Automation offer many opportunities to small and medium manufacturers. Three key areas that can bring greatest benefit to small and medium manufacturers:

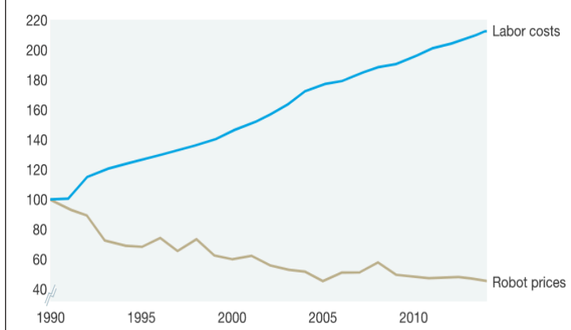
- Production efficiencies and cost savings
- Onsite safety
- Employee development.

### Opportunity #1: Production Efficiencies and Cost Savings

Manufacturers find Robotics & Automation to offer significant return on investment, as robots continue to decline in cost (see Fig. 3, at right). Most manufacturers experience ROI in 12 to 18 months after adding robotic automation.[11] When used to complete repetitious and menial manufacturing tasks, more product can be produced without quality slipping. Robotics & Automation achieve the greatest cost savings within manufacturing environments that require high output and no-to-low margins of error, though as production shifts to smaller lots of different products, companies will look to achieve shorter time-to-market and rely on robots for quick local customization.

*Figure 6: Cost of Automation*

Index of average robot prices and labor compensation in manufacturing in United States, 1990 = 100%




Source: Economist Intelligence Unit; IMB; Institute fur Arbeitsmarkt-und Berufsforschung; International Robot Federation; US Social Security data; McKinsey analysis. McKinsey & Company

### Opportunity #2: Onsite Safety

The addition of robotics to a manufacturing environment reduces worker injury rates, especially in cases where employees would be working with typically dangerous equipment. This is also a great asset to third-shift workers that may become more easily fatigued and prone to error during their shift. Robots are designed with all required safety functionality and are not prone to the same human errors, though necessary safety precautions must still be taken when integrating robots into collaborative manufacturing situations.

### Opportunity #3: Employee Development

The addition of Robotics & Automation to a manufacturing company gives its employees the chance to develop their careers in new ways, stepping out of their menial or low skill-level tasks to explore other fields that benefit the company. These may include learning to operate robots, performing more intricate or customized manufacturing assignments, focus on continuing education, or even innovation for the company. Robots may cause short-term job displacements, but long-term benefits to workers as they develop new skills and pursue jobs of greater impact, fulfillment, and salary. In turn, this boosts disposable income and positive economic impact over time.

11 http://www.boschpackaging.com/doboy/eng/pdf/bosch-delta-robot-white-paper1.pdf

## Identify Opportunities *(continued)*

**Benefits and Use Cases of Robotics and Automation Opportunities**

In this section, we'll examine the key benefits of utilizing Robotics & Automation in each of the three opportunity areas previously identified. Below, you'll also find a case example for each opportunity area that shows how a manufacturer was able to utilize robotics and/or automation to produce results.

**Opportunity #1: Production Efficiencies and Cost Savings**

- Increased efficiency and faster throughput: Industrial robots can perform tasks quicker than humans, decreasing cycle time. Robots can work around the clock as well, enabling 24/7 operations.
- Flexibility and scalability: Once a process has been defined as a series of instructions for robot execution, it can be s cheduled for a particular time – either for one robot, or many working in unison. Robots can also be programmed to prioritize tasks, if one to-do is more important than another in an evolving scenario, as each robot is typically capable of performing many actions.
- Improved accuracy: Robots are programmed to follow rules and rarely make mistakes.
- Ease of integration with existing machinery: According to McKinsey, advances in computing power, software development, and networking technologies have made assembling, installing, and maintaining robots faster and less costly than before.[12] Look for experience and industry expertise in a systems integrator that is tailored to your individual needs. Consider the integration needed to complement other new technologies as well – such as additive manufacturing, artificial intelligence, data sensors, and more.
- Real-time data gathering: Robot tasks can be monitored and analyzed at every step, producing valuable data that can support process improvement over time, and also help with regulatory compliance.[13] McKinsey also reports that, "robotic sensors and actuators can also monitor themselves and report their status to the control system, to aid process control and collect data for maintenance, and for continuous improvement and troubleshooting purposes."[14] Learn more about how to craft your data analytics strategy in our Data Analytics guidebook.

**Case Example:** Vision-guided Collaborative Robots Deliver Fast Return on Investment in Production of Firehose Valves [15] Task Force Tips, an Indiana-based manufacturer of firefighting equipment, wanted to promote and maximize their personnel tending machining cells into more complex tasks while keeping spindle time up and product quality consistent. The manufacturer has now installed four collaborative robots, working alongside employees, to deliver savings resulting in a return on their investment in only 34 days. Task Force Tips installed three robots to tend CNC machines, and a fourth is mounted to a table on wheels and moved between tasks. Now, it only takes one hour per operator per shift to operate the robot, which includes laying out parts and staging the robot. That translates into the robot running for 21 hours unassisted and seven hours of time saved in each employee shift, freeing them up to do something else more productive.

12 https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future
13 https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf
14 https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future
15 https://www.engineering.com/ResourceMain.aspx?resid=596



## Identify Opportunities *(continued)*

**Opportunity #2: Onsite Safety**

- Fewer accidents and injuries: Many robot safety features and technologies have existed for quite some time with proven success, with robotic developers and integrators using safe zones, fencing, and other technologies to ensure safe robot operation. Though accidents can happen, it's rare, and they're often caused by either operator error, setup mistakes, or entering a robot's operating zone.[16] Robots also often times take on more dangerous or ergonomically challenging tasks, lessening the chance for worker on-the-job injury.
- Faster reactions: Industrial robots take up less space than they used to, and are armed with countless sensors to help increase reaction time, use appropriate force, and stop production when nearing humans or other collision points. If sensors indicate the risk of a collision with an operator, the robot will automatically slow down or alter its path to avoid it.
- No safety training needed: Control Engineering reports on the safety of collaborative robots, stating they are, "designed . to understand their environment and interact with people, which is unlike a traditional robot that works on the assembly line. These technologies are intended to develop the natural interfaces that allow for the operation of complex robotic systems with less training and expended energy."[17]

**Case Example:** Ford Uses Collaborative Robots for Heavy Lifting, Outlook to Eliminate Employee Repetitive Strain Injuries [18]
Ford Motor Co. has been testing new collaborative robots from KUKA Robotics at its assembly plant in Cologne, Germany, on an assembly line helping workers install shock absorbers. Rather than use a heavy shock absorber installation tool, the workers have the robot lift and automatically position the shock into the wheel arch before pushing a button to install the component. Working overhead with heavy air-powered tools is a tough job that requires strength, stamina, and accuracy. For many automotive applications in particular, collaborative robots that can lift a substantial amount of weight, show a lot of promise for alleviating a number ofrepetitive strain injuries among workers. The collaborative robots also stop immediately if they detect an arm or even a finger in their path, ensuring ultimate worker safety.

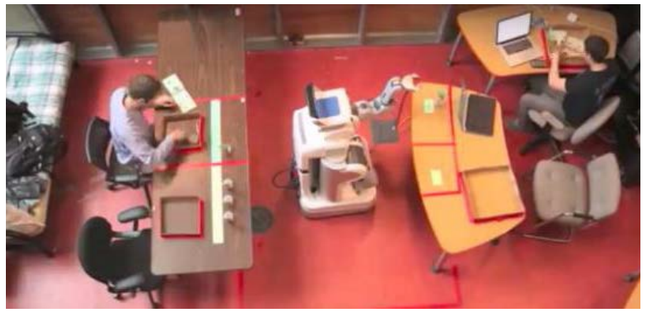
16 http://advancedmanufacturing.org/putting-safety-first-robotic-automation/
17 http://www.controleng.com/single-article/robots-are-changing-the-global-manufacturing-market/49b483d71971ca291fdaf1fdbae27df2.html
18 http://advancedmanufacturing.org/putting-safety-first-robotic-automation/

## Identify Opportunities *(continued)*

**Opportunity #3: Employee Development**

- "Upskilling" of workers: Workers whose tasks are augmented by or fully replaced by robotics have the chance to develop their careers into new roles that will be created by automation. World Economic Forum predicts that, "as robots take over the most repetitive and arduous tasks, humans will transition to less physically demanding and straining roles," learning new skills in the process.[19]
- Larger talent pools: McKinsey analysts find that people with the skills required to design, install, operate, and maintain robotic production systems are becoming more widely available, too. "Robotics engineers were once rare and expensive specialists. Today, these subjects are widely taught in schools and colleges around the world, either in dedicated courses or as part of more general education on manufacturing technologies or engineering design for manufacturers," reports Jonathan Tilley.[20]
- Improved employee morale: According to Deloitte, "the tasks and processes most suitable for automation are typically the most onerous and least enjoyed, and employees relieved of them can be refocused on more rewarding and higher-value activities." [21] This, in turn, positively impacts their morale and the overall culture of your company.

**Case Example:** MIT Research Suggests That Robot Managers are Not Just More Efficient, They're Preferred by Manufacturing Workers. [22] New research coming out of MIT's Computer Science and Artificial Intelligence Lab (CSAIL) sought to find that "sweet spot" for ensuring that the human workforce is both satisfied and productive working alongside robots in manufacturing environments. Research results concluded that the answer is to actually give machines more autonomy, if it helps people to work together more fluently with robot teammates. In the study, groups of two humans and one robot worked together in one of three conditions: manual (all tasks allocated a by human); fully autonomous (all tasks allocated by the robot); and semi-autonomous (one human allocates tasks to self, and a robot allocates tasks to other human). The fully-autonomous condition proved to be not only the most effective for the task, but also the method preferred by human workers. The workers were more likely to say that the robots "better understood them" and "improved the efficiency of the team." This study offers promise that collaborative robot-human manufacturing scenarios could lend to more positive workplace environments.



19 https://www.weforum.org/agenda/2017/05/sales-of-industrial-robots-are-surging-so-what-does-this-mean-for-human-workers/
20 https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future
21 https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf
22 http://news.mit.edu/2014/want-happy-worker-let-robots-take-control



## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to take in implementing Robotics & Automation technologies within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing Robotics & Automation is very different from traditional manufacturing equipment and processes that you may be accustomed to. We also understand that the prospect of this degree of change can be daunting! It is our hope that through the following content and previous look at the benefits of Robotics and Automation, you'll feel more comfortable exploring how you can utilize these technologies to achieve efficiencies throughout your company.

**Change Management: Building the Case Requires Data and a "Test-and-Learn" Approach**
For most small and medium manufacturers, the prospect of adopting robotics and/or automation seems risky, as it bucks the status quo and requires learning new technologies and procedures to remain relevant in a digital age. Only through experimentation, learning, and failing fast, can you quickly gain new expertise and experience that will benefit your company in years to come.

It is new technologies, like Robotics & Automation, that are shifting the manufacturing industry. New strategies and tactics are emerging, and the only way to survive is to be proactive in your adoption of Robotics & Automation in ways that fit into your current culture and align with your business growth goals. There are many ways for you to get started along the path to utilizing Robotics & Automation. Use the Change

**Management Tips below to make the case for change and immediately begin proving results:**

- Understand the business value of both Robotics & Automation separately, and set goals accordingly. Use our metrics outlined in the Build the Business Case section of this guidebook, as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating Robotics & Automation into your existing manufacturing technologies, equipment, and processes. This will help in resource planning if you're measuring the right benchmarks out of the gate. Focus on one or two main use cases first before building complexity. Also, consider connecting your Robotics & Automation goals to existing technology innovation initiatives that already have momentum or proven use cases.
- Focus on getting every employee on board with the benefits of Robotics & Automation through peer education. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of digital platform initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with digital technologies and benefits. Find more education resources and tips in the Find Help section of this chapter.
- Keep communication lines open during the trial-and-error portion of experimentation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to successfully implementing new Robotics & Automation strategies. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies. Breed risk-taking early.

## Build the Business Case & Begin Implementation *(continued)*

Part of change management also lies in understanding and planning for the challenges you will encounter in integrating Robotics & Automation into your existing operations. Below are four challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

- **Challenge 1: Robots are too expensive for small and medium manufacturers.** Many robots are flexible enough to be programmed quickly and easily, reducing the number of times it needs to repeat a task to justify the cost of buying and commissioning it. This makes industrial robots more economical for manufacturers who typically run small batch sizes, or who have a variety of products. According to McKinsey, the cost savings will benefit many different kinds of organizations: small companies will be able to access robot technology for the first time, and larger ones could increase the variety of their product offerings.[23]

- **Challenge 2: Certain tasks are difficult to automate.** Ryan Weaver, automation engineer with Axis New England, elaborates: "... as a machine becomes closer to 100% automated, the overall cost tends to rise exponentially. Certain tasks can be very challenging to automate, which adds significant cost. Those types of tasks include anything subjective, such as bin sorting, or complex inspection tasks. By slowing down the process so that you can consider a collaborative robot, you allow human operators to be involved in the more challenging portions of the task, reducing automation cost."[24]

- **Challenge 3: Robots are not safe around workers.** Robots are designed with all required safety functionality, but a robot is only as safe as the entire system design. This is where integrators become incredibly important, as they take the necessary safety precautions when integrating a robot into any system. A risk assessment should be done for the whole robotic cell where the necessary safety of the robot (especially if cooperative) may not be enough to grant a sufficient level of safety to the entire cell, according to Control Design's recommendations.[25]

- **Challenge 4: Automating tasks eliminates too many human jobs.** Although automation can replace human employees on some repetitive tasks at greater efficiencies, it also offers the potential to create jobs in manufacturing as saving money on the lowest-paying labor costs contributes to lowering prices on goods. This creates more market appeal and the need for more workers. We see this scenario unfolding with retail behemoth Amazon. Over the past three years, the company has increased the number of robots working in its warehouses from 1,400 to 45,000. Over the same period, the rate at which it hires workers hasn't changed, according to Quartz.26 Robots help Amazon keep prices low, causing increased consumer purchases, translating into the need for more employees to staff the additional warehouses (even with fewer human hours of labor needed per package).

23 https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future
24 http://www.controldesign.com/articles/2016/the-keys-to-robot-selection-safety-and-collaboration/
25 Ibid.



## Build the Business Case & Begin Implementation *(continued)*

**Processes and Frameworks for Implementing Robotics and Automation**
Integrating Robotics & Automation into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks on the following pages to aid in your high-level strategic prioritization of Robotics & Automation; we recommend you search out specific frameworks for each technology and use case chosen to guide your implementation.

**Framework 1: Robot Applications and Use Cases via Robot Worx** [27]
Each industrial robot application requires unique end-of-arm tooling, specific reach and payloads, and flexibility. An integrator will advise grouping them according to number of axes, structure type, size of work envelope, payload capacity, and speed.

WELDING ROBOT APPLICATIONS

| | |
|---|---|
| Arc Welding | Welding Automation |
| Flux Cored Welding | Electron Beam |
| MAG Welding | Laser Welding |
| Orbital Welding | Mig Welding |
| Plasma Cutting | Oxyacetylene Welding |
| Resistance Welding | Plasma Welding |
| Spot Welding | Shielded Metal Arc |
| Tig Welding | Welding |

MATERIAL HANDLING ROBOT APPLICATIONS

| | |
|---|---|
| Collaborative | Dispensing |
| Injection Molding | Machine Loading |
| Machine Tending | Material Handling |
| Order Picking | Packaging |
| Palletizing | Part Transfer |
| Pick and Place | Press Tending |
| Vision | |

OTHER ROBOT APPLICATIONS

| | | |
|---|---|---|
| 3D Laser Vision | Painting Automation | Fiberglass Cutting |
| Assembly | Refueling | Grinding |
| Cleanroom | Sanding | Material Removal |
| Cutting | Thermal Spray | Milling |
| Drilling | Appliance Automation | Polishing |
| Foundry | Bonding / Sealing | Routing |
| Laser Cutting | Coating | Spindling |
| Meat Processing Automation | Deburring | Waterjet |

27 https://www.robots.com/applications

## Build the Business Case & Begin Implementation *(continued)*

**Framework 2: Five Steps to Developing an Automation Strategy in Manufacturing, via Deloitte** [28]

| What? | Why? | How? | Who? | When? |
|---|---|---|---|---|
| **Assess for automation opportunities** | **Build your business case** | **Determine the optimal operating model** | **Identify your automation partner(s)** | **Plan the automation roadmap** |
| • Which processes are good candidates for automation?<br>• Which processes would be suitable to pilot?<br>• How should the process owners be engaged to try automation?<br>• What are the impacts of proceeding with the pilot? | • Why does automation support your business needs?<br>• What are the benefits?<br>• What are the pain points being alleviated?<br>• What are the metrics to determine whether automation is valuable?<br>• What is the strategy for re-deploying existing resources after automation? | • Which operating model works best for your organization?<br>• Do you have the right team to support the solution and carry out responsibilities (e.g., assessing new processes for automation and testing the automated jobs)?<br>• Who will manage and monitor the software robot? | • Who are the main vendors in the RPA space?<br>• Who are the providers who cater to your business needs the most?<br>• Which sourcing option do you want?<br>• How should you compare the pricing models in order to understand what you are paying for? | • How long should your pilot be?<br>• What are the stages after the pilot?<br>• What is your strategy for scale?<br>• How will you ensure impacted stakeholders understand the what, why, and how of automation? |

**Resources Needed: Technology & Staffing**

Resources required to manage implement Robotics & Automation technologies will vary by the use cases you've established. For example, utilizing collaborative robots alongside workers will yield a different cost structure than planning to use traditional stationary robots for automation of repetitive tasks. As previously outlined, you must create a strategic plan for how Robotics & Automation will augment or replace your current processes in the recommended opportunity areas before jumping the gun and investing in the latest "bright, shiny technology" or hiring unnecessary talent.

Use these recommendations to assist in the process of planning for your hard and soft costs:

- Hardware: There are many factors for consideration when deciding what types of robots are needed for your automated system, including size, payload capacity, repeatability, reach, and more. Most often, automation systems are created by combining your existing equipment with new robotics that fit your production and plant requirements.[29] See the following page for a general layout of the types of robotics hardware you'll utilize for automation.

[28] https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf
[29] *http://www.controldesign.com/articles/2017/how-to-get-started-with-robotics/*

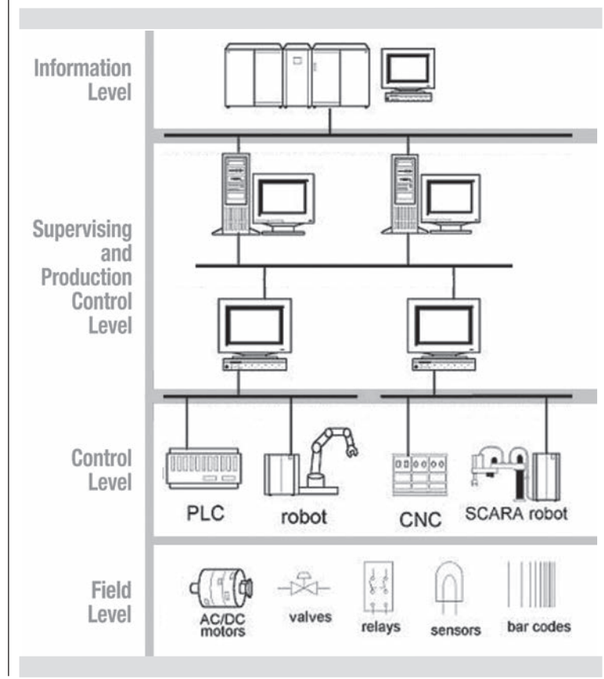


**Resources Needed: Technology & Staffing** *(continued)*

According to Robotics.org, when implementing robotics to a shop floor there are several components to review: [30]

- Can the new equipment be reduced by simply adding on to existing peripherals?
- Power requirements: can existing output support the added technologies? Look at your power grid's consumption vs. the amount you have to work with, as well as the power needed or the additional robotics. You may need temporary generators to run everything.[31]
- Floor management and building a "cell" for the robotics – a designated operating space for the robot. Prior to ordering, find out the exact dimensions and measure these on your plant's floor. Look at more than just the base of the machine's size. Consider the reach it has and how much space it will need to fully function when you're doing your measurements. Consider space for other machines or workers as needed.[32]
- Determining how much and what type of work the robot will need to do.

*Figure 5. Hierarchy of an Industrial Automation System*




- **Hardware Costs:** To make robotics and collaborative solutions more accessible, many robotics manufacturers have adopted a "service" policy that offers more accessibility to startups and cost-sensitive industries. Example from Robotiq: instead of selling farmers extremely expensive robotics, farmers can "rent" the robots at a certain price per acre driven or payload carried.[33] Collaborative robots are generally cheaper than traditional robots too, ranging from $25,000 to $45,000, whereas traditional factory floor robots can cost upward of $100,000 each.[34]

[30] https://www.robotics.org/content-detail.cfm/Industrial-Robotics-Industry-Insights/U-S-Alliance-in-Robotics-for-Manufacturing-Means-Innovation-Education-More-Jobs/content_id/6451
[31] http://blog.robotiq.com/how-difficult-is-it-to-implement-robotics-into-a-manufacturing-plant
[32] Ibid.
[33] http://blog.robotiq.com/3-trends-in-robotics-that-are-changing-manufacturing
[34] https://techcrunch.com/2016/10/09/industrial-robots-will-replace-manufacturing-jobs-and-thats-a-good-thing/

**Resources Needed: Technology & Staffing** *(continued)*

- **Software:** Running robotic machinery on your manufacturing floor requires computer software as well. See the figure below that breaks down your options for software sourcing and licensing.

- **Employees and Hiring:** Asses your current employees for skillsets and experience in Robotics U Automation to determine if expertise ande interest exists. Most manufacturers have in-house talent that is skilled in machine operation who are ready and able to augment their current skills and learn how to operate or work alongside robots and automation systems. Howere, manufacturers opt to hire new employees with Robotics & Automation expertise to speed uip the implementation process, as well as inject new approaches to innovation within the company. Work with education and hiring partners to find Robotics & Automation employees with experience or those that are recent graduates. Also consider temporary interns, ideally with intent to hire.

If you are just getting started, then it is reasonable to assume that you will want to engage the services of a systems integrator as well. Control Design advises to, "determine if the integrator has experience in your industry or application, evaluate the integrator's background and capabilities and check references, Assure the integrator has the technical expertise and staff to both provide the system and support it in the future. Also assertain they have the financial ability to procure the materials needed for your system." [35]

*Figure 6. Typical Sourcing Options, via Deloitte.*
*Note: RPA means Robotics Process Automation; and BPO means Business Process Outsourcing Provider.*

- **Direct:** Buy RPA licenses directly from the vendor
- **Direct with support:** Buy RPA licenses directly from the vendor and engage a services partner for configuration and support
- **Outsource:** Work with a traditional BPO provider, for a "business process-as-a-service" or "robots-as-a-service" arrangement

**Common direct to RPA pricing models**

**License based (most common)**

- You pay per software license for each installed robot, management server, and development tools
- Perpetual license or annual subscription
- The definition and capacity of a "robot" can vary by vendor, making direct comparisons tricky
- Hardware and maintenance will add to the cost

**Value based**

- Pricing is linked to either the FTE-equivalent savings (e.g., a fixed percentage of the FTE cost that would have been occurred), or to each completed transaction
- Can be restrictive to horizontal-scaling across the organization, as contracts will need re-evaluating to include additional business processes
- The vendor is encouraged to put "skin in the game" and maintain a good level of service

**Service based**

- You pay a regular subscription fee for the service, with a service agreement that defines the responsibilities of the provider
- This model is particularly attractive for IA solutions, which may run on complex big data technologies that can be expensive to set up and maintain in-house, or are needed on a spot basis

35 http://www.controldesign.com/articles/2017/how-to-get-started-with-robotics/



**"Quick Wins" to Get Started with Robotics and Automation**

Take a page from the best practices of Control Design, and of other manufacturers that are already up-and-running with Robotics & Automation, by following a few of their tips to jumpstart your use of these technologies.

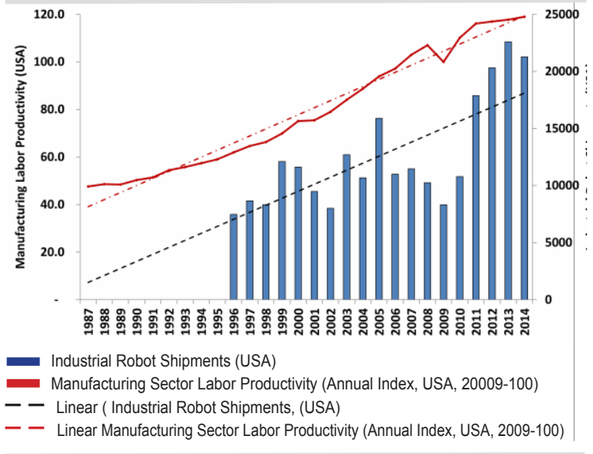
- Tip 1: Start small and grow in automation. Invest in automating one process at a time in order to understand robotics involved and learn how to properly use machinery while also allowing time to observe potential productivity gains. Look into leasing/renting robotic machinery if you are unsure of your financial commitment.
- Tip 2: Connect with robotics integrators. Integrators will conduct an onsite visit and survey the factory/enterprise to help you better understand what robotics you may need and how they can be implemented best on the shop floor. They can evaluate your processes for tasks that are dangerous to humans, boring or repetitive tasks, heavy tasks that require excessive exertion or lifting that requires multiple employees, high-speed manual moves, and tasks that do not require human decision-making.[36] Connect with multiple integrators and vet experience before choosing one.
- Tip 3: Consider collaborative robots as a jumping-off point. Though machines cannot replace human workers in many production processes, even the smallest companies are finding collaborative robots (co-bots) an easy-to-deploy solution for their worker shortage. Case in point from Automation World: Creating Revolutions was experiencing double-digit product rejection rates because of faulty assembly, and it was also unable to find skilled workers. Seeking an alternative solution for these production problems, the company turned to Hirebotics, a company that rents collaborative robot by the hour. Renting from Hirebotics eliminated the capital expense barriers for new technology that were facing Creating Revolutions. Using the robot also reduced product rejection rates to nearly zero.[37]

**Metrics for Success: How to Measure Impact**

When setting your objectives for Robotics & Automation, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance against traditional strategies, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

- Lower production costs
- Reduced time to complete tasks
- Greater real estate utilization (robots take up less space than needed for human workers)
- Increase in labor demand (as a result of higher product demand from lower product prices)
- Labor cost savings. Estimates for labor cost savings in various countries through automation and robotics now are averaging around 16% in industrialized nations.[38]
- Increased onsite safety & lower accident rate
- Higher skilled employees with greater longevity
- Reduction in changeover time
- Increased labor productivity

*Figure 7. Manufacturing Labor Productivity (Output/Hour) and Industrial Robot Shipments, via Bureau of Labor Statistics [39]*




36 Ibid.
37 https://www.automationworld.com/article/technologies/robotics/turning-out-lights-factory-floor
38 https://www.brookings.edu/blog/techtank/2016/06/02/how-technology-is-changing-manufacturing/
39 https://www.a3automate.org/docs/A3WhitePaper.pdf



## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to-implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**Advanced Robotics for Manufacturing Institute (ARM) Institute:** A resource for manufacturers of any size to utilize, ARM focuses on empowering manufacturers and providing them with the proper information on how technology can assist their company. ARM also helps on the front of educating manufacturing employees on robotics/automation usage as well as works toward overall workforce development. It is the first nationwide initiative of its kind to bring together leadership and expertise from academia, research, industry, government, and nonprofits in a collaborative effort to help revitalize American manufacturing.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Genesis Systems Group:** Genesis specializes in factory automation with robots for welding, cutting, non-destructive inspection, adhesive application, material removal, and material handling. Genesis is also AS9100D and ISO 9001:2008 Certified. Its expertise is centered on the design, manufacture, and implementation of systems for welded assemblies, mechanical assembly, handling/tending, non-destructive inspection, abrasive waterjet cutting, and material finishing.

**Hawk Technology:** Hawk Technology offers true "turn-key" solutions. Its onsite tooling department will integrate your robotic needs as well as create the tooling for seamless manufacturing solutions. Hawk Technology provides: HMI packages that display work instructions in real time, custom HMI packages tailored to your solution, single-source tooling and integration, custom cells designed on site, standard line of cells offline programming, and simulation services. It is a FANUC-authorized system integrator.

**Hiring Solutions Robert Half Technology:** Robert Half Technology specializes in placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**Vizient Manufacturing Solutions:** Vizient Manufacturing Solutions, Inc. specializes in robotic integration solutions. Its team of automation specialists have been providing robotic systems integration, dedicated customer service, and tooling solutions since 2004, installing more than 300 robotic systems. All of Vizient's products are engineered and manufactured in-house, giving them complete control over product quality and project timelines. Vizient is a Rock Island Arsenal Certified robot integrator, and a FANUC-authorized system integrator.



## Appendix

**Glossary of Key Robotics & Automation Terms**
*All definitions from Robots.com for educational purposes.*

**Actuator:** A piece of equipment that allows a robot to move by conversion of different energy types such as electrical or mechanical processes using liquid or air.

**Assembly robot:** A robot designed specifically for mating, fitting, or otherwise assembling various parts or components into completed products. Primarily used for grasping parts and mating or fitting them together, such as in assembly-line production.

**Axis:** The point that something such as a tool rotates around. The number of axes a robot has varies, but the majority of industrial robots are 4-axis or 6-axis.

**Base:** The stable platform to which an industrial robotic arm is attached.

**Cartesian robot/Manipulator:** A Cartesian Manipulator is a robot arm with prismatic joints, which allows movement along one or more of the three axes in the x, y, z coordinate system.

**Control device:** An instrument that allows a person to have control over a robot or automated system for times such as startup or an emergency.

**Degrees of freedom:** The amount of values in a system possible of variation. A robotic joint is equal to one degree of freedom.

**Drive:** A speed (gear) reducer to convert high speed low torque to low speed high torque.

**Drive power:** Actuators convert this source of energy into usable energy for the robot's movement.

**Dynamics:** Analysis of the causes of motion by the sources of forces and energy.

**Emergency stop:** The operation of a circuit using hardware-based components that overrides all other robot controls, removes drive power from the robot actuators, and causes all moving parts to stop.

**Enabling device:** A manually operated device which when continuously activated, permits motion. Releasing the device shall stop robot motion and motion of associated equipment that may present a hazard.

**End-effector:** An accessory device or tool specifically designed for attachment to the robot wrist or tool-mounting plate to enable the robot to perform its intended task. (Examples may include gripper, spot weld gun, arc weld gun, spray point gun, or any other application tools.)

**Error:** The difference between the actual response of a robot and a command issued.

**Error function:** A number is chosen to stand for a discrepancy in the actual value and the desired value for a dependent variable.

**Feedback:** A signal from the robot equipment about conditions as they actually exist, rather than as the computer has directed them to exist.

**Flexibility:** The diverse jobs that a robot is capable of executing.

**Gripper:** An end effector that is designed for seizing and holding (ISO 8373), and "grips" or grabs an object. It is attached to the last link of the arm. It may hold an object using several different methods, such as: applying pressure between its "fingers," or it may use magnetization or vacuum to hold the object, etc.

## Appendix *(continued)*

**Hazardous motion:** Unintended/unexpected robot motion that may cause injury.

**Home position:** A known and fixed location on the basic coordinate axis of the manipulator where it comes to rest, or to an indicated zero position for each axis. This position is unique for each model of manipulator.

**Integrate:** To fit together different subsystems, such as robots and other automation devices, or at least different versions of subsystems in the same control shell.

**Integrator:** A company that combines and coordinates separate parts or elements into a unified whole using mechanical means.

**Joint:** A part of the manipulator system, which allows a rotation and/or translational degree of freedom of a link of end-effector.

**Joint space:** The area and coordinate system the joints of the robot consume.

**Kinematics:** The relationship between the motion of the endpoint of a robot and the motion of the joints.

**Limiting device:** A separate apparatus that places a restriction on the maximum envelope. This restriction occurs by terminating motion of the robot.

**Link:** A rigid part of a manipulator, which connects adjacent joints.

**Manipulator:** A machine or robotic mechanism which usually consists of a series of segments jointed or sliding relative to one another, for the purpose of grasping and/or moving objects (pieces or tools) usually in several degrees of freedom. The control of the manipulator may be by an operator, a programmable electronic controller, or any logic system (for example cam device, wired, etc.).

**Motion axis:** The line defining the axis of motion either linear or rotary, of a segment of a manipulator.

**Normalize:** The process of relating factors into similar magnitudes by scaling.

**Off-line programming:** A way to store procedure information for a robot on a computer to be used in the future.

**On-line programming:** A means of programming a robot while the robot is functioning. This becomes important in manufacturing and assembly line production due to keeping productivity high while the robot is being programmed for other tasks.

**Operator:** This person begins and ends processes the robot performs while observing to ensure proper procedures are occurring.

**Pendant:** A hand-held input device linked to the control system with which a robot can be programmed or moved. This enables the human operator to stand in the most favorable position to observe, control, and record the desired movements in the robot's memory.

**Pick and place robot:** A type of robot that moves parts from one place to another.

**Point-to-point:** The user specifies points for the robot to follow along the path. The movement is point-to-point as opposed to a continuous motion.

**Presence-sensing safeguarding device:** A device designed, constructed, and installed to create a sensing field to detect an intrusion into such field by people, robots, or objects.



## Appendix *(continued)*

**Programmable logic controller (PLC):** A solid-state control system, which has a user programmable memory for storage of instructions to implement specific functions such as: I/O control logic, timing, counting arithmetic, and data manipulation. A PLC consists of a central processor, input/output interface, memory, and programming device, which typically uses relay equivalent symbols. The PLC is purposely designed as an industrial control system, which may perform functions equivalent to a relay panel or a wired solid-state logic control system, and may be integrated into the robot control system.

**Reach:** The distance from the center of the robot to the fullest extension of the robotic arm. The work envelope is determined from this distance.

**Reliability:** A measure of the robot's end-effector's ability to perform similar operations multiple times based on similar operating conditions.

**Repeatability:** The variability of the end-effector's position and orientation as the robot makes the same moves under the same conditions (load, temp, etc.).

**Remanufacture:** To upgrade or modify robots to the revised specifications of the manufacturer.

**Robot:** A piece of equipment with the capability to be programmed to perform quick and accurate operations multiple times.

**SCARA robot:** A type of robot consisting of two concurrent joints that rotate and meet certain needs within the same plane

**Sensor:** A device that responds to physical stimuli (such as heat, light, sound, pressure, magnetism, motion, etc.) and t ransmits the resulting signal or data for providing a measurement, operating a control, or both.

**Simulation:** A graphical computer program that represents the robot and its environment, which emulates the robot's behavior during a simulated run of the robot. This is used to determine a robot's behavior in certain situations, before actually commanding the robot to perform such tasks.

**Singularity:** A point in the robot's movement where the joints become redundant.

**Teach:** To program a manipulator arm by manually guiding it through a series of motions and recording the position in the robot controller memory for playback.

**Tool:** A term used loosely to define a working apparatus mounted to the end of the robot arm, such as a hand, gripper, welding torch, screw driver, etc. See Arm, Gripper, and End-effector.

**Work envelope:** The set of all points which a manipulator can reach without intrusion. Sometimes the shape of the work space, and the position of the manipulator itself, can restrict the work envelope.

**Wrist:** The end-effector is connected to this joint on the manipulator arm.

**Yaw:** Rotation of the end-effector in a horizontal plane around the end of the manipulator arm. Side-to-side motion at an axis.

CHAPTER 4

# Enterprise Resource Planning

## ERP Platforms at a Glance

**What are "ERP platforms?"**
ERP platforms are usually referred to as a category of business-management software – typically a suite of integrated applications – that an organization can use to collect, store, manage and interpret data from these many business activities. ERP provides an integrated and continuously updated view of core business processes using common databases maintained by a database management system. According to Wikipedia, ERP systems track business resources – cash, raw materials, production capacity – and the status of business commitments: orders, purchase orders, and payroll.[1]

**Why do ERP platforms matter?**
Manufacturers can be more visible and accessible to new customers, partners and geographies by utilizing ERP platforms. Building connections and communications through online methods is critical to competing in a global economy where access to potential manufacturing partners is seemingly unlimited and business information travels fast. The definition of "business as usual" has evolved as "going digital" is now table stakes for manufacturer survival.

**What are the biggest ERP opportunity areas?**
We have identified three key opportunity areas in ERP platforms for manufacturers:

Opportunity #1: Speed and responsiveness of customer and supplier material flows
Opportunity #2: Communications both within the firm and with its external environment
Opportunity #3: Improved productivity of both capital and labor for the firm

More information can be found in the Identify Opportunities section on page 7.

**What are the business benefits of utilizing ERP platforms?**
ERP platforms have been proven to be more cost-effective means of:

- Having a unified source of manufacturing data
- Providing both improved external and internal communications
- Improved productivity of operations

Customers who feel connected to their manufacturer throughout the purchase and delivery process are also more likely to purchase, recommend and refer you to their peers. Learn more below about key performance indicators you can expect to improve on by turning to the Metrics for Success section in Build the Business Case and Begin Implementation on page. 9

**Where can I find help to get started?**
There are partners who can assist you with full ERP strategies or specific implementations of tactical solutions on business functions that you've prioritized. There are also many free online resources, as well as educational courses offered by state universities and colleges. Go to Find Help on page 15 for a full list of resources to help jump-start your use of ERP solutions to grow your business.

[1] https://en.wikipedia.org/wiki/Enterprise_resource_planning




*Figure 1: Enterprise Resource Planning Chapter Information Flow*

## ERP Platforms Table of Contents

## Understand the Technology

In the first section, we take a closer look at the variety of technologies that contribute to the collective term "ERP platforms." You'll gain a better understanding of how ERP platforms contribute to an overarching strategy through diagrams, frameworks, and definitions of key terms used in the ERP system's space. This section also details additional online resources for greater understanding.

**Glossary of Key ERP Platform Terms**
Please refer to the glossary in the appendix for definitions of key ERP terminology that is utilized in this guide book. Definitions provided for educational purposes as described by the source unless otherwise noted.

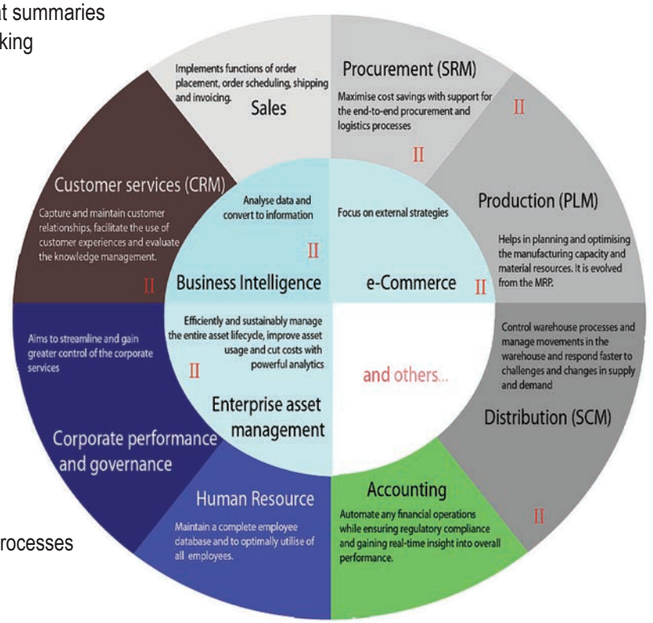
**A Starting Point for Understanding ERP**
Wikipedia defines enterprise resource planning (ERP) as "the integrated management of core business processes, often in real-time and mediated by software and technology.[2] ERP is usually referred to as a category of business- management software — typically a suite of integrated applications—that an organization can use to collect, store, manage and interpret data from these many business activities."

There are additional infographics that provide great summaries and frameworks for you to begin shaping your thinking about implementing an ERP system. They will not provide detailed solutions or plans. Those specific solutions and plans need to be developed for your individual business needs and conditions.

**7 ERP Infographics You Need to Know**
The ERPeople blog has collected seven infographics to explain ERP, its benefits, and some information on implementation.[4]

- What is ERP All About?
- The Facts of Cloud ERP
- Getting the Most out of Your ERP
- The Rise of Cloud ERP
- The ERP Experience
- What Stands in the Way of Getting Your ERP System?
- Here's How You Can Optimize ERP Business Processes

*Figure 2: Elements of the ERP Landscape* [3]




2 https://en.wikipedia.org/wiki/Enterprise_resource_planning
3 https://en.wikipedia.org/wiki/Enterprise_resource_planning#/media/File:ERP_Modules.png
4 http://erpeople.walkme.com/2016/02/22/7-erp-infographics-you-need-to-know/



## Understand the Technology *(continued)*

**What's Stopping You from Using ERP?**
Algorithm, Inc. is an ERP systems provider and shares a detailed infographic on looking at a "cloud" versus "on-site" ERP solution.[5] The included infographic also helps you walk through the challenges that you may be concerned about with an ERP system. Some of concerns addressed are:

- ERP costs too much.
- ERP requires too much effort.
- ERP is too complicated.
- My company is too small for ERP.

**Top 15 Benefits of Implementing ERP Software**
Workwise Software shares a post and a framework describing the top 15 benefits of utilizing an ERP platform.[6] Some of those are:

- Productivity through eliminating or automating redundant tasks
- Better customer service
- Integrated information
- Better collaboration both internally and externally

**Additional Online Resources**
There are many online resources for review to deepen your understanding of ERP platforms, technologies, processes, opportunities, challenges, and more. We've outlined a few below:

- Can Your Small Business Afford ERP? Can You Afford to Operate Without It? Via Mint Jutras.[7] In this whitepaper, you'll find out how neglecting to invest in appropriate ERP technology can negatively impact a company's future financial and sales success.
- Small Business ERP – Misinformation, via Tegrous Consulting.[8] This article provides a quick summary and answers the questions of what is an ERP, why does a company need it, and can they afford it.
- 10 Steps to Choosing the Right Manufacturing ERP System, via OptiProERP.[9] According to the article, if these 10 steps are followed, they will guide you on the path to choosing the right ERP system for your manufacturing business.

There is a wealth of information available by searching online to help you get started with your understanding of ERP. You can use Google images or Pinterest to find ideas using the suggested search terms below:

- Enterprise resource planning infographics
- Enterprise resource planning elements infographic
- Enterprise resource planning benefits
- Enterprise resource planning implementation

5 http://www.algorithminc.com/blog/bid/258755/Cloud-vs-On-Premise-Enterprise-Resource-Planning
6 https://www.workwisellc.com/erp-software/15-benefits-implementing-erp-software/
7 http://www.mintjutras.com/can-your-small-business-afford-erp-part-1/
8 http://tegrous.com/small-business-erp/
9 https://www.optiproerp.com/blog/10-steps-choosing-right-manufacturing-erp-system/

## Identify Opportunities

Even though ERP technology is not new, some companies still have not adopted the platform as part of their manufacturing process. A consultant gave the following reasons why companies haven't already invested in an ERP platform:

**It's 30 year-old technology! Why are we still talking about it?**

- "Things are working fine."
- "Good enough" vision doesn't always see the train.
- Afraid to "pull the covers back;" it's scary in there!
- Feels complicated, can't see the ROI.
- More important things to invest time and money in.
- Too busy today, maybe tomorrow.

**Benefits and Use Cases of ERP Platform Opportunities**

ERP solutions offer many operational opportunities to small and medium manufacturers. Here are some other commonly cited benefits of using ERP platforms:

- Integration of a single source of data
- Common data definition
- A real-time system
- Improved internal communication
- Improved customer service and order fulfillment
- Improved communication with suppliers and customers
- Enhanced competitive position
- Increased sales and profits

In addition, these are three key areas that can bring greatest benefit to small and medium manufacturers:

**Opportunity #1:** Streamline processes for better customer and supplier material flows
**Opportunity #2:** Integrated information and better collaboration both within the firm and with its external environment
**Opportunity #3:** Improved productivity of both capital and labor for the firm

On the following page, we'll examine the key benefits of utilizing ERP by using a case example from each opportunity area that shows how a manufacturer was able to utilize ERP platforms to produce positive results.

### Opportunity #1: Streamline Processes for Better Customer and Supplier Material Flows

**Case Example: Software and Process Updates Improve Visibility and Flexibility for Planning, Scheduling** [10]

Hansaloy Corporation, a Davenport, IA based manufacturer of bread blades, lattice, blade guides and honing equipment for bread slicers, needed to improve their existing ERP platform. Not only was technology outdated, but it was unable to handle certain elements to help the business run efficiently.

They worked with CONTAX, an ERP software and consulting company, to adopt new software and processes. By improving their ERP platform, Hansaloy Corporation:

- Improved visibility into production planning, scheduling, and control
- Increased flexibility in demand planning and forecasting
- Allowed for more flexibility in handling a wider variety of orders

Download the full case study at http://www.contax.com/lp/lp10/index.asp.

10 http://www.contax.com/lp/lp10/index.asp



## Identify Opportunities *(continued)*

### Opportunity #2: Integrated Information and Better Collaboration Both within the Firm and with its External Environment

**Case Example: Mr. P meets ERP** [11]

A Midwest-based manufacturer of primarily milk and whey-protein based food ingredients had implemented an early MRP system, lovingly referred to as "Mr. P," in March 2001. "Mr. P" routinely tried to predict when the company would run out of raw material. However, he was never given any data from which to draw accurate conclusions. Significant operational issues still remained after implementing the initial MRP package:

- Over 300 products, maintained within Word Perfect
- Weekly "wall-to-wall" counts (inventory assumes a blind count!)
- Counts captured on spreadsheets for finance input to ERP/valuation
- < 60% lot traceability for ingredients
- < 56% on-time delivery, with some customers experiencing 50% "scrap" upon receipt

Over time the company decided to implement a more modern ERP platform and processes that go along with it. By doing so, they experienced the following improvements:

- ZERO new raw material buys for 2 months!
- Dramatic reduction in biological contamination due to reduced holding
- Revolving debt reduction (dramatic!), greatly improved cash flow
- Simplified manufacturing process through elimination of "recipe" complexity
- Throughput improved over 80%
- Efficiency climbed from 47% to 89%
- On-time delivery reached over 90% for first time in company history
- Recovered 4 MAJOR customer accounts, providing a 6% increase in revenue
- Established end-to-end transparency, allowed focus on additional improvement actions
- Created OPPORTUNITY!

11 Presentation from Tom Waggoner, Living More, Inc., at ERP users group meeting

## Identify Opportunities *(continued)*

### Opportunity #3: Improved Productivity of Both Capital and Labor for the Firm

Case Example: Investment in ERP Finds a Quarter of a Million Dollars in Savings for Mar-Bal, Inc.[12]

"The Company: Mar-Bal serves the appliance, electrical, transportation and industrial marketplaces from its four facilities in North America … Mar-Bal, Inc. was experiencing growing pains with their antiquated software that couldn't keep up with the increase in their manufacturing activity. Their old system didn't have EDI, lacked inventory scanning, didn't track customer inventory and VMI accurately, and had limited reporting and forecasting tools."[13]

By implementing an ERP platform, the company found the following return on investment:

- 5,000 potential machine hours no longer lost to downtime for physical inventory
- More efficient inbound order EDI processing: $40,000 annually
- Capacity for outbound EDI invoice and ASN processing: $20,000 annually
- Regular and monthly physical inventories eliminated: $83,000 annually
- Quicker month-end close: $23,000 annually
- Accurate production reporting through the RealTime interface: $62,000 annually

Download the full white paper case study.[14]

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## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to take in implementing strategies and tactics of ERP platforms within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing an ERP platform may be very different from what you may be accustomed to, and that the prospect of this degree of change to your communications and operations can be daunting and frightening. It is our hope that, through the following content and previous look at the benefits of ERP platforms, you'll feel more comfortable exploring how you can utilize these technologies to better connect with your internal and external information flows to ultimately increase your product and service sales.

Key Considerations to Understand Your Business Case

First, here is an online whitepaper by Mint Jutras [15] to help you understand your business case:

Can your Small Business Afford ERP? Can you afford to operate without it? [16]

12 https://www.iqms.com/company/mar-bal/
13 https://www.iqms.com/company/mar-bal/
14 https://www.iqms.com/files/case-studies/ERP_software_saves_Mar-Bal_quarter_million_dollars.pdf
15 http://www.mintjutras.com/can-your-small-business-afford-erp-part-1/
16 https://www.vision33.com/media/57333/affordableerpforsmb_whitepaper.pdf



## Build the Business Case & Begin Implementation *(continued)*

**What to Look for in an ERP Platform**

The following suggestions were discussed during a presentation at a recent Innovation Hub users group meeting: [17]

**General Features:**

- Overall usability & ease of use
- MRP capabilities
- Costing Run, AR and AP functionality, Chart of Accounts
- Production planning & control, BOMs, routings, work centers
- Roles and authorizations (Sox compliance)

**Manufacturing Features:**

- Job shop functionality (clock in and out, project-based)
- Serialization and/or batch management
- Planned vs. actual costing, profitability reporting
- Quality management (inspections)

**Future Features - Extra $$$?**

- Engineering change management
- Add a plant, add a company, sell to customers in alternate currency
- E-commerce
- EDI integration

**What to Look Out for in an ERP Platform Implementation**

- Is my consulting team local (no ongoing travel costs)?
- Does my consulting team consist of W2 employees or 1099?
- Is the solution built by the vendor?
- Are there other vendors/consultants that can support me?
- What is the ERP community/user group like?
- What is the help platform/mechanism for the ERP?
- Make sure you get documentation on business process and procedures (BPPs) from consultants.

17 Presented by Corey Herchenroder, CONTAX, Inc., at Hub ERP user group meeting

## Build the Business Case & Begin Implementation *(continued)*

**Change Management: Building the Case Requires Defining Your Business Requirements**
For most small and medium manufacturers, the prospect of adopting an ERP platform into your internal and external operations seems risky, as it requires "unlearning" the methods and habits that you have used to run your business to this point. And it requires learning new technologies and procedures to remain relevant in a digital age.
There are many ways for you to get started along the path to utilizing ERP. Use the change management tips below to make the case for change and immediately begin proving results:

- Understand the business value of ERP and set goals accordingly. Use our metrics outlined below as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating ERP into your existing manufacturing processes. This will help in resource planning if you're measuring the right benchmarks out of the gate.
- Focus on one or two key areas (such as financial reporting, inventory control, or ordering) first before adding complexity to your production process and supply chain.
- Focus on getting every employee on board with the benefits of ERP through peer education. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision.
- Make them as knowledgeable as you possibly can, taking ownership of ERP initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse-mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with new technologies and benefits. See below for more education resources and tips.
- Keep communication lines open during the trial-and-error portion of ERP implementation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to prototyping successful new business processes. This mindset must be led from the top down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies from ERP. Breed risk-taking early.

**Processes and Framework for Implementing ERP Platforms**
Integrating ERP platforms into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks below to jumpstart your efforts. The framework in this section are presented to aid in your high-level strategic prioritization of ERP platforms; we recommend you search out specific frameworks for each platform and tactic chosen to guide your implementation.



## Build the Business Case & Begin Implementation *(continued)*

**Framework: ERP Implementation: A Best Practices Guide for Small & Midsized Businesses** [18]
According to this online guide presented by SAP, a business software company, "… ERP is no longer a luxury that only the largest companies can afford. Quite the contrary, it is fast becoming a necessity that companies cannot afford to be without – regardless of their size. New pricing and more flexible architectures, such as those based in the cloud and offered on a pay-as-you-go software-as-a-service (SaaS) model, are contributing to increasingly rapid adoption among small to midsize businesses (SMBs) around the world." Read this guide at the link provided in the footnote below. [19]

**Resources Needed: Technology & Staffing**
Resources required to manage and implement ERP platforms will vary by which area of your business that you've prioritized. As previously outlined, you must create a strategic plan for how ERP platforms will augment or replace your current operational processes. How and where to begin implementing elements of ERP needs to be strategic in order to avoid investing in the latest "bright, shiny technology" or hiring unnecessary talent.

Use the following general checklist to assist in the process of planning for your hard and soft costs. Probably one of the first questions that you will have to answer is whether or not to use a cloud-based ERP software or have an on-sight system of hardware and software. As has been mentioned before, this will depend on your business needs and processes.

**Software:**
- There are many systems available, and they are constantly changing.
- You might try to search the term "best small business ERP" online to find options.
- As mentioned above, a key decision will be whether or not to use a cloud-based system.
- You may want to learn what systems your customers and suppliers are using now or planning for the future.
- Learn how the pricing of the software is calculated. It may be by user or by site. This can be important when looking at the future growth of your company.

**Hardware:**
- You will need to review your current systems and equipment to see how you currently capture and share data (it may be on paper).
- Even cloud-based systems will require some equipment like PCs or tablets.
- You will need to consider how and who will support whatever equipment you adopt.

**Employees and Hiring:**
- You will most likely need some expert assistance in implementing an ERP platform. You will also probably like to have that assistance to be on-site and face-to-face for some period of time. You may want to check for ERP integrators and the software that they support.
- You will need someone within your company to be the "owner" and project lead for the new system. This will require a significant amount of time in the start-up and also be needed to train new or additional people in the future.
- As mentioned in the change management sections, there will be a significant amount of your and your people's time and energy devoted to this implementation. You will be changing the way your company's work gets done, not just adopting a computer system.

18 http://docs.media.bitpipe.com/io_10x/io_102514/item_472800/ERP_Implementation__A_Best_Practices_Guide_for_Small and_Midsized_Businesses.pdf
19 http://docs.media.bitpipe.com/io_10x/io_102514/item_472800/ERP_Implementation__A_Best_Practices_Guide_for_Small_and_Mid

## Build the Business Case & Begin Implementation *(continued)*

**"Quick Wins" to Get Started with ERP Platforms**

Here are a few areas to focus on to jumpstart your preparation for implementing elements of ERP:

- **Tip 1:** Begin mapping your existing business and manufacturing processes. This is probably the very best thing you can do to prepare. There are many resources to help with this. Many are listed in the resources below.
- **Tip 2:** Validate your data. An ERP platform is only useful if the data is accurate and up-to-date.
- **Tip 3:** Find or appoint an internal project manager. You need someone within your company to be the "owner" of the new system. This is the only way to sustain the implementation and train additional people.
- **Tip 4:** Identify the information "bottlenecks" where you are losing time. Where are the places that either information or material have to "wait" before they can move to the next step?
- **Tip 5:** Ask your customers about their plans for future operational systems. While systems are getting much better at exchanging data, it makes sense to be proactive in understanding what is going on in your whole supply chain. You may also find others who are sharing your implementation journey.
- **Tip 6:** Reach out to people in the community. You've already taken the first step by reviewing this Guidebook. Go to the Find Help with Assets and Partners section for further information.

**Metrics for Success: How to Measure Impact**

When setting your objectives for your ERP platform, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance against where you are today, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

The following two articles offer insight into the measurement process:

***"How to Measure the Success of Your ERP Implementation"*** [20]

***"Six Great Metrics To Measure ERP Success"*** [21]

The list below provides a variety of conventional and unconventional ways to measure the success of your ERP implementation.

While having ERP systems is standard, not nearly as much attention is being paid to the actual tangible results derived from them. Measurement, when done, is often one-dimensional: have we made a bigger dollar bottom line after the implementation? Here are a few other metric examples:

- Cycle time to process an order
- Lead times
- Inventory accuracy
- Time to product delivery
- Inventory level
- Number of "rush" shipments
- Increased employee productivity
- Quality of delivered product
- Supplier lead times
- Cycle time for financial processes like monthly closing

20 http://it.toolbox.com/blogs/inside-erp/how-to-measure-the-success-of-your-erp-implementation-58042
21 https://psierp.com/6-great-metrics-measure-erp-success/



## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to-implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**CONTAX, Inc:** CONTAX is an SAP Gold partner and global SAP consulting services provider. From nine locations in four countries around the world, CONTAX delivers the highest quality of SAP services for SAP implementations, SAP application managed services, and SAP support services. CONTAX is an authorized reseller and certified SAP Enterprise Support service provider. CONTAX develops and markets cloud-based application extensions for the SAP Cloud Platform (SAP CP) environment, and is one of the leading adopters of SAP CP in the SAP ecosystem.

**Coursera:** Coursera provides universal access to the world's best education, partnering with top universities and organizations to offer courses online. Every course on Coursera is taught by top instructors from the world's best universities and educational institutions. Courses include recorded video lectures, auto-graded and peer-reviewed assignments, and community discussion forums. When you complete a course, you'll receive a sharable electronic Course Certificate.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwidenetwork provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manfacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**Quadyster:** Quadyster is an Information Technology solutions provider. With over three decades of Information Technology experience, its professionals bring extensive knowledge and experience to solve the complex IT challenges. Highly accessible and flexible executive team with global experience to promptly resolve any issues.

**Robert Half Technology:** Robert Half Technology specializes in hiring solutions, placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Udemy:** Udemy is a global marketplace for learning and teaching online where students are mastering new skills and achieving their goals by learning from an extensive library of over 55,000 courses taught by expert instructors.

**Yash Technologies:** YASH started off as an IT consulting partner for one of the most recognized brands in the agricultural equipment manufacturing industry. With steady and planned growth, YASH's vision went global in the year 2000, with introduction of offshore operations in Indore, India. Named as of one of the "Fast 500 companies," YASH has grown organically through strategic acquisitions. They currently have over 4,500 global employees, and growing.

## Appendix

**Glossary:** Key Enterprise Resource Planning (ERP) Software Terms and Definitions
*Definitions provided for educational purposes as described by Work Wise unless otherwise noted.*[15]

**3rd Party Application:** Software that has been developed by an outside company and is sold through a vendor.

**Average Order Amount:** The amount of all orders divided by the total number of orders; used in digital marketing to help calculate the necessary reach, along with CTR (click-thru rate) and conversion rate.

**Accounts Payable:** Any unpaid balances that your company owes to vendors.

**Accounts Receivable:** Any outstanding balances that your customers owe to your company.

**Actual Cost:** The actual amount of money either paid for material or charged as labor, material, or overhead to a work order.

**Aging:** When assets are organized and sorted according to how long they have existed.

**Allocation:** Distribution of cost in a manufacturing process.

**Assemble-To-Order (ATO):** A manufacturing strategy that allows users to combine a limited number of sub-assemblies into a large number of possible finished items. This strategy is designed to allow a wide variety of customization options, shorter lead times, and low inventory risk.

**Business To Business (B2B):** When the vendor and consumer are both businesses, not end consumers.

**Bill Of Material:** A list of the type and quantity of components needed to build a part.

**Bottleneck:** A machine or workstation through which many production items must flow and which when overloaded causes a delay in the production process.

**Build-To-Stock:** A build-ahead approach to production where items are built ahead of time according to sales forecasts or historical demand.

**Capacity Requirements Planning (CRP):** The process of calculating the production capacity that a business requires to meet planned and actual demand.

**Cloud Computing:** A process whereby users are connected to their ERP software via the internet rather than to computer equipment at their location, thus eliminating the cost and need to have the hardware infrastructure located and maintained at their site.

**E-Commerce:** The process by which goods and services are bought and sold via the internet utilizing web sites that are virtual stores. Examples include businesses from banking to baked goods and everything on between.

**Electronic Data interchange (EDI):** EDI replaces paper mail, fax, and email by electronically exchanging order and fulfillment/billing information in a standard format between trading partners.

**Engineer-To-Order:** A production approach where components are designed, engineered, and built to specifications after the order has already been received.

15 https://www.workwisellc.com/erp-software/erp-terms-and-definitions/



## Appendix *(continued)*

**Fixed Assets:** Assets that are necessary for production, but that are not going to generate cash within a year. These include assets such as equipment, vehicles, buildings, and more.**orecasting:** A process that uses historical data to predict future outcomes.

**General Ledger:** A permanent, ongoing record that contains all of an organization's financial transactions.

**Implementation:** The process of installing and configuring ERP software. This process involves installing, configuring, testing, training, and preparing an organization for the change.

**Integrated Software:** Two or more software functions within the overall ERP application that share data and combine functions, such as order processing and inventory control or invoicing and accounts receivable.

**Job Cost:** A method in which all costs associated with a project are recorded over time, totaled at the end, and where the actual and planned costs are compared to generate variances that can be fed to accounting systems.

**Job Shop:** A manufacturing facility that produces discrete, specialized, and fairly small manufacturing runs of products that are usually not repeated.

**Kaizen:** In Japanese, the word means "improvement." This is the philosophy of continuous process improvement using analytical tools and methods.

**Kanban:** A communication system that controls the flow of the shop and synchronizes the level of production to customer demand. It normally uses standardized quantities and movement tickets that travel with the production pieces from operation station to operation station.

**Key Performance Indicator (KPI):** An approach to helping a business achieve its goals through the development of agreed-upon critical performance targets and the measurement of progress toward those targets. It can be, and often is, applied at every level of the business.

**Lean Manufacturing:** A manufacturing method that focuses on the elimination of waste within a manufacturing system. This approach helps determine the right combination of value for the customer needs, and producing that value in the most efficient and effective manner possible.

**Liquidity:** The degree to which capital can be turned into cash quickly.

**Lot Number:** A number that is used to identify a specific quantity or lot of material from a manufacturer.

**Make-To-Order:** A manufacturing process where manufacturing starts after receiving a customer's order.

**Master Production Schedule:** The schedule that a company uses to plan how many items need to be produced within a given timeframe. This time-phased production plan is comprised of forecasts, actual demand and supply and attempts to balance these components taking into account all resources.

**Material Control Management:** Associated primarily with moving, storing, and assessing materials used or consumed in manufacturing. Inventory management, quality assurance, production reporting, and cycle counting. Most material master data and inventory movements all fall within the scope of materials management.

## Appendix *(continued)*

**Material Requirements Planning (MRP):** A system used to plan production, scheduling, and inventory. An MRP system ensures that enough materials are available for production, enough finished products are available to deliver to customers, and that the lowest amount of materials and products needed are on hand. MRP also plans manufacturing activities, delivery schedules and purchasing activities.

**Materials Management:** Activities involved with transporting, storing, and evaluating materials used during the manufacturing process.

**Mixed Mode Manufacturers:** In discrete manufacturing, the requirement to produce Make-to-Stock, Make-to-Order, Configure-to-Order, and Engine-to-Order products. In order to accomplish this, an ERP application must provide robust functionality for all modes simultaneously, which can prove to be extremely challenging and often requires creativity in configuration as well as flexibility on the business processes.

**Mobile Data Collection:** A suite of mobile transactions designed for hand-held devices. This allows users to selectively deploy bar-code enabled, hand-held mobile devices.

**Network Administrator:** The person who is responsible for managing the computer network of a business, including its security and performance.

**Operations Management:** A group who is responsible for overseeing all aspects of a customer's production resources.

**Opportunity Cost:** The loss of potential gain from other alternatives when one choice is made.

**Order Management:** The process of fulfilling and tracking customer orders.

**Part Numbers:** Unique identifiers that identify every SKU.

**Point Of Sale (POS):** The time and place that a sales transaction took place. In ERP applications, this is normally the ability to handle retail or counter sales.

**Purchase Requisition:** A request for approval to purchase a material or service.

**Return Merchandise Authorization (RMA):** A unique document with an identifying number that grants a customer permission to return goods to a manufacturer.

**Return On Investment (ROI):** A financial measurement that accesses how profitable investments are. This is calculated by dividing the expected return (profit) by the financial outlay.

**Routing:** A description of the sequence of steps that materials need to go through in order to produce a fabricated part, sub-assembly, or finished product.

**Scheduling:** The process of planning and arranging orders to maximize productivity, cost, and delivery times.

**Six Sigma:** An approach that is designed to improve quality and lower the number of defects. This approach aims for six standard deviations between the mean and the nearest specification limit in any process.



## Appendix *(continued)*

**Upgrade (Software):** The replacement of a software product with a newer, improved version.

**Software License:** A way of granting multiple people access to the same shared software application. An ERP buyer pays a one-time fee for each named or concurrent user to use the software.

**Total Quality Management (TQM):** A manufacturing philosophy focused on improving quality across the operation.

**User Interface (UI):** The way in which a software user is able to interact with a computer system.

**Value Stream Mapping (VSM):** A tool that helps businesses understand how their flows currently operate and helps them figure out ways to improve them in the future. This is achieved by creating a process map that is used to streamline processes across the entire supply chain. A value stream map (VSM) is a process map that identifies all the steps and data streams required to produce a particular product or service while adding value to each step that results in improved customer satisfaction.

**Value-Added Reseller (VAR):** A reseller that adds value to an existing software product through the addition of features or services, then resells it to end users.

**Visual Scheduling:** A real-time database of shop floor activity, including new work, current work-in-progress, and completions. As work moves through the plant and operations are completed, the user receives instant feedback and is able to make adjustments to both the load (work orders) and the capacity to achieve a do-able schedule.

**Work Orders:** A request that specifies the quantity and type of a material to be manufactured, as well as the date that it needs to be manufactured by. A work order also defines all component material and labor operations required to complete production of the manufactured item.

CHAPTER 5

# Digital B2B Platforms

## Digital B2B Platforms At a Glance

**What are "Digital B2B Platforms?"**

"Digital B2B Platforms" encompass all the digital communications, sales, commerce, and engagement channels that manufacturers can use to communicate with prospects, customers, employees, and colleagues. From websites to social media, email marketing to online video, manufacturers utilize Digital B2B Platforms to connect with their audiences throughout every phase of their online decision journey.

**Why do Digital B2B Platforms matter to the manufacturing community?**

Manufacturers can be more visible and accessible to new customers, partners and geographies by utilizing digital platforms. Building relationships through online methods is critical to competing in a global economy where access to potential manufacturing partners is seemingly unlimited and word-of-mouth referrals travel fast. The definition of "business as usual" has evolved as "going digital" is now table stakes for manufacturer survival within our communities.

What are the biggest opportunity areas?

We have identified four key opportunity areas in Digital B2B Platforms for manufacturers:

- **Opportunity #1:** Expanding reach beyond current geographic constraints to remain competitive in a global economy
- **Opportunity #2:** Deepen engagement with prospects and customers as they traverse their digital customer journey
- **Opportunity #3:** Close sales using e-commerce options and other online sales and customer service tools
- **Opportunity #4:** Foster a more collaborative relationship between colleagues, peers, and among your employees to grow your company's digital culture. More information can be found in the Identify Opportunities section of this guidebook.

**What are the business benefits of Digital B2B Platforms?**

Digital B2B Platforms have been proven to be more cost-effective means of advertising, marketing, and customer service over traditional offline tactics. Customers who feel connected to their manufacturer throughout the decision and purchase process are also more likely to purchase, recommend and refer you to their peers. Learn more about key performance indicators you can expect to improve in the Build the Business Case and Begin Implementation section.

**Where can I find help to get started?**

There are agencies who can assist you with full digital strategies or specific implementations of tactics on digital platforms that you've prioritized. There are also many free online resources, as well as educational courses offered by universities and colleges. Go the Find Help with Expert Partners for a full list of resources to help jump start your use of Digital B2B Platforms to grow your business.

*Figure 1: Digital B2B Platforms Chapter Information Flow*

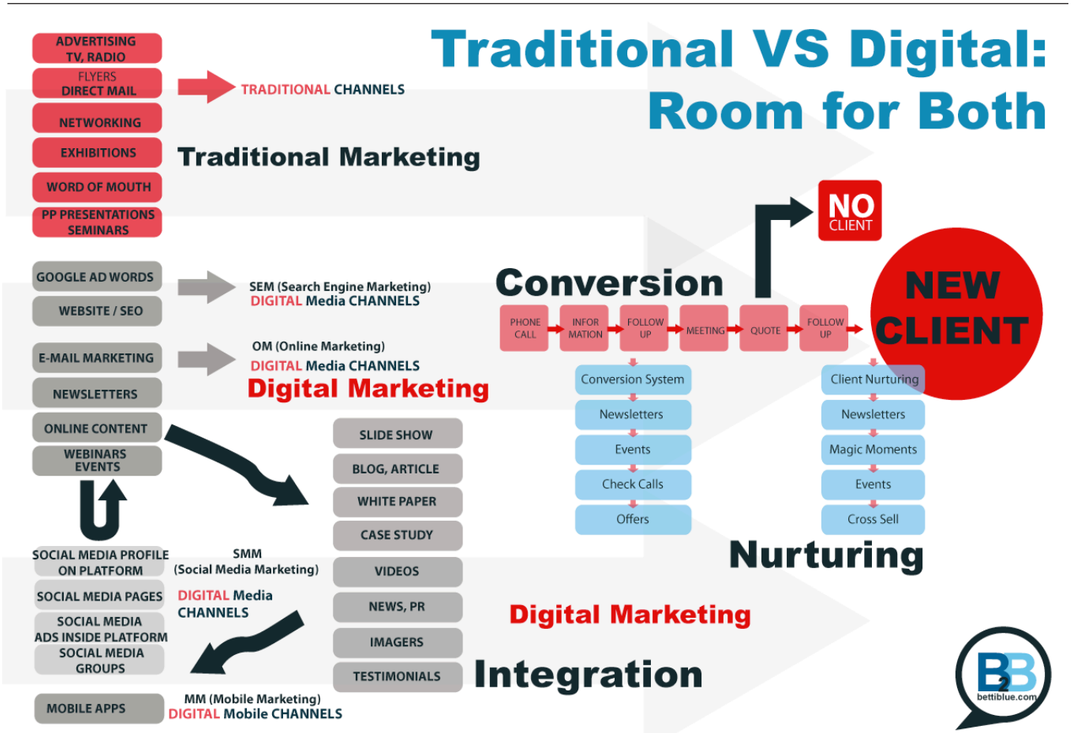

## Table of Contents

## Understand the Technologies

In the first section, we take a closer look at the variety of technologies that contribute to the collective term "Digital B2B Platforms." You'll gain a better understanding of how Digital B2B Platforms contribute to an over-arching digital customer experience and marketing strategy through diagrams, frameworks, and definitions of key terms used in the digital marketing space. This section also details additional online resources for greater understanding. Digital B2B Platforms encompass all the digital communications, sales, commerce, and engagement channels that manufacturers can use to communicate with prospects, customers, employees, and colleagues. From websites to social media, email marketing to online video, manufacturers utilize Digital B2B Platforms to connect with their audiences throughout every phase of their online decision journey.

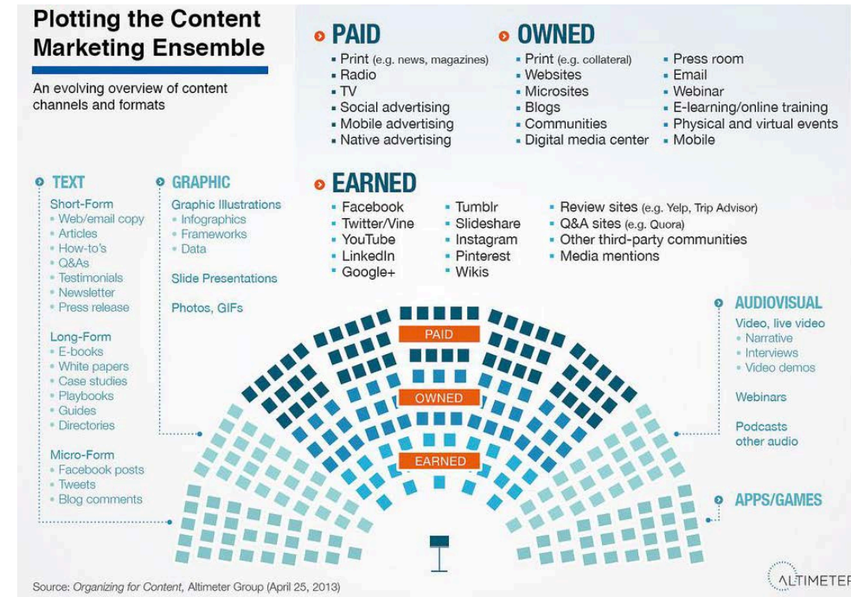
Please refer to the glossary in the Appendix for definitions of key digital B2B platform terminology that is utilized in this guidebook. Definitions provided for educational purposes as described by General Assembly unless otherwise noted.

Figure 2. Traditional vs. Digital Marketing via Bettiblue.com




## Understand the Technologies *(continued)*

*Figure 3: Plotting the Content Marketing Ensemble.*[1]



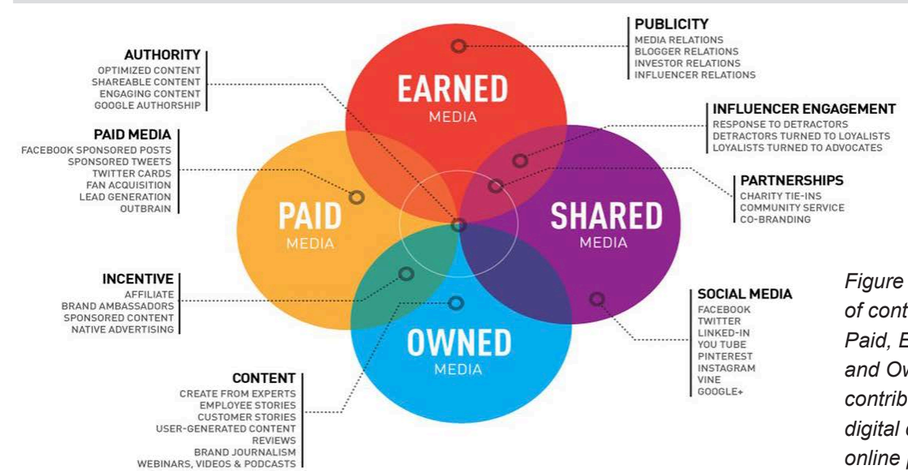




*Figure 4. "PESO model" of content marketing:* [2] *Paid, Earned, Shared, and Owned media contribute to a company's digital content mix on online platforms.*

1 https://c1.staticflickr.com/9/8390/8678279079_1507741120_b.jpg
2 Image from Mashable as accessed on https://thinkpyxl.com/blog/peso-model-pr.

## Understand the Technologies *(continued)*

**Additional Online Resources**

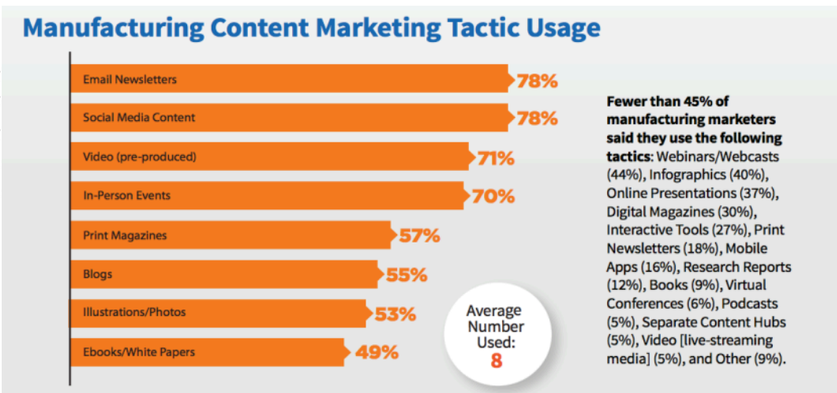
There are many online resources for review to deepen your understanding of Digital B2B Platforms, technologies, processes, opportunities, challenges, and more. We've outlined a few below:

- Industrial Marketing Today by Tiecas, Inc.: Updated daily, this website includes practical insights and actionable marketing advice for manufacturers, distributors, and engineering companies. You can also download an Industrial Marketing Guidebook from the site, as well as many other niche whitepapers to dive deeper into specific use cases and implementation of Digital B2B Platforms.[1]
- Digital Marketing for Today's Manufacturing Marketers from Kuno Creative: This e-book explains how inbound marketing and content marketing can help you form valuable relationships with leads that yield big benefits. Topics covered include: how to build effective online lead generation and demand generation campaigns; how to position yourself as a helpful partner to your customers; how to create and distribute engaging content that resonates with your audience; and how to establish your company as an industry thought leader.[2]
- The B2B Digital Marketing Guidebook from Kapost: In this guidebook, you'll learn tactics to: plan a collaborative B2B digital marketing strategy across channels, campaigns, and teams; create impactful, consistent, persona-driven content for every stage of the buyer's journey; distribute marketing content to your internal and external channels to gain traction with your buyers and enable sales; and optimize your digital marketing strategy based on data-driven insights to boost conversions and track the metrics that matter.[3]

## Identify Opportunities

Digital B2B Platforms offer many marketing and engagement opportunities to small and medium manufacturers (see Figure 5 for most common tactics used, below). These marketing channels contribute to great opportunities for manufacturers (see Figure 6 on following page). Examining specific opportunities, we have identified four key areas that can span all channels to bring greatest benefit to small and medium manufacturers: expanding reach; deepening engagement; closing sales; and collaboration with peers.

*Figure 5. Most commonly used B2B content marketing tactics by manufacturers in 2017.*

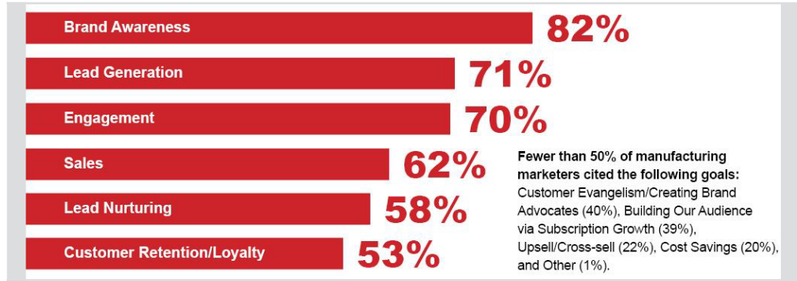



1 https://www.amazon.com/Industrial-Marketing-Today-Achinta-Tiecas/dp/B0089FMO4S
2 https://www.kunocreative.com/digital-marketing-for-manufacturers
3 https://www.kapost.com/portfolio/ebook-11/



## Identify Opportunities *(continued)*

*Figure 6. Manufacturers share their planned opportunity areas for digital content marketing in 2017.*




### Opportunity #1: Expand Reach

Digital B2B Platforms expand the reach of manufacturers that are looking to increase their customer base outside of the region and into national, even global, territories. The internet is "the great equalizer," bringing people closer together and connecting you to more customers than was ever possible through traditional marketing channels and communication outlets. As global competition grows for manufacturing contracts, and outsourcing appeals to many potential customers due to assumed cost-savings, expanding your reach and value proposition to new markets via a larger digital footprint has never been easier or more important.

### Opportunity #2: Deepen Engagement

Using traditional marketing and media, it's hard to gauge customer needs, expectations, and engagement throughout their decision journey in working their way toward signing the dotted line with your company. Using Digital B2B Platforms and the data they generate, you're able to peer into how your prospects and customers are interacting with your content from awareness, through purchase, to loyalty and advocacy. And, you're able to communicate with them two-way during their journey, further deepening engagement and fostering the connection needed to make a decision, land the contract, and garner repeat business.

### Opportunity #3: Close Sales

Digital B2B Platforms—like your website, e-commerce engine, online customer service, and online quote forms - allow your prospects and customers to complete their purchase and have their questions answered seamlessly as part of their digital lifestyle. Gone are the days when sales calls alone did the trick. Today, customers expect five-star service, regardless of their preferred methods of communication and payment. Find your own sweet spot based on customer feedback and behavior; it may lie somewhere in the middle between digital and traditional sales and service efforts.

### Opportunity #4: Collaborate with Peers

The fourth opportunity Digital B2B Platforms bring to manufacturers affects both external and internal audiences. By using platforms like email marketing, LinkedIn, customer relationship management (CRM) tools, and more, manufacturers are able to collaborate in real-time with their industry peers, employees, and even customers in certain use cases. This lends to quicker business deals through ease of networking, less time waiting for responses to critical questions, better ideas with more minds at the table, and greater customer satisfaction overall. When used within your own organization, Digital B2B Platforms increase productivity and strengthen employee relationships.

## Identify Opportunities *(continued)*

**Benefits & Use Cases of Digital B2B Platform Opportunities**

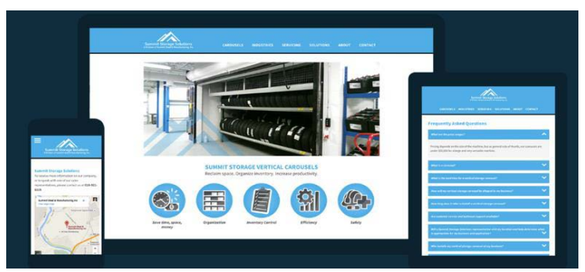
From website traffic to sales, qualified leads to higher conversion rates, there are many benefits to utilizing Digital B2B Platforms over traditional marketing and engagement methods. In this section, we'll examine the key benefits of utilizing Digital B2B Platforms in each of the four opportunity areas previously identified. Below, you'll also find a case example for each opportunity area that shows how a manufacturer was able to utilize Digital B2B Platforms to produce results throughout the purchase funnel.

### Opportunity #1: Expand Reach

- Engaging, authoritative website content (text, images, videos, et. al.) with the right keywords for your business increases your search engine optimization. This helps prospects and customers find you online from anywhere with internet access.
- Content production can be more cost-effective than traditional advertising and media buys in attracting the right audiences during their decision cycle.
- Guest blog posts or articles, and other forms of "sponsored content" or "influencer marketing" can also help expand your reach into new audiences, positioning you and your company as an expert in the manufacturing industry on a specific process, machine, product, etc.
- Common tactics include: search engine optimization (SEO); Google Adwords and other search engine and keyword advertising; social media advertising; e-commerce; online quotes; email.

**Case Example: Summit Steel Increases Inbound Leads 238% Using SEO Strategies**

Summit Steel manufactures custom steel parts, servicing each step in the process from blueprints to powder coating. They redesigned their website with the goal of allowing customers to see their full range of offerings, the scale of their operations, and their dedication to quality before ever setting foot in the Summit Steel facility. Additionally, Summit Steel launched a separate division to sell vertical storage carousels, a new stand-alone product.




At first Summit Steel's vertical storage product was given a page on the main corporate site, but it was confusing to users and holding back sales. Summit Storage was then given its own brand and web presence, with design and development of a separate website. Inbound leads quickly increased after launching the new Summit Storage site.

With a better site in place, Summit Steel looked to expand reach and increase quality leads through digital marketing. They launched a pay-per-click (PPC) and display advertising campaign targeted at procurement officers of large companies that Summit wanted as customers. Improvements to on-page SEO and paid ad campaigns led to favorable results in the first six months of the marketing campaign. Summit Steel became the #1 and #2 Google Search Result for "Steel Manufacturing Company" nationally during the run of its search advertising campaign. With improvements across the board, Summit Steel saw a 238% increase in quarterly leads YoY.[4]

4 http://brolik.com/casestudy/73



## Identify Opportunities *(continued)*

### Opportunity #2: Deepen Engagement

- Fostering dialogue between your sales and customer service teams and your customers can make the difference in closing a deal vs. them walking away confused or in deliberation. The greater connection you can build at every stage of their purchase decision, the increased likelihood of sale, amount of sale, and eventual customer satisfaction.
- Customers want to be met on the digital channels they're already using. By examining your customer data on platforms used, for how long, what content is being consumed, and click-paths, you will be able to pinpoint where to invest your marketing budget. You'll also uncover the places where your sales staff will be most effective, e.g. LinkedIn, email marketing, etc.
- According to Chief Marketer, internal communication and training are key to success in deepening engagement on digital channels. Whether your brand is reaching consumers through an email blast or on social media, every promotion and response needs to be consistent. To avoid poor customer service experiences, train your staff to respond the same way, every time, and to feel confident bringing in management before the situation publicly escalates online.[5]
- Common tactics used: online customer service, data-based targeting, geolocation, mobile marketing, online communities, social media, and customer relationship management (CRM) sales software.

**Case Example: AGCO Focuses on Connecting with Customers and Dealers on Social Media** [6]

Global agriculture manufacturer AGCO's social media strategy is aimed at connecting the businesses with farmers and machinery dealers, mainly through thought leadership. The company owns a range of brands including Massey Ferguson, Challenger and Valtra that deal in farm machinery around the world. As reported by Econsultancy, before launching its own social profile, AGCO analyzed the current behaviors of its target audience and found that they were already posting YouTube clips of themselves using the company's equipment. By actively engaging these users with a mix of informational and educational content the company has managed to attract 289,000 Facebook followers, 31,800 Twitter followers and almost 8,000 YouTube subscribers as of July 2017. The content includes weekly "tillage tips" and photos of the farming equipment in action.


AGCO also partners with its dealers to offer training and marketing tools to help them promote themselves. One way is through a widget that allows dealers to host and curate new content, such as blog posts, without having to invest in content creation themselves.

5 http://www.chiefmarketer.com/3-ways-digital-deepens-customer-relationships/
6 https://econsultancy.com/blog/63646-b2b-social-five-case-studies-from-brands-achieving-great-results#i.1040s4lf20cs2u

## Identify Opportunities *(continued)*

### Opportunity #3: Close Sales

- Concentrate on the opportunity to move your prospect or customer along their purchase decision journey at each phase. What digital platforms are they utilizing to inform their decision? What actions are they taking? Setting your sales team up to engage at those key moments keeps your customer headed toward the dotted line.
- E-commerce and mobile commerce solutions make it easier for your customers to do business with your company. Consider your options for making the sales quoting, payment, and customer service processes simpler using digital channels. Online forms are a low-cost and low-maintenance way to start, as well as using email to consistently follow-up with leads.
- Closing sales is as much about the initial sale as it is about fostering loyalty and repeat business. Digital platforms enable manufacturers to schedule follow-up on set intervals using the channels that their customers prefer. This saves time for your sales team as well as increases the relevancy of communications to contribute to increased customer satisfaction, positive word-of-mouth, and re-ordering when the time is right.
- Common tactics used: e-commerce website, mobile commerce, online quote, online contact forms, online customer service, informative website and other digital content, social media, and CRM/sales software.

**Case Example: IHS Increases Lead Volume and Sales Using Online Quote Wizard with Other Digital Tactics** [7]

Industrial Heat Sources (IHS) is one of four U.S. Leister Technology master distributors. The company provides sales and service of hot-air equipment to customers across six different vertical markets: roofing, sign and banner, flooring, civil engineering, process heat, and plastic fabrication.

Despite being hit hard by the financial crash of 2008, the company had remained profitable, but as of 2010, had seen little growth to recoup the lost revenue. Rather than hiring another sales professional to "knock on doors" as it had in the past, IHS launched a digital marketing campaign with PR20/20 that included an online sales and service tool created to help visitors identify the proper process heater or hot-air blower for their specific needs. The "Process Heat Wizard" asked users a series of questions, and used responses to automatically narrow down tool options from more than 100 to between 2-5. From here, users were encouraged to call or complete a lead form to speak to an IHS Leister certified representative and finalize their selection. As a result of its online quoting wizard, IHS territory lead volume (contact form submissions only) grew 243.5% YoY, contributing to a 27.3% sales increase over the same time period.

7 http://www.pr2020.com/blog/how-an-equipment-distributor-increased-traffic-leads-and-sales



## Identify Opportunities *(continued)*

### Opportunity #4: Collaborate with Peers

- Underlying any company's successful digital transformation lies a strong culture that values digital tools and the impact they have on relationship building—both in and out of the organization.
- Digital B2B Platforms contribute to increased employee productivity, idea generation, efficient problem-solving, and more when embraced by leadership as part of an ongoing commitment to continuing education.
- Collaboration is intensified with customers when utilizing Digital B2B Platforms as well. Using crowdsourcing communities, online feedback tools, and other forms of digital research and engagement, manufacturers are alerted to potential issues before they become costly to fix.
- Digital networking through platforms like LinkedIn or other relevant industry forums is also popular to build relationships with suppliers, vendors, and thought leaders to inspire innovation.
- Common tactics used: enterprise social networks; online/cloud collaboration tools; video conferencing; screen sharing software; social media; online chat; and other project management software.

**Case Example: Pirelli Opens Collaboration Opportunities for Improved Teamwork and Speed to Innovation** [8]

One of the world's top five tire manufacturers, Pirelli has 22 production plants globally with a commercial presence in 160 countries. In its quest for a majority share of the premium tire market, the company decided to improve collaboration across its organization.

Eager to explore an alternative to physical meetings, Pirelli partnered with Cisco to carry out a transformative networking assessment. This served as the basis for a network refresh, designed to give Pirelli one of the most advanced collaboration platforms in the industry, including a broad range of videoconferencing endpoints. Now, Pirelli employees can engage and innovate: anywhere, anytime, on any device. Operations are better connected, with richer interaction between sales and production. High-definition (HD) video has provided greater opportunity for virtual face-to-face meetings, resulting in stronger working relationships, cost control, and improved productivity. Staff can share desktops, content, and applications, and create cloud-based meeting spaces for project teams.

*Photo: Stock image of Cisco video conferencing product pictured, not actual Pirelli solution.*

8 http://www.cisco.com/c/dam/global/it_it/assets/pdf/pirelli_v2cs_-_final.pdf

## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to take in implementing strategies and tactics of Digital B2B Platforms within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing digital marketing, sales, and service is very different from traditional marketing methods that you may be accustomed to, and that the prospect of this degree of change to your sales funnel is daunting and frightening. It is our hope that, through the following content and previous look at the benefits of Digital B2B Platforms, you'll feel more comfortable exploring how you can utilize these technologies to better reach your customers, on their digital terms, to ultimately increase your product and service sales.

**Change Management: Building the Case Requires a "Test-and-Learn" Approach**

For most small and medium manufacturers, the prospect of adopting digital platforms into your marketing and sales mix seems risky, as it bucks the status quo and requires learning new technologies and procedures to remain relevant in a digital age. Only through experimentation, learning, and failing fast, can you quickly gain new expertise and experience that will benefit your company in years to come. It is new technologies, like many Digital B2B Platforms, that are shifting the very marketing and customer engagement structure of the manufacturing industry. New strategies and tactics are emerging, and the only way to survive is to be proactive in your adoption of digital marketing in ways that fit into your current culture and align with your business growth goals.

There are many ways for you to get started along the path to utilizing Digital B2B Platforms. Use the change management tips below to make the case for change and immediately begin proving results:

- Understand the business value of each individual digital B2B platform, and set goals accordingly. Use our metrics outlined at the end of this section as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating digital platforms into your benchmarks out of the gate. Focus on one or two main use cases first before building complexity.
- Focus on getting every employee on board with the benefits of Digital B2B Platforms through peer education. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of digital platform initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with digital technologies and benefits. Visit the Find Help section for more education resources and tips.
- Keep communication lines open during the trial-and-error portion of experimentation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to successfully implementing new engagement strategies on Digital B2B Platforms. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies. Breed risk-taking early.



## Build the Business Case & Begin Implementation *(continued)*

Part of change management also lies in understanding and planning for the challenges you will encounter in integrating Digital B2B Platforms into your existing operations. Below are three challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

- Challenge 1: Time commitment and prioritization. Many manufacturers, especially those small and medium in size, find it difficult to allocate precious time to digital marketing in lieu of other pressing priorities. In order to achieve results from Digital B2B Platforms, it takes commitment from both leadership and those responsible for implementation. Start with part-time allocation of one or two employees, and grow from there.
- Challenge 2: Strategic oversight and education. Digital B2B Platforms must be an integrated cog into a manufacturer's overarching growth strategy, contributing to increased awareness, sales, and more. This takes foundational education for not only those leading the charge but all employees who are responsible for living the "digital lifestyle" in order to better connect with customers. Visit the Find Help section for recommended educational partners.
- Challenge 3: Budget availability and measurement. Allocating budget to Digital B2B Platforms often goes hand in hand with measuring its impact. Why invest if you benchmarks for returns? Use the key performance indicators in the Metrics section on p. 19 as a starting point for integrating Digital B2B Platform metrics into your company's overarching strategic goals.

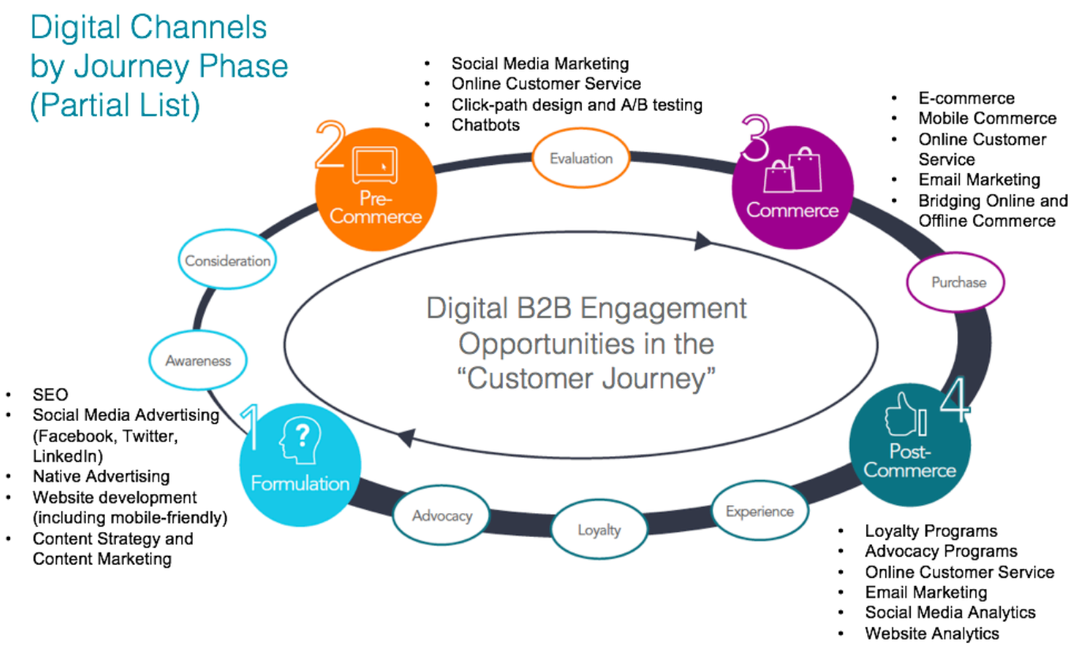
**Processes and Frameworks for Implementing Digital B2B Platforms**

Integrating Digital B2B Platforms into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks below to jumpstart your efforts. The frameworks in this section are presented to aide in your high-level strategic prioritization of Digital B2B Platforms, and we recommend you search out specific frameworks for each platform and tactic chosen to guide your implementation.

## Build the Business Case & Begin Implementation *(continued)*

**Framework 1: Digital B2B Engagement Opportunities in the "Customer Journey"** [9]

To reach your customers on Digital B2B Platforms, you must first understand where they are interacting with your company at each phase of the digital customer journey. These phases and a corresponding partial list of digital platforms are depicted below, with another version shared in Fig. 3 earlier in the guidebook. By beginning here, you'll save time and money in investing in the right platforms that actually reach your customers on their digital terms.




Ask yourself these questions when filling in your customer journey map:

- What digital channels do my customers use for research and decision-making when they realize they have a manufacturing need? Where do they go to find out more?
- How often do they visit their go-to digital channels, and for how long?
- How do they use each platform during the purchase decision cycle (what action is completed at each step)?
- What devices are used to take the customer from awareness through advocacy

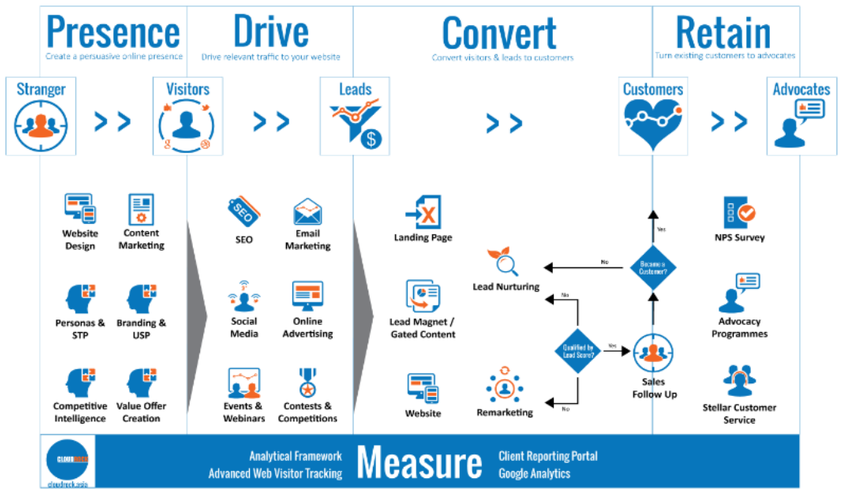
9 Workflow adapted from Altimeter Group report, "The Inevitability of a Mobile-Only Customer Experience." Szymanski, Jaimy and Brian Solis. 2015



## Build the Business Case & Begin Implementation *(continued)*

**Framework 2: Digital Marketing Framework from CloudRock** [9]

Here's another view that you may find helpful in planning and prioritizing your Digital B2B Platform use to turn prospects into leads, leads into customers, and customers into advocates.




**Resources Needed: Technology & Staffing**

Resources required to manage and implement strategies within Digital B2B Platforms will vary by the use cases you've established and which platforms you've prioritized. For example, utilizing digital platforms for search engine advertising to increase awareness will yield a different cost structure than planning to use social media as a replacement for all customer service requests. As previously outlined, you must create a strategic plan for how Digital B2B Platforms will augment or replace your current marketing, sales, and engagement processes in the recommended opportunity areas before jumping the gun and investing in the latest "bright, shiny technology" or hiring unnecessary talent.

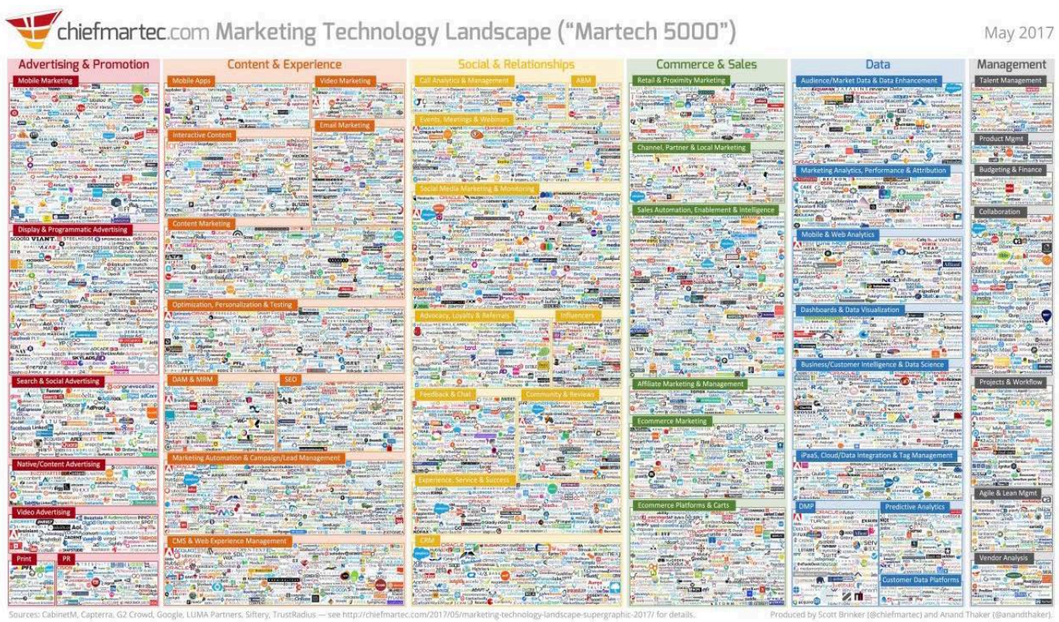
Use this general checklist to assist in the process of planning for your hard and soft costs:

- **Hardware:** Utilizing cloud-based Digital B2B Platforms typically doesn't require you to purchase any new hardware, as these platforms exist online with access through your internet browser. Some sales and analytics tools may require the purchasing of software, but it is rare that a hardware component be necessary. The exception lies in some e-commerce solutions that require a hardware solution in the form of a server to host cameras, and/or increased network support.
  Hardware purchases may be prudent for your company to foster a digital workforce, too. A manager or sales lead armed with a tablet to check product or machine specs and use it to collaborate across teams can be useful in growing your company's overall acceptance to digital technologies. This goes hand-in-hand with the "collaboration" opportunity area earlier addressed.

## Build the Business Case & Begin Implementation *(continued)*

● **Software:** Depending on the digital platforms you've chosen to utilize, there will be varying degrees of software needed. Many platforms offer "Software as a Service" or SaaS, which means that you can access the software in the cloud (often on a subscription-based model) to use from any computer with internet access vs. having to install it directly on your device. Other platforms are simply self-serve online, such as Google Adwords, social media platforms, email marketing, and many other online advertising options. The framework below is a low resolution image for a general representation. Go to the link in the footnote below for a full resolution version. Use this framework to begin deciding which software is right for your application(s) and continue research online. Each category offers a plethora of options, as you can see!

*Figure 7: Marketing Technology Landscape by ChiefMartec.com* [10]




● **Employees and Hiring:** Assess your current employees for skillsets in each opportunity area, as well as in individual platforms, to determine if expertise and interest exists. Most manufacturers have in-house talent that is ready and able to augment their current skills. However, some small and medium manufacturers have opted to hire new employees with online marketing, e-commerce, digital sales, and/or social media expertise to speed up the implementation process, as well as inject new approaches to innovation within the company. Work with the education and hiring partners listed in the Find Help section to find digital talent with experience, freshly graduated, or as a temporary intern (with, ideally, intent to hire).

10 http://cdn.chiefmartec.com/wp-content/uploads/2016/03/marketing_technology_landscape_2016.jpg



## Build the Business Case & Begin Implementation *(continued)*

**"Quick Wins" to Get Started with Digital B2B Platforms**

Take a page from the guidebooks of manufacturers that are already up-and-running with digital platforms by following a few of their tips to jumpstart your use of these technologies:

- Set up Google Analytics on your website. Work with your IT lead, web developer, or agency to install Google Analytics code on the back-end of your website. This will allow you to begin tracking a myriad of customer data points to inform your digital strategies, including: keywords visitors are searching to find your site; what pages they click through; how long they spend on each page; how many convert to contact you; and more. The service is free, and Google even offers a free beginner's course to help you understand the most important data points to track.[11]
- Talk to your customers. In addition to making use of all the customer data at your disposal, direct customer research through one-on-one interviews, focus groups, and surveys is critical to understanding their communication preferences, device ownership, digital platform and social network usage, and more. Rather than guess at what digital properties you should invest in, find out where your customers are and engage them on their terms.
- Give them options to contact you online. Consider your customers as digital customers in today's age. Digital customers want a simple way to contact you online, whether it's filling in an online lead form, emailing you directly, posting on your social media page, or messaging you or your sales and customer service teams through online chat. Give them one or more methods to reach out that fit seamlessly into their online experience.
- Ensure your website is "mobile-friendly." Since 2015 when Google and other search engines tweaked their algorithms, websites that do not display properly on mobile devices have been penalized in search engine results. Translation? If your site still isn't mobile friendly, it may not be showing up in prospect and customer searches for keywords related to your services and the products you manufacture.[12] The most popular website content management systems all have bolt-on solutions to make your site mobile-friendly, or you can incorporate responsive web design into an overhaul of the site. Talk to your IT lead, web developer, or agency about your options.
- Gain experience through events and free online resources. Turn to the Find Help section for educational and partnership resources. It's also a great time to consider digital platforms for your business, as there are many free webinars and reasonably priced online courses to get up-to-speed with your technologies of choice. These resources all help to build the business case if you need to "sell" the idea of using digital platforms to leadership within your company.

11 https://analytics.google.com/analytics/academy/course/6
12 http://www.practicalecommerce.com/make-your-website-mobile-friendly-now-3-ways




## Build the Business Case & Begin Implementation *(continued)*

**Metrics for Success: How to Measure Impact**

When setting your objectives for digital platforms, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance against traditional marketing, sales, service, and other customer engagement tactics, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

- Website (measure for each device that drives traffic, e.g. mobile, tablet, etc.): traffic; time spent on site; bounce rate; conversion rate; new vs. returning visitors
- Sales: lead quantity and quality; increased sales; repeat sales
- Search: higher SEO ranking for choice keywords
- Social media: increased engagement and sharing; brand sentiment
- Email: open rates, click-through rates
- Online advertising: impressions, click-through rates, conversions
- Operations: decreased cost of customer acquisition; increased employee productivity, ideas generated; efficiencies

## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to- implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Hiring Solutions:** Robert Half Technology specializes in placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

## Appendix

**Glossary: Digital B2B Platforms Terms**
*All definitions provided by online education source, General Assembly, unless otherwise noted.*[13]

**Analytics:** Information resulting from the systematic analysis of data or statistics. In digital marketing, analytics is the information resulting from systematic analysis of data gathered from marketing activity such as email marketing, landing page A/B testing, or Google Adwords purchases.

**Average Order Amount:** The amount of all orders divided by the total number of orders; used in digital marketing to help calculate the necessary reach, along with CTR and conversion rate.

**Banner Ads:** Also known as "display ads", these advertising units are images that advertisers place on known publishers' websites in order to attract or re-attract their target audience.

**Baseline:** An established level of normalcy; in digital marketing, for example, the normal or regular number of unique visitors per day to a website.

**Blogging:** From the term "web log", in which a user actively updates a visible section of a website in order to inform or attract users and customer on a regular basis.

**Channels:** A delivery mechanism; in digital marketing, a business's message is delivered via one or more marketing channel such as email, social media, blogging, advertisements, etc. 22

**Click Through Rate (CTR):** The percentage of the targeted audience that is exposed to the marketer's message that click on the link provided in the message and land on the marketer's web property.

**Conversion Rate:** The percentage of unique visitors to a website that are "converted" into customers, users, or leads.

**Digital Marketing Calendar:** A tool that provides for time-based structure and discipline for the digital marketer in planning, assigning, creating, and delivering content to the marketer's target audience.

**Digital Marketing Funnel:** A visualization of the calculations that starts with the total universe of targeted audiences, then measures those who click on a link from marketing content, the click through rate (CTR), the conversion rate, total conversions, order amount, and revenue.

**Distribution:** The means by which a product or service is delivered to its end user or customer.

**Earned Content:** Content not created by the marketer, but rather created and shared by fans of the marketer's message to the fan's social and other digital connections.

**Engagement:** In digital marketing, the term for user interaction with a particular piece of shared content: Likes, shares, comments on Facebook; RTs, replies, favorites on Twitter, and link clicks on all social media.

**Facebook Ads:** The program operated by Facebook that enables paying customers to use hyper-targeting via Facebook profile tags and traits to reach a certain specific audience via advertisements placed in the users' timeline.

13 https://generalassemb.ly/blog/digital-marketing-glossary/



## Appendix

**Frequency:** In digital marketing, how often a task is performed; for example, the frequency of a blog post or twitter update.

**Google Adwords:** The program operated by Google that enables paying customers to use hyper-targeting via Google Search Engine Results Page (SERP) to reach a certain specific audience via advertisements placed at the top and right sides of the search results.

**Google Keyword Planning Tool:** A free tool provided by Google within the Google Adwords interface that helps users find and plan which keywords to target with their advertising campaigns

**KPIs:** Key Performance Indicators

**Owned Content:** Content created or curated by the marketer in order to promote the marketer's message to the target audience; owned content typically consists of blog posts and social media posts and images, but should also be applied to any message that proceeds out of the marketer's company and into the target audience, such as email signatures.

**Page Views:** The number of times a web page or set of web pages are viewed during a given time period.

**Pages Per Visit:** The average number of pages viewed by a single visitor during a given time period.

**Paid Content:** Content pushed out by the marketer via any paid means such as Facebook ads, Google Adwords, Twitter Ads, or banner (display) ads.

**Persona:** The ideal compilation of all the traits of the "perfect" user or customer for a marketer's product or service.

**Retargeting:** The technology, driven by web browser cookies, that enables a marketer to continually put a digital message in front of a user who has visited that marketer's web property.

**Sales Cycle:** The time required for a sales conversion to be completed after the prospect initially becomes aware of the marketer's brand or product.

**SEO:** Search Engine Optimization – the practice of preparing a web property to be quickly, easily, and properly indexed by a search engine, usually Google.

**SERP:** Search Engine Results Page

**Time On Site:** The average time that a website visitor remains active on a particular website.

**Total Reach:** The total exposure (measured in web users or "eyeballs") of an advertisement or piece of content.

**Twitter Ads:** The program operated by Twitter that enables paying customers to use hyper-targeting via Twitter users' profile data to reach a certain specific audience via advertisements placed in the users' timeline. N

CHAPTER 6

# Data Analytics

## Data Analytics at a Glance

**What is "Data Analytics?"**

"Data Analytics" in manufacturing is the strategic use of data collected from a wide range of business areas (eg. supply chain, finance, sales, marketing, machine sensors, distributors, customers, vendors, and more) to inform product and operational decisions. Data can be generated from external or internal sources, or even machine-to-machine interactions via the "Industrial Internet of Things (IIoT)." When in aggregate, this data is often referred to as "Big Data," due to the large amount of information collected for analysis.

**Why do Data Analytics matter to the manufacturing community?**

Manufacturers are increasingly pressured to make decisions quickly, and even predictively, to retain product quality, achieve onsite safety standards, and remain competitive on national and global levels. Decision-making must be based on data. In order to make sense of all of a manufacturer's data sources and analyze them for action, companies must have a Data Analytics strategy. Data Analytics is a critical component of every innovative manufacturer's roadmap, informing decisions related to product development, supply chain optimization, sales and marketing spend, and other onsite efficiencies.

**What are the biggest opportunity areas?**

We have identified three key opportunity areas in Data Analytics for manufacturers (more information on each in the Identify Opportunities section on p.10):

- **Opportunity #1:** Product quality control. Collecting data from machine sensors allows manufacturers to see and correct problems quickly, often in near real-time (or even predictively!).
- **Opportunity #2:** Cost and operational efficiencies. Analyzing data throughout the supply chain, as well as other employee and operational data, contributes to lower costs, faster outputs, and easier long-term decision-making.
- **Opportunity #3:** Predictive demand forecasting. Better data yields more accurate demand forecasting as manufacturers are able to use smaller amounts of current data to predict responsive customer behaviors in the future.

**What are the business benefits of Data Analytics?**

Though dependent on the Data Analytics opportunity area(s) you pursue, manufacturers witness many benefits from implementing these technologies, including increased operational efficiencies, lower manufacturing costs, streamlined value and supply chains, continuous process and product improvements, less downtime, and greater nimbleness leading to competitive advantage. For a full list of metrics, refer to the Metrics for Success section near the end of this guidebook.

**Where can I find help to get started?**

There are agencies who can assist you with full digital strategies or specific implementations of tactics on digital platforms that you've prioritized. There are also many free online resources, as well as educational courses offered by universities and colleges. Go the Find Help with Expert Partners for a full list of resources to help jump start your use of Data Analytics to grow your business.

*Figure 1: Data Analytics Chapter Information Flow*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CHAPTER 6
# Data Analytics

## Understand the Technologies

In the first section, we take a closer look at the technologies that enable Data Analytics. You'll gain a better understanding of how Data Analytics can contribute to your company's digital technology and innovation strategy through diagrams, frameworks, and definitions of key terms used in the space. This section also details additional online resources for greater understanding.

Data Analytics in manufacturing is the strategic use of data collected from a wide range of business areas (eg. supply chain, finance, sales, marketing, machine sensors, distributors, customers, vendors, and more) to inform product and operational decisions. Data can be generated from external or internal sources, or even machine-to-machine interactions via the "Industrial Internet of Things (IIoT)." When in aggregate, this data is often referred to as "big data," due to the large amount of information collected for analysis.

According to Forbes, 68% of manufacturers are investing in Data Analytics strategies.[1] These Data Analytics strategies are often combined with the use of predictive analytics to reveal potential supply chain, operational, or other weaknesses before they become an issue. Data Analytics is also used to streamline processes, create leaner operations, and predict demand.

Many data sources contribute to a robust Data Analytics strategy within the manufacturing environment. These may include:

- ERP system (learn more about ERP in the ERP Guidebook).
- Machine-to-machine sensor data (includes location, weight, temperature, vibration, flow rate, humidity, balance, and more[2])
- Operational data from distributors, suppliers, vendors, employees, customers, and other areas of the supply chain.

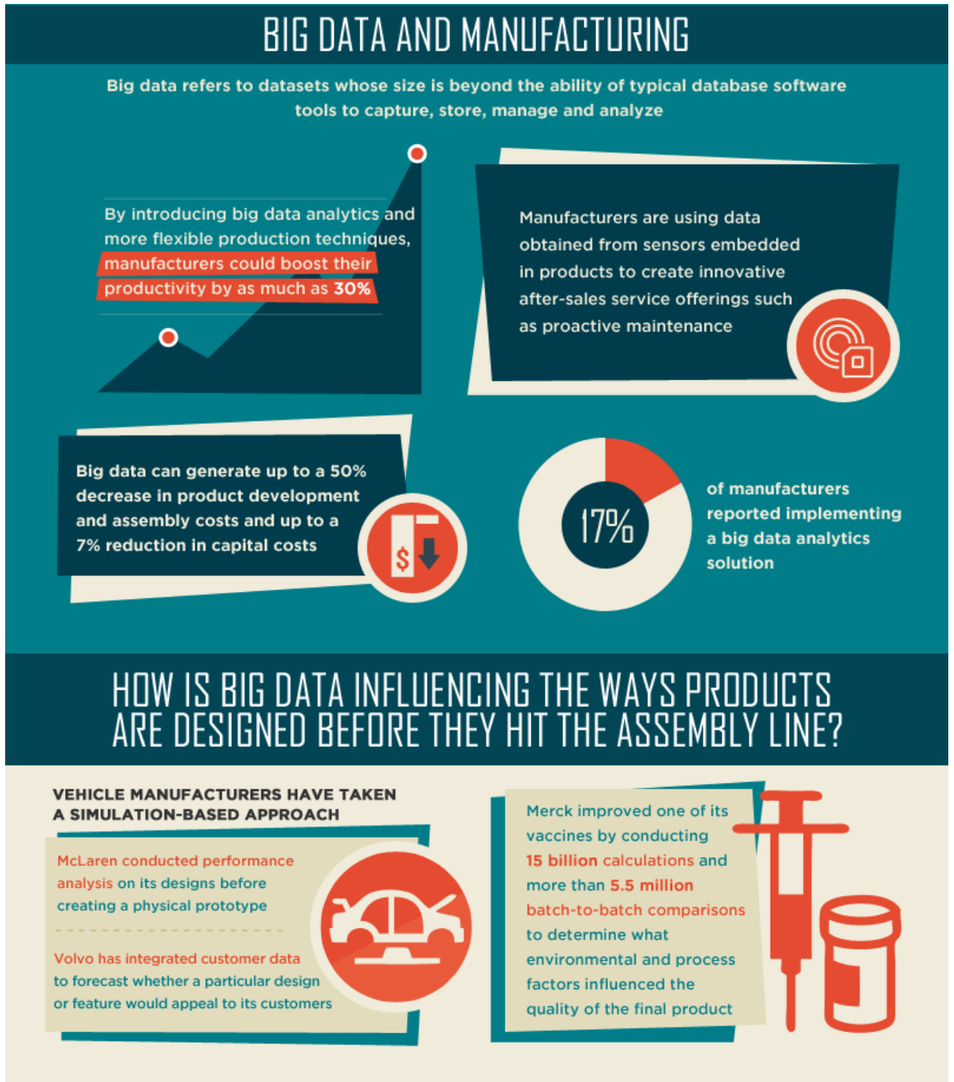
**Glossary: Data Analytics Terms**
Please refer to the glossary in the Appendix at the end of this guidebook for definitions of key Data Analytics terminology that is utilized in this guidebook.

1 https://www.liaison.com/blog/2017/09/20/big-data-analytics-tools-manufacturing-industry/
2 http://www.infor.com/content/industry-perspectives/big-data-in-manufacturing.pdf



## Understand the Technologies *(continued)*

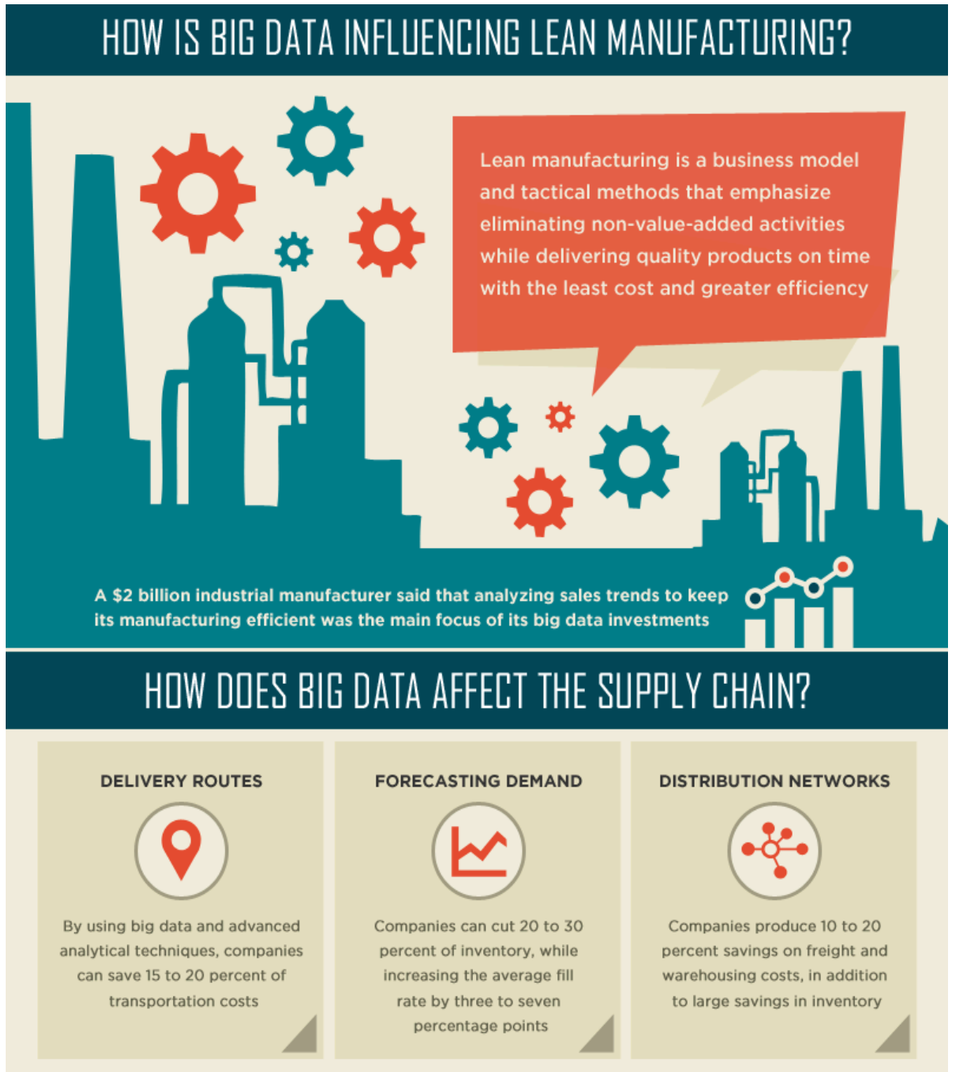
*Figure 1. How Software and Big Data Are Changing Manufacturing in the United States (abridged), via Ohio University*[3]




3 https://onlinemasters.ohio.edu/wp-content/uploads/2016/06/Big-Data-Changing-manufacturing-R5.png

## Understand the Technologies *(continued)*

*Figure 1 continued*




## Understand the Technologies *(continued)*

*Figure 1 continued*

## Understand the Technologies *(continued)*

*Figure 2. Data Sources Within the Manufacturing Ecosystem, via iCrunchData* [4]

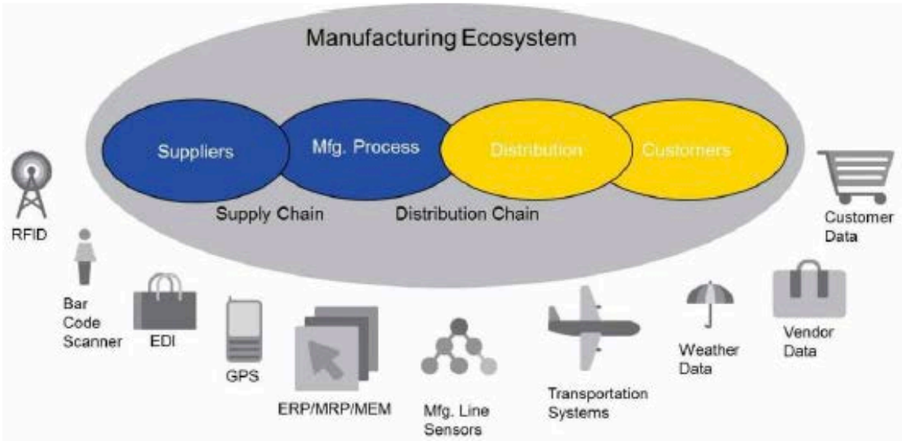
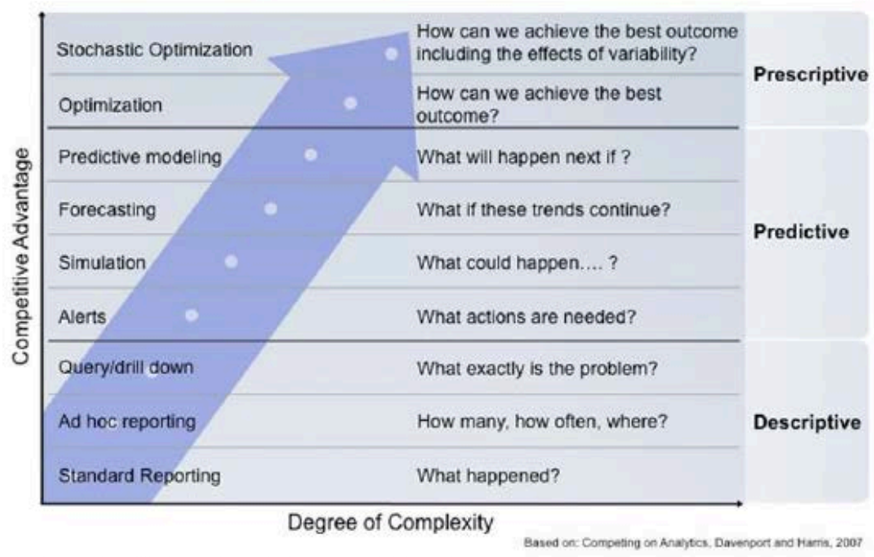



*Figure 3. Types of Analytics, via Competing on Analytics. Presented in a Quad Cities Chamber of Commerce Data Analytics user group meeting.*[5]




4 https://icrunchdata.com/blog/423/why-most-manufacturers-are-not-data-ready/
5 Graphic presented in John Deere presentation, adapted from "Competing on Analytics," Davenport and Harris 2007.



## Understand the Technologies *(continued)*

**Additional Online Resources**

There are many online resources for review to deepen your understanding of Data Analytics strategies, programs, software, applications, technologies, use cases, opportunities, challenges, and more. We've outlined a few below:

- Guide to Big Data in Manufacturing, via InsideBigData. https://insidebigdata.com/white-paper/insidebigdata-guide-to-big-data-for-manufacturing/. This guide provides strategic direction for enterprise thought leaders in the manufacturing sector in leveraging the big data technology stack.
- Industry 4.0: Building the Digital Enterprise, via PwC. https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf. In this report PwC describes how Industry 4.0 facilitates a complete value chain transformation for manufacturers, beginning with a foundation of robust, enterprise-wide Data Analytics capabilities.
- Big Data in Manufacturing: A Compass for Growth, via Infor. http://www.infor.com/content/industry-perspectives/big-data-in-manufacturing.pdf/. In this whitepaper, you'll learn more about the drivers behind Data Analytics and big data movements; sources for data; actionable items for manufacturers; key challenges; and how to move forward with a Data Analytics program.

## Identify Opportunities

Data Analytics offers many opportunities to small and medium manufacturers. We have identified three key areas that can bring greatest benefit to small and medium manufacturers: product quality control, cost and operational efficiencies, and predictive demand forecasting.

### Opportunity #1: Product Quality Control

Utilizing machine and line sensors throughout production, manufacturers can monitor product quality data and make changes in real-time. With a strong Data Analytics program and software solution, product defects are spotted more quickly and sorted, leading to better margins and less discard. Resources are managed more efficiently, and product failures can even be predicted in some instances. Assembly lines become more efficient, batch quality is increased, regulatory compliance in design and practice is upheld, and waste reduced. Manufacturers witness similar benefits from monitoring machine-level data for potential issues and course-correcting before disruption.

### Opportunity #2: Cost and Operational Efficiencies

Implementing a Data Analytics programs allows manufacturers to reduce costs throughout their supply chain and increase operational efficiencies. By monitoring their machinery, production lines, assembly, warehousing, packaging, inventory, and transportation, they're able to make decisions that reduce costs, waste, and downtime. Combined with the "Industrial Internet of Things (IIoT)," Data Analytics can also positively impact maintenance and repair schedules and employee workloads. Production floor error-rates and employee performance data is easily monitored, giving manufacturers the quick feedback mechanisms needed to implement changes quickly and effectively.

## Identify Opportunities *(continued)*

### Opportunity #3: Predictive Demand Forecasting

Traditionally, manufacturers annually predict demand based on historical data (often YoY). But, with a robust Data Analytics program, they can identify trends or anomalies based on recent data capture. This leads to more accurate demand forecasting and the ability to alter operational components to course-correct before resources are wasted on product that will ultimately be warehoused. Operational efficiencies can also be achieved when demand is forecasted off of hypothetical "what-if" production scenarios, tested fluidly based on continuously collected data.

**Benefits and Use Cases of Data Analytics Opportunities**

In this section, we'll examine the key benefits of utilizing Data Analytics in each of the three opportunity areas previously identified. Below, you'll also find a case example for each opportunity area that shows how a manufacturer was able to utilize Data Analytics to produce results.

**Opportunity #1: Product Quality Control**

- Improved product safety: Rather than simply discarding low-quality products after production, many manufacturers utilize data sensors and scans throughout the production process to sift through products and determine which are not fit for shipment and why. The data leads to continuous product improvements for quality and safety as well as lower waste over time.[6]
- Lower product and machine failure rate: Data Analytics combined with the IIoT helps manufacturers analyze product failures before customers experience them and machine failures before they disrupt operations or cause potential workplace inefficiencies. Machines that continuously capture data for analysis and reporting contribute a culture of preventative maintenance, allowing manufacturers to respond quickly to signals of breakage, torn belts, reduced product demand and/or load, and more.[7]
- Reduced product development errors: When engineering modeling is combined with analytics-based computer simulations, errors are predicted, reduced, and corrections can be made before a product or tool even goes into production. Test data can also improve productivity in helping streamline processes when utilized in a rapid test-and-learn environment.
- Ensure regulatory compliance: According to MSR Cosmos, Data Analytics can help detect, "digressions or patterns, or even the slightest hints of non-conformity to standard procedures or protocols."[8] This real-time monitoring ensures regulatory standards are met without material waste or the need for reconfiguration.

6 https://tech.co/big-data-analytics-manufacturing-2016-12
7 http://cerasis.com/2016/03/16/predictive-analytics-in-manufacturing/
8 https://www.msrcosmos.com/blog/challenges-of-the-manufacturing-industry-big-data-analytics/



## Identify Opportunities *(continued)*

**Case Example: Intel Improves Product Quality with Big Data and Automation Strategy in its "Smart Factories"**[9]

Intel's vision for smart manufacturing is based on the importance of big data and automated process control in ongoing analysis and decision-making. Utilizing the data captured from its factory automation processes, Intel's engineers are able to identify opportunities for improved efficiency, velocity, and quality. For example, in producing silicon wafers, Intel must adhere to strict quality standards, including traceability, that require consistent data capture and measurement monitoring during production. Throughout its factories, historic and current data are used to plan and implement new or improved automation for better quality, cycle time, and yield. Engineering analysis targets product quality improvements and increases equipment performance over time. When processes exceed statistical thresholds, production tools are taken offline and materials are rerouted or put on hold for quality validation. Intel's full case study details more benefits of automation and big data.

**Opportunity #2: Cost and Operational Efficiencies**

- Decreased warehousing and inventory costs: Acting on real-time insights into inventory throughout the supply chain, including delivery route optimization, can help dramatically reduce warehousing costs and increase profit margins.
- Improved employee efficiency: Utilize big Data Analytics to study error rates on the production floor and assess specific areas where employees are excelling and under-performing. This leads to not only improved employee efficiency, but better-informed management, engineers, and operators.[10]
- Quickly implement changes: When data is flowing throughout your organization and accessible to those who can act on it, your workforce is empowered and enabled to implement changes quickly and effectively. This increases workplace efficiency and collaboration as well as catches operational issues before they become downtime-inducing problems.
- Identify bottlenecks: Data Analytics can be used to pinpoint specific tasks throughout the manufacturing process or supply chain to assess components, processes, or employees that may be contributing to bottlenecks. In turn, managers can then create contingency plans to minimize the effect of potential inefficiencies.[11]

**Case Example: Versatech Improves Manufacturing Quality, Efficiency, and Performance with Data Analytics Strategy and Inter-departmental Collaboration**[12]

When Versatech realized their paper tracking system was no longer effective, the company sought a way to cut costs and improve manufacturing performance with a digital Data Analytics strategy. Partnering with software provider SensrTrx, Versatech began collecting and distributing data to the quality, engineering, maintenance, and production staff who could use it to enhance the efficiency of their operations, reduce overtime work, decrease downtime, and improve machine utilization. Versatech saw these measureable results in less than three months of implementing its Data Analytics program. This resulted from not only collaboration, but also less data entry and real-time access to the information needed to make critical decisions. Versatech was able to see downtime and scrap rates as they were occurring, correlate it with known causes, and improve "uptime" in the process.

9 https://www.intel.com/content/dam/www/public/us/en/documents/best-practices/using-big-data-in-manufacturing-at-intels-smart-factories- paper.pdf
10 https://tech.co/big-data-analytics-manufacturing-2016-12
11 https://www.liaison.com/blog/2017/09/20/big-data-analytics-tools-manufacturing-industry/ 12 https://www.sensrtrx.com/wp-content/ uploads/2017/07/ Manufacturing-Analytics-Case-Study-Versatech.pdf
12 https://www.sensrtrx.com/wp-content/uploads/2017/07/Manufacturing-Analytics-Case-Study-Versatech.pdf

## Identify Opportunities *(continued)*

### Opportunity #3: Predictive Demand Forecasting

- Reduce stock levels: Utilizing predictive analytics as part of a Data Analytics strategy, manufacturers can reduce both raw materials and finished goods stock levels. This ultimately improves quality of service due to better product availability and reduced delays. Manufacturers can more quickly recognize anomalies in the supply chain and erratic demand patterns as well.[13]
- Rapid test-and-learn: Operational efficiencies are achieved when manufacturers can quickly act on the data they gather in running test scenarios. If A is changed, what happens to B in real-time? This provides insight into everything from labor costs to inventory prices that may shift as a result of production changes.[14]
- Better understand customer purchase behaviors: With consistently collected data at your fingertips, it's easier to analyze buying patterns over time and adjust supply as necessary. Data Analytics allows manufacturers to make decisions based not only on what they'll likely ask for in the future, but also what they're asking for now.

**Case Example: Trenton Corporation Meets Product Demand and Predicts Production Capacity with Data-driven Forecasting Model**[15]

Trenton Corporation manufactures anti-corrosion products for the pipeline industry and is challenged by a limited production capacity to make all of its offerings – as well as fluctuation in demand for those offerings. They sought a solution to quickly and systematically allocate production capacity each month to meet demand while also avoiding excessive labor or inventory costs. With input from sales data, Trenton Corporation worked with Simafore software solutions to build a high-quality forecasting model that provides monthly and quarterly demand projections for a range of products as well as historical trends and break-downs of input data into key segments as chosen by the customer. The results: 90% reduction in planning time, reduced reliance on experience and knowledge of a single person, and confidence in proactive planning by eliminating human error and bias.

## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to take in implementing Data Analytics technologies within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing a Data Analytics program is very different from traditional measurement and innovation processes that you may be accustomed to. We also understand that the prospect of this degree of change is daunting! It is our hope that through the following content and previous look at the benefits of Data Analytics, you'll feel more comfortable exploring how you can utilize these technologies to achieve efficiencies throughout your company.

13 https://www.lokad.com/inventory-forecasting-for-manufacturing
14 https://www.microstrategy.com/us/blog/stories/3-ways-data-analytics-impacts-manufacturing
15 http://resources.simafore.com/hs-fs/hub/64283/file-2491160174-pdf/2015_Updated_Documents_-_Rapidan/Simafore-Production_Planning_Analytics_2014.pdf?t=1496839460448



## Build the Business Case & Begin Implementation *(continued)*

**Change Management: Building the Case Requires Data and a "Test-and-Learn" Approach**

For most small and medium manufacturers, the prospect of launching a Data Analytics program seems risky, as it bucks the status quo and requires learning new technologies and procedures to remain relevant in a digital age. Only through experimentation, learning, and failing fast, can you quickly gain new expertise and experience that will benefit your company in years to come. It is new technologies, like Data Analytics, that are shifting the manufacturing industry. New strategies and tactics are emerging, and the only way to survive is to be proactive in your adoption of Data Analytics in ways that fit into your current culture and align with your business growth goals.

There are many ways for you to get started along the path to utilizing Data Analytics. Use the change management tips below to make the case for change and immediately begin proving results:

- Understand the business value of Data Analytics separately, and set goals accordingly. Use our metrics outlined later in this guidebook as well as your own research to set realistic expectations of how you will measure the impact and success of integrating Data Analytics into your existing manufacturing technologies, equipment, and processes. This will help in resource planning if you're measuring the right benchmarks out of the gate. Focus on one or two main use cases first before building complexity.
- Focus on getting every employee on board with the benefits of Data Analytics through peer education. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of digital platform initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse-mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with digital technologies and benefits. Turn to the Expert Partners section for education resources and tips.
- Keep communication lines open during the trial-and-error portion of experimentation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to successfully implementing new Data Analytics strategies. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies. Breed risk-taking early.

Part of change management also lies in understanding and planning for the challenges you will encounter in integrating Data Analytics into your existing operations. Below are four challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

- **Challenge 1: Understanding and managing the data at your disposal.** Every manufacturer collects troves of process data that is most often utilized for tracking purposes, not improving operations. The challenge becomes investing in systems and employees with expertise to optimize their existing data, centralizing it, and analyzing it efficiently in order to glean actionable insights.[16] More on hiring later.
- **Challenge 2: Taking action based on events not time-based milestones.** Most manufacturing runs are based on demand signals that feed into an ERP system, with no randomness, with each moving part in the production line based on a time trigger. This is a predictable process that thrives on stability, not data-based events that can be random. Manufacturers that base actions \off of data signals respond to customer demand, machine performance, and other events. This dramatically shifts how data is collected and how systems are engineered to maintain stability.[17]

16 https://www.mckinsey.com/business-functions/operations/our-insights/how-big-data-can-improve-manufacturing
17 https://hbr.org/2016/05/the-biggest-challenges-of-data-driven-manufacturing

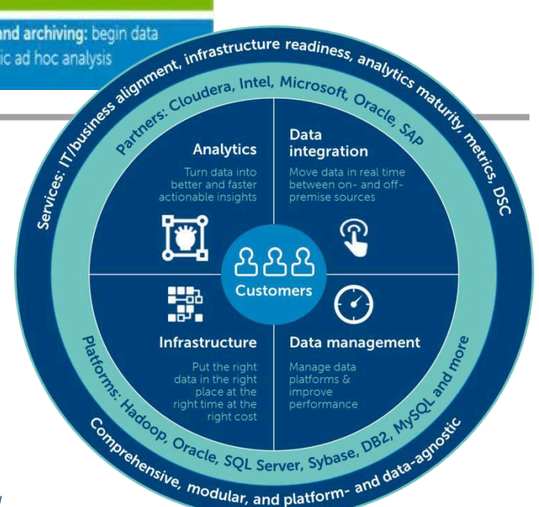
## Build the Business Case & Begin Implementation (continued)

- **Challenge 3: Integrating Data Analytics with legacy systems.** There are multiple systems within every factory, collecting its own data. Information is passed from these systems to an ERP solution, or even among systems in some mature cases. Challenges arise when legacy systems don't have, "well-defined interfaces, documentation is scarce, or software engineers are not available anymore," according to Harvard Business Review.
- **Challenge 4: Opening your factory to security risks.** The promise of receiving, marrying, and analyzing data for rapid action within your facility is exciting, but it is not without its security risks in data collection, storage, and transmission practices. Systems can be exposed to attackers, especially if security precautions are not taken when data is transmitted from sensors and machines via the IIoT.[18]

**Processes and Frameworks for Implementing Data Analytics**

Integrating Data Analytics into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks on the following pages to aid in your high-level strategic prioritization of Data Analytics. We recommend you search out specific frameworks for each technology and use case chosen to guide your implementation.


*Framework 1: Maturity Pyramid for Adopting Big Data in Manufacturing, via Inside Big Data.*[19]




*Framework 2: The Four Components of Big Data Management in Manufacturing, via Inside Big Data.*[20]

18 Ibid.
19 https://insidebigdata.com/2015/04/22/adopting-big-data-for-manufacturing/
20 https://insidebigdata.com/2015/04/16/big-data-technology-for-manufacturing/





## Build the Business Case & Begin Implementation (continued)

**Resources Needed: Technology and Staffing**

Resources required to implement Data Analytics technologies will vary by the use cases you've established. For example, concentrating on better product quality will yield a different cost structure than using data for predictive inventory forecasting. As previously outlined, you must create a strategic plan for *how* Data Analytics will augment or replace your current processes in the recommended opportunity areas before jumping the gun and investing in technology solutions.
Use these recommendations to assist in the process of planning for your hard and soft costs:

**Hardware and Software**: In implementing a Data Analytics strategy, especially where big data is concerned, hardware and software technologies go hand-in-hand. Acquire one without the other, and you're either unable to securely store the data you're gathering or unable to extract actionable insights or value from the complex data you've collected. Data Analytics systems require many components that contribute to their overall "workload," including ERP, CRM, SQL, and other data sources as well as processes of data validation, cleaning, transforming, aggregating, and loading to extract and organize data prior to its transition to a data warehouse. From there, companies use a variety of software to analyze, mind, visualize, and report on the data.

**Other hardware considerations include:**

- **Data warehousing –** Where will you store the data you're collecting? This is one of the first and most important decisions. Assess how much data you're gathering, from what sources, and where computing will take place. Costs of data warehousing and datamarts vary by amount stored.
- **Sensors** – Automate the collection of data on machines, lines, shipping, etc. Often connected to other sensors and technologies through the IIoT.
- **Mobile devices** – For employee use in on-the-job monitoring and reporting to give easy and quick access to data for decision-making.

Software selection requires an in-depth look at your Data Analytics use cases, the actions you hope to take based on the data, how much data you're collecting, what components you'll be analyzing, the velocity at which you'll be extracting insights, and how the data is being combined with other sources. According to criteria set forth in Industry Week, the goal of an effective Data Analytics software platform is to provide features that allow engineers and analysts to quickly interact with data without acquiring IT expertise. Look for the following in your deployment:

- Accessibility via a browser or app to provide a web-based interface
- Usability by process experts and manufacturing engineers
- Lightweight deployment that does not require data duplication
- Designed for time series data analysis in process plant and other manufacturing applications
- Features that apply machine learning and other advanced algorithms to simplify analysis
- Interactive, visual representation of data and results
- Ability to quickly iterate, and to combine one result with another
- Ease of collaboration with colleagues within and across companies [21]

Data Analytics software choices are plenty, with the most often-used resources included in Fig. 4 to begin forming your consideration set.

21 http://www.industryweek.com/technology/creating-value-big-data

## Build the Business Case & Begin Implementation *(continued)*

*Figure 4. Top Data Tools for Extraction, Storage, Cleaning, Mining, Visualizing, Analyzing and Integrating, via Import.io.*[22] *More information on each outlined on their site, including pricing.*

| CATEGORY | SOFTWARE | CATEGORY | SOFTWARE |
|---|---|---|---|
| Data Storage & Management | Hadoop | Data Visualization | Tableau |
| | Cloudera | | Silk |
| | MongoDB | | CartoDB |
| | Talend | | Chartio |
| | Quantum | | Plot.ly |
| Data Cleaning | OpenRefine | | Datawrapper |
| | DataCleaner | | Ideata |
| | Trifacta | | Google Chart |
| Data Mining | RapidMiner | Data Integration | Blockspring |
| | IBM SPSS Modeler | | Pentaho |
| | Oracle Data Mining | | Stitch |
| | Teradata | | Magento |
| | R-Project | | Informatica |
| | OptiMove | Data Collection | Import.io |
| | Kaggle | | |
| Data Analysis | Qubole | | |
| | BigML | | |
| | Statwing | | |
| | Domo | | |
| | ThoughtSpot | | |

**Employees and Hiring:** Assess your current employees for skillsets and experience in Data Analytics or data science to determine if expertise and interest exists. If not, you may opt to hire new employees with Data Analytics expertise to speed up the implementation process, as well as inject new, passionate approaches to innovation within the company.

Work with the education and hiring partners listed in the next sections to find Data Analytics employees with experience, or those that are freshly graduated, or as a temporary intern (with, ideally, intent to hire). Look for analytical capabilities and training in spotting patterns and drawing actionable insight from large quantities of information, advises McKinsey and Co.[23] As Data Analytics programs can be quite complex, also consider partnering with an expert consultancy to assist with strategy and implantation.

22 https://www.import.io/post/best-big-data-tools-use/
23 https://www.mckinsey.com/business-functions/operations/our-insights/how-big-data-can-improve-manufacturing



## Build the Business Case & Begin Implementation *(continued)*

When assessing existing or potential employees, consider their key competencies for the seven criteria in Fig. 5, below:

*Figure 5. Building a World-Class People Analytics Team: Seven Key Competencies Needed for Long-term Success. Presented in a Quad Cities Chamber of Commerce Data Analytics user group meeting. Via David Green, IBM.*[24]

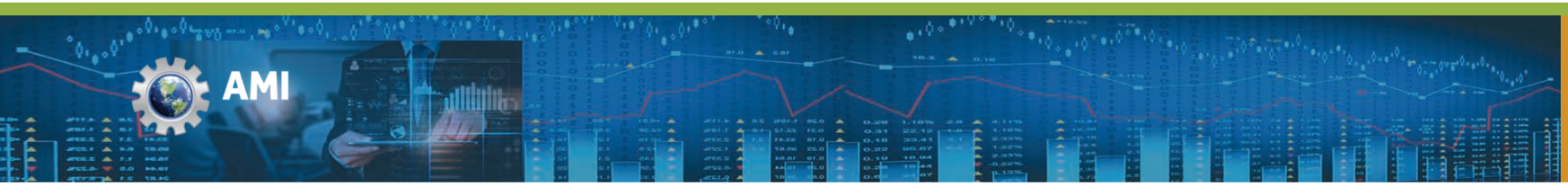
| Have | Be Good At | Have | Master Techniques Of | Have Strong | Master | Have Expertise In | | |
|---|---|---|---|---|---|---|---|---|
| Good Data | Story Telling | Business Acumen | Visualization | Psychology Skills | Numbers & Statistics | Change Management | = | Maximum Impact |
| × | Story Telling | Business Acumen | Visualization | Psychology Skills | Numbers & Statistics | Change Management | = | Unable to perform analytics |
| Good Data | × | Business Acumen | Visualization | Psychology Skills | Numbers & Statistics | Change Management | = | Unable to get message across |
| Good Data | Story Telling | × | Visualization | Psychology Skills | Numbers & Statistics | Change Management | = | Focus on the wrong problems |
| Good Data | Story Telling | Business Acumen | × | Psychology Skills | Numbers & Statistics | Change Management | = | Boring and confusing output |
| Good Data | Story Telling | Business Acumen | Visualization | × | Numbers & Statistics | Change Management | = | Bias and unable to interpret results |
| Good Data | Story Telling | Business Acumen | Visualization | Psychology Skills | × | Change Management | = | Poor analysis |
| Good Data | Story Telling | Business Acumen | Visualization | Psychology Skills | Numbers & Statistics | × | = | Unable to turn insights into outcomes |

**"Quick Wins" to Get Started with Data Analytics**

Take a page from the best practices of other manufacturers that are already up-and-running with Data Analytics programs, by following a few of tips to jumpstart your use of these technologies.

- **Tip 1: Understand the data you already have.** It can be tempting to expand your Data Analytics strategy into sources that don't even exist yet, like line sensors or machine-to-machine interfaces. However, you likely have multiple data streams you're already collecting (especially in ERP), but may not be connecting or analyzing in real-time. Spend time conducting a data audit as a starting point to see if you have the minimum amount of data required to apply analytics – typically, at least 15 data sets per influencing variable. [25]
- **Tip 2: Don't boil the ocean.** Focus on one use case or business function first to produce more relevant results (quicker and cheaper!) than an enterprise-wide approach. You'll generate value early and often when implementing Data Analytics in smaller initiatives – contributing to more momentum and support throughout. Roll out your strategy in phases that align with your company's strategic priorities over the coming three years.[26]
- **Tip 3: Determine what person or department should lead the Data Analytics program.** According to advice from experts at Bosch, start by deciding what function makes the most sense to take charge. Start by holding a data analytics orientation workshop for management to cover the basics of Data Analytics. That will help uncover if there is already an understanding of Data Analytics within the company (and a natural leader will emerge), or if hiring someone in IT or data science is necessary. Either way, you'll need buy-in from management, which starts in knowledge-sharing. [27]
- **Tip 4: Invest in seasoned talent and necessary infrastructure.** The foundation of any Data Analytics strategy lies in not only IT solutions but also experienced analysts who can extract value from troves of data. One begets the other. Invest in your team and your technology infrastructure, and consider other professional consultants to help with initial strategy and set-up.

24 https://www.linkedin.com/pulse/what-constitutes-best-practice-people-analytics-david-green
25 https://blog.bosch-si.com/categories/manufacturing/2016/08/how-to-start-a-data-analytics-project-in-manufacturing/
26 https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Deloitte-Analytics/dttl-analytics-us-da-manufacturinganalytics3minguide..pdf






## Build the Business Case & Begin Implementation *(continued)*

**Metrics for Success: How to Measure Impact**

When setting objectives for your Data Analytics program, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the machine, product, and operational performance against traditional data management strategies, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

- Better forecasting of products/production
- Greater understanding of single and multi-plant performance
- Faster service and support to customers
- Real-time alerts and actionable data analysis
- Predictive modeling on manufacturing data, including inventory forecasting and supply/demand
- Improved interactions and relationships with suppliers
- Understand requirements for new products based on existing product/machine data [28]
- Reveal potential supply chain, operational, or other weaknesses before they become an issue, leading to better margins, increased batch quality, and less discard
- Streamlined processes, including maintenance and repair schedules and assembly lines
- Create leaner operations and manage employee productivity and error
- Quicker test-and-learn process prototyping leading to more operational innovation
- … And more, depending on your use case

27 https://blog.bosch-si.com/categories/manufacturing/2016/08/how-to-start-a-data-analytics-project-in-manufacturing/
28 https://www.forbes.com/sites/louiscolumbus/2014/11/28/ten-ways-big-data-is-revolutionizing-manufacturing/#2cbac7d9ce16



## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to-implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**Bimotics:** https://www.bimotics.com/manufacturing-analytics
Bimotics' cloud-based big data solutions address manufacturing data analytics programs. Its data scientists and consultants work powerful cloud platforms to deliver advanced inventory planning and optimization, business intelligence-based production performance analysis, dark data analysis for optimized preventative maintenance, error-log analysis for predicting recall and customer service issues, secure cloud solution infrastructure, and more.

**Bosch:** https://www.bosch-si.com/manufacturing/solutions/data-analytics/data-analytics-workshop.html
Bosch's data analytics consulting contributes to specific, implementable results that will help manufacturers take a systematic approach to their analytics projects. Their tool set provides added support. Workshop trainings offered for employees.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Hiring Solutions:** Robert Half Technology specializes in placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**Teradata**: http://www.teradata.com/Industries/Manufacturing
Teradata works with large industrial manufacturers on data analytics strategies to streamline supply chain performance and provide end-to-end visibility; establish asset and process performance improvements using analytics, not capital; bolster bottom line using analytics to reduce overall spend; and develop a deeper understanding of customers to grow revenue via customer engagement.

**WCI Data Solutions**: http://wciconsulting.com/industries/manufacturing-analytics/
WCI works with manufacturing organizations to reduce ineffective systems and help structure data analytics plans to help your business with data organization, trend forecasting, improved after-sales services, improved supplier relations, consolidated information, and regulatory compliance.

## Appendix

**Glossary:** Key Data Analytics Terms
*Definitions from Liaison,[29] Sight Machine,[30] and Lean Methods[31] for educational purposes.*

**Aggregation:** A process of searching, gathering and presenting data.

**Algorithm:** A mathematical formula or statistical process used to perform analysis of data.

**Analysis:** Data analysis tools enable manufacturers to identify patterns, measure the impact of those patterns, create actionable insights, and even predict outcomes. By breaking down equipment, production, and supply chain data, analysis tools help manufacturers drive outcomes through better decision-making.

**Analytics:** The computational analysis of data to discover patterns and information.

**API:** Application program interface (API) specifies how software components should interact and facilitates the integration of features, sharing of data, etc.

**Batch processing:** Batch data processing is an efficient way of processing high volumes of data where a group of transactions is collected over a period of time. Hadoop is focused on batch data processing.

**Big Data:** The analysis of extremely large and diverse data sets to reveal patterns, trends, and associations.

**Cleansing:** As Big Data comes from numerous structured and unstructured sources; it is critical for manufacturers to ensure the quality and integrity of their data for analysis. Big Data Analytics tools enable this by cleaning and transforming data into readable, unified data sets for multiple users. Cleansing also involves standardization and parsing data into consistent formats that are usable by different enterprise applications and systems.

**Cloud:** A broad term that refers to any internet-based application or service that is hosted remotely.

**Cloud c:** A distributed computing system hosted and running on remote servers and accessible from anywhere on the internet.

**Cluster:** A group of servers and other computing resources to enable high availability.

**Data collection:** The process of identifying data sources and variables of interest and systematizing the gathering ring of those variables.

**Data conditioning:** The process of cleansing the data, transforming and blending it into useful data models, and optimizing the data for future analysis.

**Data governance:** A set of processes or rules that ensure data integrity and that data management best practices are met.

**Data integration:** The process of combining data that's been collected from disparate sources including merging multiple sources of the same type or combining data from multiple different types of sources into single records.

**Data integrity:** The measure of trust an organization has in the accuracy, completeness, timeliness and validity of the data.

**Data lake:** A large repository of enterprise-wide data in raw format. Supposedly data lakes make it easy to access enterprise-wide data. However, you really need to know what you are looking for and how to process it and make intelligent use of it.

29 https://www.liaison.com/blog/2017/09/20/big-data-analytics-tools-manufacturing-industry/
30 http://sightmachine.com/how-to-articles/manufacturing-analytics-glossary/
31 https://www.leanmethods.com/resources/articles/data-analytics-glossary



## Appendix *(continued)*

**Data modeling:** Understanding business and technical requirements, and identifying data sources and variables to satisfy those requirements.

**Data storage:** Gathering data and having the capacity to store data are the first steps in utilizing Big Data Analytics. Data storage allows manufacturers to keep equipment, production process, and supply chain data for analysis.

**Data visualization:** Presentation of data to improve the ability to understand and communicate meaning.

**Discovery:** Data discovery or data mining tools enable manufacturers to quickly identify and access the information they need to make production and supply chain decisions.

I**ndustrial Internet of Things (IIoT):** The application of data science to sensor data, M2M communications, automation technologies, and industrial systems.

**Machine-generated data:** Data automatically created by machines via sensors or algorithms or any other non-human source.

**Machine learning:** A method by which computer programs examine prior data to discover trends and outliers, and predict potential future outcomes.

**Mapping:** Data mapping tools help manufacturers understand the flow of data within data environments, production processes, and supply chains. These tools enable manufacturers to identify dependencies and address potential problems at the cause. At the same time, they help identify potential data risks and leakages in the data environment.

**MapReduce:** A programming model for processing and generating large data sets. This model does two distinct things First, the "Map" includes turning one dataset into another, more useful and broken down dataset made of parts called tuples Tuples may typically be processed independently from each other across multiple processors. Second, "Reduce" takes all of the broken down, processed tuples and combines their output into a usable result. The result is a practical breakdown of processing.

**Metadata:** Data about data – can describe how the data is structured or provide summary descriptions of the data.

**Monitoring:** Monitoring tools ensure that compliance with data quality standards are met on an ongoing basis. They also help ensure the good performance of equipment and the efficiency of the production process. Monitoring tools also enable manufacturers to automate quality assurance processes.

**Predictive analytics:** A branch of analytics in which historic data is used to make predictions about future events or states.

**Predictive modeling:** The process of developing a model that will most likely predict a trend or outcome.

**Profiling:** Profiling tools provide greater visibility into a manufacturer's production and supply chain. Profiling tools capture information up to the metadata level, enabling manufacturers to create a comprehensive inventory of their critical data so that they can make the most of the information they have.

**Real-time data:** Data that is created, processed, stored, analyzed and visualized within milliseconds.

**Visualization:** Visualization tools communicate the results of analytics to manufacturers and other professionals. It transforms data in spreadsheets and SQL databases into user-friendly graphs and charts, making it easier for manufacturers to generate insights and make data-driven decisions regarding their production processes and supply chain.

CHAPTER 7
# Cybersecurity

## Cybersecurity at a Glance

**What does Cybersecurity encompass?**
Wikipedia has a simple definition: Cybersecurity is the protection of computer systems from the theft or damage to their hardware, software or information, as well as from disruption or misdirection of the services they provide.[1] What is difficult to grasp is the scope. Cyber-attacks threaten all businesses from personal computers to large organizations. Virtually everyone is vulnerable regardless of their business size, the sophistication of their systems, or connectivity to a network. Every single digital device is a target.

**Why does Cybersecurity matter to your business?**
Cybersecurity is a shared responsibility among suppliers. Many manufacturers interact with large customers or they do business with the Department of Defense (DoD). These organizations are constantly raising the bar requiring that their suppliers' systems are adequately protected. Why? Because criminals find the weakest link, and once one system is compromised it moves around the supply chain leading to data theft, corruption, and business disruption. You can create a competitive advantage by being known as a leader in Cybersecurity and a place in the supply chain where customers have confidence that their data and systems are safe.

Regulation deadlines will impact many businesses that are not even aware that they could become noncompliant. The DoD required suppliers to reach NIST/DFARS 800-171 compliance by Dec. 25, 2017, and if they do not comply they may face fines or loss of DoD business. The Special Publication outlining the new requirements can be found at: http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-171.pdf

**What are the biggest opportunity areas?**
We have identified three key opportunity areas in Cybersecurity for manufacturers. More information can be found in the Identify Opportunities section on pg.8

**Opportunity #1:** Protect your company's data and systems. Understanding and mitigating risks reduces the likelihood of and damage associated with a breach.

**Opportunity #2:** Minimize the impacts of an incident. Proactively planning for an incident increases your ability to detect, react, and recover, greatly reducing the cost associated with each occurrence.

**Opportunity #3:** Gain competitive advantage as a secure partner. As you work to meet industry standards or become NIST certified, your customers will gain confidence in your capability to be a trusted partner in the supply chain, turning Cybersecurity into a competitive advantage for your company.

1 https://en.wikipedia.org/wiki/Computer_security



**What are the business benefits of a Cybersecurity program?**
The business benefits of a Cybersecurity program can be very impactful.[2]

- Protect your business from disruptions of operations
- Protect your company's brand and reputation
- Avoid lost sales, fines and legal costs
- Faster recovery times in case you have a breach

Cyber-crime costs are predicted to hit $6 trillion annually by 2021.[3] Most people have a personal experience or know someone who has gone through and horror of dealing with a personal or company breach. Loss of productivity, damaged company image, consulting fees, and financial losses are among the ruins. These costs are real and can be devastating to a company. Being cyber secure and keeping your business safe is a fundamental responsibility of every business owner and leader.

**Where can I find help to get started?**
There are resources that can assist you with the development and implementation of Cybersecurity program. There are also many free online resources, as well as educational courses offered by universities and colleges. Turn to page 20 for a full list of resources to jump start your Cybersecurity journey.

*Figure 1: Cybersecurity Chapter Information Flow*


2 Per Quad Cities Cybersecurity Alliance
3 https://cybersecurityventures.com/hackerpocalypse-cybercrime-report-2016/

CHAPTER 7
# Cybersecurity

## Table of Contents





## Understand the Technologies

In the first section, we take a closer look at the variety of technologies that contribute to the collective term "Cybersecurity." You'll gain a better understanding of Cybersecurity through diagrams, frameworks, and definitions of key terms. This section also details additional online resources for greater understanding.

We have defined Cybersecurity as the protection of computer systems from the theft or damage to their hardware, software or information, as well as from disruption or misdirection of the services they provide. Most of the information shared in this guidebook will be on the process of identifying risks and designing secure systems and tools to mitigate those risks. We will use a couple of the most popular models as the basis for our common understanding.

**The Large Organization**

The breadth and depth of Cybersecurity systems can be quite complex. Large organizations will typically have a large security challenge driven by the complexity of their underlying information technology systems and networks. Regardless of the size of the organization, the risk analysis needs to be thorough. Every unaddressed vulnerability puts your organization at risk. While it is never possible to eliminate 100% of the risk, an organization can dramatically reduce the likelihood of an incident by anchoring their security programs to recognized security standards.

The good news is The National Institute for Standards and Technology (NIST) has a simple and logical framework to help you get started and prioritize and address the key risks (see Fig. 2).

*Figure 2: The Five Functions of Cybersecurity* [4]


**Executive Order 13636**

On Feb. 12, 2013, the President issued an executive order that called for the development of a "risk-based Cybersecurity Framework - a set of industry standards and best practices to help organizations manage Cybersecurity risks." The resulting framework, created by NIST through collaboration between government and the private sector, will provide "prioritized, flexible, repeatable, performance based, and cost-effective approach" and enable organizations, regardless of size, degree of Cybersecurity risk or sophistication, improve the security and resilience of their systems.[5]

4 https://www.nist.gov/sites/default/files/documents////draft-cybersecurity-framework-v1.1-with-markup1.pdf
5 https://www.nist.gov/sites/default/files/documents////draft-cybersecurity-framework-v1.11.pdf

## Understand the Technologies *(continued)*

**The NIST Model**
Figure 2 illustrates the high-level view of the cycle for managing an organization's Cybersecurity risk. This framework is the basis for most of the Cybersecurity products and services being developed and provides a common language and framework to facilitate collaboration and communications across businesses and organizations.

**Overview of the Framework**
The framework is a risk-based approach to managing Cybersecurity, meaning business drivers and activities help define the risk and the appropriate focus and mitigation strategies. The framework has three parts: framework core, implementation tiers, and framework profile.

**The Framework Core**
The core is organized around a set of five functions that describe the cycle for managing Cybersecurity risk: identify, protect, detect, respond and recover. Each function is further divided into categories and subcategories. The core then describes the activities and desired outcomes, along with existing standards, guidelines, and best practices that apply to each category and subcategory.

**Three Perspectives**[6]
Cybersecurity threats can be viewed from three different perspectives: Defense, Offense, and Use.[7]

First: defense is something that system administrators typically do to protect their systems from threats and the perspective most often taken.

Second: to defend systems effectively we need to get into the minds of attackers and look at systems from the offense viewpoint.

Third: human factors make or break security, so it is critical to look at the security challenges from the use viewpoint. Your users can either help or hinder security, so it is important to design security that doesn't stand in the way of use.

As you go through this guidebook we would encourage you to take time to think about each issue from the additional perspective of the attackers and the users.

**Glossary: Cybersecurity Terms**
Please refer to the glossary in the appendix for definitions of key Cybersecurity terminology utilized in this guidebook.

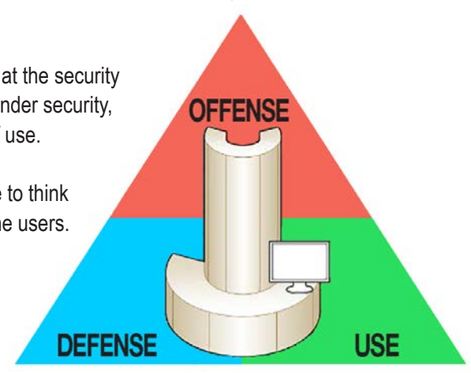



*Figure 3: Three Perspectives to View Security Challenges.*

6 Courtesy of Binto George, Ph.D., Professor, School of Computer Sciences, Western Illinois University
7 Ibid



## Understand the Technologies *(continued)*

**Additional Online Resources**
There are many online resources for review to deepen your understanding of Cybersecurity strategies, programs, software, applications, technologies, use cases, opportunities, challenges, and more. We've outlined a few below:

- "Risk Appetite Statement" This whitepaper from Willis is not directly about Cybersecurity, but it does a masterful job of describing why organizations need to be intentional as they deal with risk. Mitigating risk is what Cybersecurity is all about and the fundamental insight on how to think about risk is a great place to start your journey. https://www.willis.com/subsites/australia/Documents/Publications/services/BusinessRisk/W0477AU_Thought_Leadership_Article_Risk_Appetite_Statement_web.pdf
- "State of Illinois Cybersecurity Strategy" This document does a great job of describing the Cybersecurity challenge, and how the state is addressing it. Any organization can learn more about what Cybersecurity is, why it is important, and how to put a strategy together to meet the challenge. https://www2.illinois.gov/sites/doit/Strategy/Cybersecurity/Pages/cybersecurity.aspx
- IEEE Cybersecurity Initiative This website provides the go-to online presence for Cybersecurity professionals with the goal to educate and improve Cybersecurity program designs and implementations with current articles and case studies. https://cybersecurity.ieee.org/

## Identify Opportunities

**Benefits and Use Cases of Cybersecurity Opportunities**
In this section, we'll examine the key benefits of cybersecurity in each of the three opportunity areas previously identified. Cybersecurity offers many opportunities to small and medium businesses. We have identified three key areas that can bring greatest benefit to small and medium manufacturers and the DoD supply chain.

**Opportunity #1: Protect Your Company's Data and Systems**
Protecting your company's data and systems begins with understanding the risks. Understanding and prioritizing the risks helps you adjust your procedures and training, as well as your investment in systems and tools. With a thorough understanding of the risks and a well thought out mitigation plan, the chances and potential severity of a breach can be greatly reduced protecting your company's valuable assets and reputation.

## Identify Opportunities *(continued)*

### Protect Your Company's Data and Systems

- **Minimize disruptions of operations:** Eliminating opportunities for a breach reduces the risk of these common disruptions: machines and systems are down due to corrupted data, operating systems can become disabled or locked with a virus, the entire business may need to shut down until data is recovered and the root cause of the breach identified
- **Reduce cost of recovery:** Proactively planning for an incident can reduce the time of recovery. The time saved from planning can be used to get into corrective action. Also, understanding your risks ahead of time dramatically increases your ability to accurately detect and mitigate the incident.
- **Protect your company's brand and reputation:** Avoiding an incident is the best way to keep your reputation intact, but if a breach occurs, your ability to swiftly communicate and implement a corrective action plan can add to your reputation as a competent partner.

**Opportunity #2: Minimize Impacts of an Incident**
An organization can dramatically reduce damage through timely detection, preplanned response, and protected and backed up data. The time to think through your response and action plan is before an incident occurs. Proactive planning and thinking through possible corrective action scenarios buys you critical time and helps reduce the overall impact to the business.

### Minimize Impacts of an Incident

- **Reduce damage through timely detection and response:** Understanding your vulnerabilities is important to helping develop countermeasures, but it also enables you to establish early detection and corrective action plans. The damage that is done is often a result of your reaction time. Proactive planning and effective countermeasures can dramatically limit the damage.
- **Faster recovery times:** Time is money when it comes to response. By planning your recovery in advance of a breach, valuable time is saved. Understanding what is needed to recover is best done without the pressure of bringing a business back on line. A pre-established recovery process and communication plan can help you effectively restore your operations and your credibility.
- **Protected and backed up data:** Even with the best planning and reaction, a breach can result in a loss of data and contaminated programs. Having data and programs backed up and a system in place to convert to the backup is critical to restoring operations. Without it permanent damage to the business is likely.

**Opportunity #3: Gain Competitive Advantage as a Secure Partner**
The regulatory and commercial risk for large customers and DoD contractors is constantly increasing. Their business depends on your ability to meet the requirements of the DoD so they can meet their business commitments. Customers will award business to those they trust as being a secure partner; the risk is too great to do otherwise.



## Identify Opportunities *(continued)*

**Gain Competitive Advantage as a Secure Partner** *(continued)*

- Exceed customer expectations: A solid Cybersecurity program will impress your customers, but your ability to demonstrate that you are a secure partner by effectively dealing with a breach is "priceless."
- Reduce costs of non-compliance: The best way to reduce cost is to eliminate incidents. The second-best way is to react quickly. Over time both will reduce your operating costs, making you more competitive in the marketplace.
- Speak the industry standard language: Being cyber-secure requires collaboration with the supply chain and the partners you choose to help you on your journey. Your ability to speak the language and interact in a knowledgeable and efficient way is another way to demonstrate that you are a secure partner.

## Build the Business Case & Begin Implementation

In this section, we'll outline the steps to implement a Cybersecurity program within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing a Cybersecurity program may be an entirely new technical area for your organization, and it involves everyone. We also understand that the prospect of this degree of change can be daunting! It is our hope that through the following content and previous look at the benefits of being cyber-secure you'll feel more comfortable exploring how you can utilize these technologies to protect your data and systems.

**Change Management: Building the Case Requires a "Test-and-Learn" Approach**
For most small and medium manufacturers, the prospect of launching a Cybersecurity program seems enormous, as it requires learning new technologies and procedures to prevent some future attack from an unknown enemy. The threat seems very hypothetical until you experience an incident. Only through thorough planning, continuous implementation, learning, and adjusting, can you build the expertise and experience that will keep your company's assets safe for years to come.

These new digital technologies are shifting the supply chain into the next industrial age. Unfortunately, these new technologies depend on increased connectivity and the Internet of Things (IoT), dramatically increasing your exposure to cyber-crime. To be successful, you will need to pursue Cybersecurity in ways that fit into your current culture, enrolling your people and aligning with your leadership's risk management goals.

There are many ways for you to get started along the path to utilizing Cybersecurity. Use the Change Management Tips below to make the case for change and immediately begin proving results:

- Create a vision of what success looks like and set goals accordingly. Great metrics start with a clear vision of success. This vision will help identify the measures important to the organization. Metrics will include the business benefits along with project milestones that represent the progress being made in the implementation. Be sure to measure the initial progress and the quick wins that energize the organization. We have identified some typical metrics outlined on p.19.

## Build the Business Case & Begin Implementation *(continued)*

- Focus on getting every employee on board with the benefits of Cybersecurity. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of Cybersecurity. The IT professionals will be crucial in implementing the technical solutions, but the success of a Cybersecurity program relies on everyone following policies every single day. Turn to Quick Wins on pg. 18 for tips.
- Plan thoroughly and implement continuously. Initial planning should be large in scope to make sure all major risks are identified. After that, implementing a Cybersecurity program is all about prioritizing and making choices. The typical company will have more risks than capacity to mitigate them, and risks and technologies change over time. Set the expectation that this is a never-ending journey but be sure to celebrate each milestone along the way.

Part of changing management also lies in understanding and planning for the challenges you will encounter in integrating Cybersecurity into your existing operations. Below are three challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

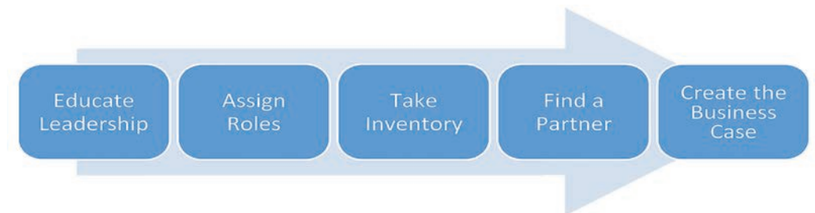
- Challenge 1: You will never have enough resources. The vast majority of the organizations implementing a program need help. Most companies have a limited budget for consultants, and consultants themselves are running at capacity. Part of the solution is to leverage internal resources where possible. Education and getting everyone involved is initially time-consuming but in the long run, a requirement.
- Challenge 2: Your employees are not IT professionals. Lots of education and patience will be required to train your employees with the day to day skills required for success. Because the challenge is never-ending and technologies are changing quickly, education will need to be ongoing. In addition, the skills required for implementation and training may be outside your organization. Turn to Resources Needed: Technology and Staffing to learn more about hiring the right talent for the job.
- Challenge 3: This feels are overwhelming. A thorough risk analysis is typically one of the first steps in implementing a program. The bad news is the analysis is likely to uncover a long list of required corrective actions and changes. The good news is the analysis helps prioritize which risks need immediate attention. Understanding risk and prioritizing are key skills your leadership will need to wisely use your resources during this journey.



## Build the Business Case & Begin Implementation *(continued)*

**Processes and Frameworks for Implementing Cybersecurity**
Integrating Cybersecurity into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks on the following pages to aid your high-level strategic prioritization of Cybersecurity. We recommend you search out specific frameworks for each technology and use cases chosen to guide your implementation.

*Figure 4: How to get started.*




**Step 1: Educate your leadership.** There are many introductory training programs readily available regionally and virtually. These programs teach your organization the basic strategies to manage cyber risks. Each business typically has dozens of different risks and putting together a plan to deal with them is typically beyond the scope of these overview courses. However, you will find this very helpful if you are just beginning or upgrading your Cybersecurity program. With this basic understanding in hand, you can better evaluate the resources needed to help in your journey.

**Step 2: Assign roles and responsibility.** Implementing or upgrading your Cybersecurity program needs to be managed like any other investment your organization makes. Finding the person with the right skills to lead the project is critical. Basic understanding of the underlying systems and tools is important, but the project will impact every single person in your organization, so good people and communications skills are a must. Beyond the project management, leadership needs to support the project and take ownership of the activities in their functional areas.

**Step 3: Take inventory of your assets.** To scope and plan the project you need a basic understanding of what needs to be protected. A high-level map of your assets is a good way to start – anything that uses, stores, or transmits data: networks, devices, controllers, machines, computers, data storage etc. These can be stand-alone or connected, personal or company-owned, digital or paper-based. This will help leadership understand the breadth and depth of the risks involved.

**Step 4: Find a partner.** Most companies will need help. There are many resources, including from community colleges, accounting firms, IT consulting firms, and government funded organizations. Some regional choices are listed in our Appendix. If you approach the partner with a basic understanding of the Cybersecurity process and your digital assets, you will have good chance of collaborating on a project proposal that meets your needs and budget.

**Step 5: Create the business case.** Avoiding the costs associated with an incident is the main reason organizations invest in the required countermeasures. There are numerous other business benefits of an effective Cybersecurity program that are described in the following sections along with some guidance on how to calculate a return on investment (ROI).

## Build the Business Case & Begin Implementation *(continued)*

### The Basic Business Benefits

The business case for Cybersecurity is based on cost-avoidance, which can be a challenging sell. Fortunately, business journals and media are packed with cyber-crime stories making these risks real for every business. As more and more devices get connected to the internet, and more and more business is driven digitally, risks will continue to increase. Here are a few of the most frequently discussed reasons to be cyber-secure:

- Protects your business from costs of disruption to operations
- Protects your company's brand and hard-earned reputation
- Avoids lost sales, penalties, and litigation expenses
- Small businesses or organizations are not immune; hackers target based on vulnerability
- More and more companies are concerned about how their information is being stored/used
- Most Federal agencies will require DoD/DFARS mandates

**DFARS Certification**

Due to Executive Order 13556, contractors or sub-contractors to government agencies and organizations must provide documentation and evidence that they are protecting Controlled Unclassified Information (CUI) to show DFARS compliance. To be considered in compliance, an organization must complete a security assessment based on National Institute of Standards Technology (NIST) Special Publication 800-1718. In addition, any areas found to be at risk need documented remediation strategies. Contractors affected by this mandate must implement the remediation strategies in order to continue to do business with governmental agencies and organizations after December 2017. Those not in compliance may be fined or lose government contracts.

**Calculating ROI**

Calculating a return on investment (ROI) for your Cybersecurity program can be a difficult task. Quantifying risk is the key to understanding potential return, and often the risks are not known until you are deep into the program. In addition, leaders seem to prefer projects that create traditional savings since they show up in increased profits. Cost avoidance is harder to appreciate since it focuses on keeping your costs from going up. Management understanding their appetite for risk is pivotal in guiding the organization's investment.

Cost avoided = risk - cost of countermeasures
Risk = likelihood of an incident x cost of the incident
ROI = cost avoided/cost of countermeasures

**Risk**

The product of the likelihood of exposure and the magnitude of the loss due to the exposure. The exposure is caused by criminals successfully exploiting vulnerabilities in business processes and systems. Cost of an incident can be based on experience or estimates gathered from industry studies, agencies, or consultants. Estimates will require lots of background and generally come under intense leadership scrutiny. The use of non-technical language and case study examples, along with your own internal assessment of risk helps make the numbers real.

8 http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-171.pdf
9 https://www.nist.gov/sites/default/files/documents////draft-cybersecurity-framework-v1.1-with-markup1.pdf



## Build the Business Case & Begin Implementation *(continued)*

**Cost of countermeasures:**

The investment you make in resources and tools will be prioritized based on your risk. Your partner should be able to give you a good idea of the cost of each type of countermeasure. If you are just starting a program, the one-time cost associated with consulting fees and staff time to organize and do an initial assessment is often taken out of the ROI analysis and considered part of the cost of doing business, especially if it is a government or customer requirement.
The following is an excellent article on calculating ROI: https://www.csoonline.com/article/3010007/advanced-persistent-threats/how-to-calculate-roi-and-justify-youcybersecurity-budget.html

**Establishing or Improving a Cybersecurity Program**

Once you are ready to begin, we highly recommend that you follow a proven methodology to thoroughly analyze your risk. Most consultants will use terminology and processes consistent with Section 3.2 of the NIST Framework[9] and follow a process similar to the framework recommendations outlined below:

**Step 1: Prioritize and Scope** The organization identifies its business/mission objectives and high-level organizational priorities. With this information, the organization makes strategic decisions regarding Cybersecurity implementations and determines the scope of systems and assets that support the selected business line or process. The Framework can be adapted to support the different business lines or processes within an organization, which may have different business needs and associated risk tolerance. Implementation Tiers may be used to express varying risk tolerances.

**Step 2: Orient** Once the scope of the Cybersecurity program has been determined for the business line or process, the organization identifies related systems and assets, regulatory requirements, and overall risk approach. The organization then consults sources to identify threats and vulnerabilities applicable to those systems and assets.

**Step 3: Create a Current Profile** The organization develops a Current Profile by indicating which Category and Subcategory outcomes from the Framework Core are currently being achieved. If an outcome is partially achieved, noting this fact will help support subsequent steps.

**Step 4: Conduct a Risk Assessment** This assessment could be guided by the organization's overall risk management process or previous risk assessment activities. The organization analyzes the operational environment in order to discern the likelihood of a Cybersecurity event and the impact that the event could have on the organization. It is important that organizations identify emerging risks and use cyber threat information from internal and external sources to gain a better understanding of the likelihood and impact of Cybersecurity events.

**Step 5: Create a Target Profile** The organization creates a Target Profile that focuses on the assessment of the Framework Categories and Subcategories describing the organization's desired Cybersecurity outcomes. Organizations also may develop their own additional Categories and Subcategories to account for unique organizational risks. The organization may also consider influences and requirements of external stakeholders such as sector entities, customers, and business partners when creating a Target Profile. When used in conjunction with an Implementation Tier, characteristics of the Tier level should be reflected in the desired Cybersecurity outcomes.

## Build the Business Case & Begin Implementation *(continued)*

**Step 6: Determine, Analyze, and Prioritize Gaps** The organization compares the Current Profile and the Target Profile to determine gaps. Next, it creates a prioritized action plan to address those gaps - drawing upon mission drivers, a cost/benefit analysis, and risk understanding - to achieve the outcomes in the Target Profile. The organization then determines resources necessary to address the gaps. Using Profiles in this manner enables the organization to make informed decisions about Cybersecurity activities, supports risk management, and enables the organization to perform cost-effective, targeted improvements.

**Step 7: Implement Action Plan** The organization determines which actions to take in regard to the gaps, if any, identified in the previous step. It then monitors its current Cybersecurity practices against the Target Profile. For further guidance, the Framework identifies example Informative References regarding the Categories and Subcategories, but organizations should determine which standards, guidelines, and practices, including those that are sector-specific, work best for their needs.

**Step 8: Continuous Improvement** An organization may repeat the steps as needed to continuously assess and improve its Cybersecurity. For instance, organizations may find that more frequent repetition of the orient step improves the quality of risk assessments. Furthermore, organizations may monitor progress through iterative updates to the Current Profile, subsequently comparing the Current Profile to the Target Profile. Organizations may also utilize this process to align their Cybersecurity program with their desired Framework Implementation Tier.

**Resources Needed: Technology and Staffing**
Resources required to manage and implement a Cybersecurity program will vary by the complexity of your systems and business. As was described in getting started, a basic inventory and map of your digital assets goes a long way in describing your future technology challenges and the skills required to address them.

A strong Cybersecurity program will require an investment in internal and external resources: training, assessments, tools, consulting, and staffing. How and where you invest will be driven by your risk assessment and business needs. Clear priorities based on a rigorous risk assessment are the key to spending your resources wisely.

**Hardware and Software:** In implementing a Cybersecurity program, hardware and software technologies go hand-in-hand.

- Antivirus Software – The best antivirus software includes virus removal, internet security, malware and adware protection, as well as spyware removal. Viruses can make your computer run slow, steal important personal information or hold your computer ransom. Protecting against these types of threats typically requires you to download the antivirus software and pay an annual subscription charge. Most software will automatically update and scan individual devices to prevent or eliminate viruses.



## Build the Business Case & Begin Implementation *(continued)*

- *Data Backup and Recovery* – For most organizations, data is the lifeblood of their business. Data can get corrupted, infected, or lost. We have all heard stories of ransomware that cost companies many thousands of dollars to restore. To prevent this, your organization needs a process in place to periodically copy your data to a source outside your systems and retrieve it when and if needed. There are multiple approaches to data backup and recovery.

  Some organizations or individuals use services, like Carbonite, to automate the process for their home or small businesses. Some homeowners or small business may prefer to do it themselves, manually connecting to an auxiliary storage device off their network and periodically saving data to that device.

  Data backup and recovery for a larger business can be a complicated process. Where to back up the data is the first decision; cloud, on-site, or an off-site service are the main choices. Depending on the criticality of the data, frequency and security need to be considered as well. Weekly or daily backups may be good for some businesses where others may need real time updates so that no single transaction is lost. Some companies my need to encrypt and/or verify the security of the storage location.

- *Network and Vulnerability Scanners* – Network scanning tools help discover all the devices present on your organization's network. The discovery process provides details such as name, the type of device, and the operating system. Being aware of all the assets on your network is required if you want to defend your network from threats and attacks. Networks are often entered through devices that are overlooked in the analysis.

  Vulnerability scanners are programs that include analysis routines that evaluate your network and devices looking for weaknesses. There are different levels of sophistication and commercial or open-source products designed to do these evaluations. Unfortunately, these tools are also used by hackers looking for vulnerabilities to exploit.

- *Penetration Testing* – Penetration testing goes one step further than vulnerability scanning and tries to breach the system both from inside and outside the network. Testing includes network and application security as well as controls and processes around the networks and applications. Often, penetration testing may be a deliverable required to meet certain regulatory requirements.

- *Firewalls and Intrusion Prevention Systems (IPS)* – Firewalls and IPS are security programs that monitor traffic coming into and out of your network. Data travels on the internet in packets, each with the data being transferred along with information about its origin. They use security protocols that look for and block suspicious data packet by packet coming into your network. There is subtle difference in the technology they use; firewalls and IPS are often found working in tandem to control incoming traffic.

  Laptops should always run a software firewall to prevent unintended incoming traffic. Computer operating systems offer basic firewall security that can be supplemented with other commercial products based on your organization's need.

## Build the Business Case & Begin Implementation *(continued)*

**Employees and Hiring:** Assess your current employees for work habits, skillsets and experience in Cybersecurity to determine if expertise and interest exists. If not, you may opt to hire new employees with Cybersecurity expertise to speed up the implementation process.

This article has some more detailed suggestions on work habits, soft skills, and technical foundation, both general and specific: https://insights.dice.com/cybersecurity-skills/2/

*Work Habits*:[10]

- Ability to work methodically and is very detail oriented
- Eagerness to dig into technical questions and examine them from all sides
- Enthusiastic and highly adaptable
- Strong analytical and diagnostic skills
- Demonstrated skills in innovation and collaboration
- Keep a current understanding of vulnerabilities from the Internet
- Maintaining awareness and knowledge of contemporary standards, practices, procedures and methods
- Ability to get the job done

*General Skillsets*: [11]

- Understand architecture, administration, and management of operating systems, networking, and virtualization software
- General programming/software development concepts and software analytical skills
- Proficiency in programming in Java, C/C++, disassemblers, and assembly language and programming knowledge of two or more scripting languages (PHP, Python, Perl, or Shell)
- Understanding of how the different type of firewalls and network load balancers work
- Deep understanding of how network routers and switches work
- Evaluate and design systems and network architectures

Finding hiring partners will often need to be a regional or national effort. Limited local Cybersecurity programs along with a very competitive market will make a local hire unlikely. Keep in mind consultants are very actively substituting for internal capabilities as the Cybersecurity talent shortage continues for the foreseeable future.

10 https://insights.dice.com/cybersecurity-skills/2/
11 Ibid



## Build the Business Case & Begin Implementation *(continued)*

**"Quick Wins" to Get Started with Cybersecurity**
Take a page from the best practices of other manufacturers already up-and-running with Cybersecurity programs by following a few of tips to jumpstart your use of these technologies.

**Tip 1: Understand the scope of your challenge** Taking inventory of your digital assets and mapping their integration is a good way to both educate your team and find some initial vulnerabilities. Prioritizing and executing some quick hits will give your team energy and maybe stop a potential threat. Addressing all your needs could take months or years. Having a solid plan based on prioritized needs makes the plan feel doable and practical.

**Tip 2: Create organizational alignment** Part of your challenge will be to change the culture. Changing culture is a complex task. For your employees to buy in, management must be clear on the importance of Cybersecurity and how it is critical to the future of your business. Cybersecurity requires the implementation of new processes and behaviors throughout the organization. Make sure you take the time to involve your people in each step of the process creating their understanding and ownership.

**Tip 3: Develop the needed resources and skills** Most companies don't have the resources and skills available to plan and implement a Cybersecurity program. Many companies look at consultants to fill this gap. Make sure that you use the implementation phase as an opportunity to train your people. Also, take the time to identify the level of skills needed in your company to sustain the program throughout your journey and hire and/or train the technical employees required.

**Tip 4. Set the expectation that this is a journey** Cybersecurity programs are based on the idea of continuous improvement. Cyber threats are constantly changing, and customer and government regulations increase over time. As your business changes, new risks will be introduced requiring new mitigation strategies. Tools and systems are being upgraded, making more effective solutions available to combat the evolving threats. This should always be thought of as a never-ending journey.

## Build the Business Case & Begin Implementation *(continued)*

**Metrics for Success: How to Measure Impact**

When setting objectives for your Cybersecurity program, you'll need to use a combination of activity goals as well as business outcomes. The business benefits of avoidance are hard to quantify, but the activities need to reduce and mitigate risks are readily identified.

*Figure 5. Typical Cybersecurity Metrics* [12]

| Function | Management Perspective | Defined Metrics |
|---|---|---|
| **Incident Management** | How well do we detect, accurately identify, handle, and recover from security incidents? | • Mean Time to Incident Discovery<br>• Number of Incidents<br>• Mean Time Between Security Incidents<br>• Mean Time to Incident Recovery |
| **Vulnerability Management** | How well do we manage the exposure of the organization to vulnerabilities by identifying and mitigating known vulnerabilities? | • Vulnerability Scanning Coverage<br>• Percent of Systems with No Known Severe Vulnerabilities<br>• Mean Time to Mitigate Vulnerabilities<br>• Number of Known Vulnerabilities |
| **Patch Management** | How well are we able to maintain the patch state of our systems? | • Patch Policy Compliance<br>• Patch Management Coverage<br>• Mean Time to Patch |
| **Application Security** | Can we rely on the security model of business applications to operate as intended? | • Number of Applications<br>• Percent of Critical Applications<br>• Risk Assessment Coverage<br>• Security Testing Coverage |
| **Configuration Management** | How do changes to system configurations affect the security of the organization? | • Mean Time to Complete Changes<br>• Percent of Changes with Security Reviews<br>• Percent of Changes with Security Exceptions |
| **Financial Metrics** | What is the level and purpose of spending on information security? | • IT Security Spending as % of IT Budget<br>• IT Security Budget Allocation |

12 http://securitymetrics.org/attachments/Metricon-6.5-Kwon.pdf



## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to-implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economiesthroughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Hiring Solutions:** Robert Half Technology specializes in placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Imprimis:** A technology consulting company out of Colorado that specializes in assessment and compliance tools. They have successfully worked with several companies as they begin their journey to become DFARS 800-171 compliant. Their tool set efficiently takes an organization through a self-discovery process that creates a Cybersecurity program that meets government standards

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**Procircular:** An Iowa-based consulting firm that specializes in Cybersecurity. They offer a broad range of services from education and planning to implementation of individual tools to mitigate specific risks.

**Twin State Technical Services:** Consulting service that provides technology solutions to help businesses thrive, including infrastructure and network solutions to ensure a company's network is operational and secure. Their security networkers ensure appropriate security measures are in place for their clients' systems – from servers and websites to individual workstations and mobile devices. This includes any hardware, software, or human factors that may pose a security risk to your company. They also audit systems to test their strength, regardless of whether they had a hand in their development.

## Appendix

**Glossary: Cybersecurity Terms**
Definitions provided from the National Initiative for Cybersecurity Careers and Studies[13] for educational purposes.

**Antivirus software**: A program that monitors a computer or network to detect or identify major types of malicious code and to prevent or contain malware incidents. Sometimes by removing or neutralizing the malicious code.

**Asset**: A person, structure, facility, information, and records, information technology systems and resources, material, process, relationships, or reputation that has value.

**Attack**: An attempt to gain unauthorized access to system services, resources, or information, or an attempt to compromise system integrity.

**Cybersecurity:** The activity or process, ability or capability, or state whereby information and communications systems and the information contained therein are protected from and/or defended against damage, unauthorized use or modification, or exploitation.

**Data breach:** The unauthorized movement or disclosure of sensitive information to a party, usually outside the organization, that is not authorized to have or see the information.

**Disruption:** An event which causes unplanned interruption in operations or functions for an unacceptable length of time.

**Enterprise risk management:** A comprehensive approach to risk management that engages people, processes, and systems across an organization to improve the quality of decision making for managing risks that may hinder an organization's ability to achieve its objectives.

**Event**: An observable occurrence that an incident is occurring or at least raise the suspicion that an incident may be occurring

**Exposure:** The condition of being unprotected, thereby allowing access to information or access to capabilities that an attacker can use to enter a system or network.

**Incident:** An occurrence that actually or potentially results in adverse consequences to (adverse effects on) (poses a threat to) an information system or the information that the system processes, stores, or transmits and that may require a response action to mitigate the consequences.

**Incident response**: The activities that address the short-term, direct effects of an incident and may also support short-term recovery.

**Incident response plan:** A set of predetermined and documented procedures to detect and respond to a cyber incident.

**Intrusion:** An unauthorized act of bypassing the security mechanisms of a network or information system.

**Mitigation:** The application of one or more measures to reduce the likelihood of an unwanted occurrence and/or lessen its consequences by implementing appropriate risk-reduction controls based on risk management priorities and analysis of alternatives.

**Preparedness:** The activities to build, sustain, and improve readiness capabilities to prevent, protect against, respond to, and recover from natural or man made incidents.

13 https://niccs.us-cert.gov/glossary



## Appendix *(continued)*

**Recovery:** The activities after an incident or event to restore essential services and operations in the short and medium term and fully restore all capabilities in the longer term.

**Response:** The activities that address the short-term, direct effects of an incident and may also support short-term recovery.

**Risk:** The potential for an unwanted or adverse outcome resulting from an incident, event, or occurrence, as determined by the likelihood that a particular threat will exploit a particular vulnerability, with the associated consequences.

**Risk analysis:** The systematic examination of the components and characteristics of risk.

**Risk assessment:** The product or process which collects information and assigns values to risks for the purpose of informing priorities, developing or comparing courses of action, and informing decision making.

**Risk management:** The process of identifying, analyzing, assessing, and communicating risk and accepting, avoiding, transferring or controlling it to an acceptable level considering associated costs and benefits of any actions taken.

**Supply chain:** A system of organizations, people, activities, information and resources, for creating and moving products including product components and/or services from suppliers through to their customers.

**Threat:** A circumstance or event that has or indicates the potential to exploit vulnerabilities and to adversely impact (create adverse consequences for) organizational operations, organizational assets (including information and information systems), individuals, other organizations, or society.

**Virus:** A computer program that can replicate itself, infect a computer without permission or knowledge of the user, and then spread or propagate to another computer

**Vulnerability:** A characteristic or specific weakness that renders an organization or asset (such as information or an information system) open to exploitation by a given threat or susceptible to a given hazard.

**Weakness:** A shortcoming or imperfection in software code, design, architecture, or deployment that, under proper conditions, could become a vulnerability or contribute to the introduction of vulnerabilities.

CHAPTER 8
# CAD / CAM

## CAD/CAM at a Glance

**What are CAD/CAM systems?**
Wikipedia has a simple definition for both computer-aided design[1] and computer-aided manufacturing:[2]

"Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations."

"Computer-aided manufacturing (CAM) is the use of software to control machine tools and related ones in the manufacturing of workpieces." Inc. Magazine also published a summary of both online:
https://www.inc.com/encyclopedia/computer-aided-design-cad-and-computer-aided-cam.html

"Computer-aided design (CAD) involves creating computer models defined by geometrical parameters. These models typically appear on a computer monitor as a three-dimensional representation of a part or a system of parts, which can be readily altered by changing relevant parameters. CAD systems enable designers to view objects under a wide variety of representations and to test these objects by simulating real-world conditions.

"Computer-aided manufacturing (CAM) uses geometrical design data to control automated machinery. CAM systems are associated with computer numerical control (CNC) or direct numerical control (DNC) systems. These systems differ from older forms of numerical control (NC) in that geometrical data are encoded mechanically. Since both CAD and CAM use computer-based methods for encoding geometrical data, it is possible for the processes of design and manufacture to be highly integrated. Computer-aided design and manufacturing systems are commonly referred to as CAD/CAM."

**Why do CAD/CAM systems matter?**
Manufacturers can be more fast and flexible as well as more visible and accessible to new customers, partners and geographies by utilizing CAD/CAM systems. Building your part related data online and being able to update and share that data with suppliers and customers is critical to competing in a global economy where access to potential manufacturing partners is seemingly unlimited and business information travels fast. The definition of "business as usual" has evolved to "going digital" is now crucial for manufacturer survival.

**What are the biggest CAD/CAM opportunity areas?**
We have identified three key opportunity areas in CAD/CAM systems for manufacturers. More information and case studies can be found in the Identify Opportunities section on pg. 8.

**Opportunity #1:** Streamline processes for better engineering and manufacturing productivity
**Opportunity #2:** Reduce lead times, design time, programming time, and rework
**Opportunity #3:** Improve time to market and exceptional design

1 https://en.wikipedia.org/wiki/Computer-aided_design
2 https://en.wikipedia.org/wiki/Computer-aided_manufacturing



**What are the business benefits of utilizing CAD/CAM systems?**

There are numerous benefits to implementing CAD/CAM systems into your workflow. For example, CAD/CAM has been proven to be more cost-effective means of:

- Having a unified source of part geometry and manufacturing data.
- Providing both improved external and internal communications.
- Improved productivity of operations.

Customers who feel connected to their manufacturer throughout the design, purchase, and delivery process are also more likely to purchase as well as recommend and refer you to their peers.
This article lists the top benefits to incorporating CAD/CAM software into your CNC manufacturing:

- The 10 Top Advantages to Using CAD-CAM in the CNC Manufacturing Process, via BobCAD-CAM.
  http://bobcad.com/10-top-advantages-to-using-cad-cam-in-the-cnc-manufacturing-process/

CAD/CAM also can be used to reduce product development costs, with 60 percent of overall project cost determined during the concept stage:

- 10 Ways to Reduce Product Development Costs, via SolidWorks.
  http://blogs.solidworks.com/solidworksblog/2016/04/10-ways-reduce-product-development-costs.html

**Where can I find help to get started?**
There are partners who can assist you with full CAD/CAM strategies or specific implementations of tactical solutions on business functions that you've prioritized. There are also many free online resources, as well as educational courses offered by state universities and colleges. Turn to p.16 for a list of resources to help jumpstart your use of CAD/CAM solutions available to grow your business.


*Figure 1: Data Analytics Chapter Information Flow*

CHAPTER 8

# CAD / CAM

## Table of Contents





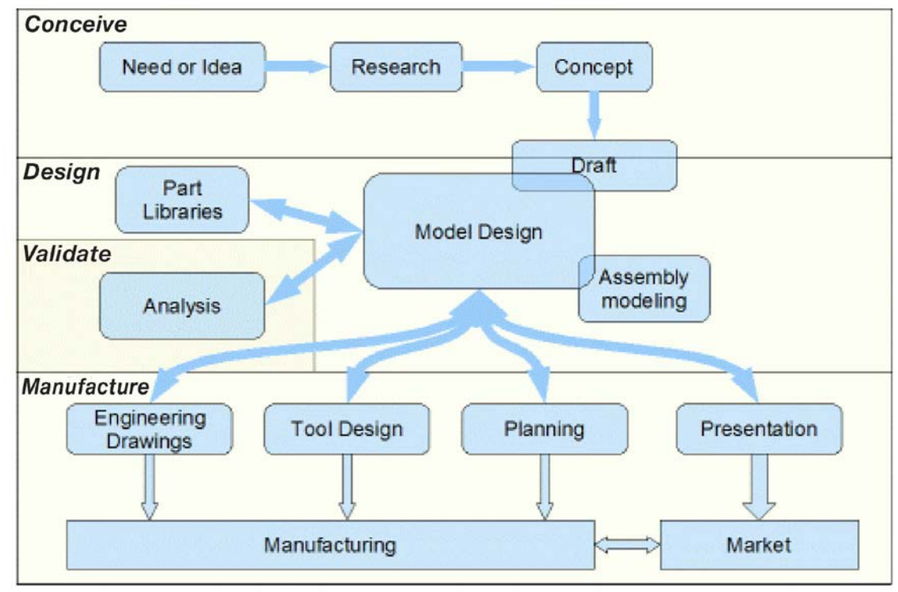
## Understand the Technologies

In this section, we take a closer look at the variety of technologies that contribute to the collective term "CAD/CAM systems." You'll gain a better understanding of how CAD/CAM systems contribute to an overarching strategy through diagrams, frameworks, and definitions of key terms used in the CAD/CAM system's space. This section also details additional online resources for greater understanding.

**Computer-aided design (CAD)**[3] is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design.

**Computer-aided manufacturing (CAM)**[4] is the use of software to control machine tools and related ones in the manufacturing of workpieces.

*Figure 2. A chart describing the design process using CAD systems*[5]




By User: Vrecion - Own work, CC BY-SA 2.5, https://en.wikiversity.org/w/index.php?curid=8395

3 https://en.wikipedia.org/wiki/Computer-aided_design
4 https://en.wikipedia.org/wiki/Computer-aided_manufacturing
5 https://en.wikiversity.org/wiki/Computer-aided_design/Principles_and_terminology



## Understand the Technologies *(continued)*

By using 2-dimensional CAD software, designers can create accurate, scaled drawings of parts and assemblies for designs. It can also be used to develop and firm up design ideas by concentrating on single views and using the range of geometric tools available.

By using 3-dimensional CAD software designers can create fully rendered 3D models of parts and whole assemblies for designs. Designs can be tested virtually before being made from costly materials. 3-dimensional CAD allows all of the parts of a design to be modeled in separate files and then assembled together into a final model. Each part can be modified at any time and changes will be applied to the final model also. 3D models can be viewed from any angle allowing complete visual testing. Assembly of the final model allows the designer to check for exact fit of the parts.

Being digital ready includes all three elements of computer-aided design, computer-aided manufacturing, and materials requirements planning.

*Figure 3. How do CAD/CAM systems fit into the digital enterprise*[6]

**Digital Ready = CAD + CAM + MRP**

| Computer Aided Design | Computer Aided Manufacturing | Materials Requirements Planning |
|---|---|---|
| - Collaborate on the Design<br>- Provide Exceptional Service<br>- Manage Design Updates | - Verify the Pilot<br>- Collaborate the Build | - Receive the Order, Plan the Order, Acquire the Materials, Build & Deliver the Order<br>- Provide Exceptional Service & Manage Demand Changes<br>- Manage Design Updates |

**Additional Online Resources**

Here are additional sources of information about CAD/CAM and implementation. Many of these are infographics or provide great summaries and frameworks for you to begin shaping your thinking about implementing a CAD/CAM system. They will not provide detailed solutions or plans. Those specific solutions and plans need to be developed for you individual business needs and conditions.

- **The 10 Top Advantages to Using CAD-CAM in the CNC Manufacturing Process,** via BobCAD-CAM. This article provides top benefits to incorporating CAD/CAM software into your CNC manufacturing. http://bobcad.com/10-top-advantages-to-using-cad-cam-in-the-cnc-manufacturing-process/
- **5 Reasons to Update your CAD Software.** This infographic outlines the benefits to updating software from time to time from cadlogic.com via Pinterest! https://www.pinterest.com/pin/322077810843912953/
- **The Benefits of Using CAD Software.** https://www.pinterest.com/pin/322077810838087656/ There are so many benefits to using this software, easily explained in this infographic from cadlogic.com via Pinterest!

There is a wealth of information available online to help you get started with your understanding of CAD/CAM. You can use Google images or Pinterest to find ideas using the four suggested search terms below.

CAD/CAM infographics; CAD/CAM elements infographic; CAD/CAM benefits; CAD/CAM implementation

6 Graphic included in presentation at CAD/CAM tech team meeting by project manager Bob Smolatt



## Identify Opportunities

Using CAD/CAM systems offers many key benefits to small and medium manufacturers. We have identified three key opportunity areas that can bring greatest benefit to small and medium manufacturers. We will look more in depth at a couple of those opportunities. Below, you'll also find a case example for different opportunity areas that shows how a manufacturer was able to utilize CAD/CAM systems to produce results.

### Opportunity #1: Streamline processes for better engineering and manufacturing productivity

**Case example: Race car company uses CAD to realize both engineering and manufacturing productivity**

Texas Chassisworks produces high-end drag-racing cars and associated parts. By applying CAM operations directly to the Solidworks CAD model and using advanced tool-path operations, the Tyler-based company can decrease cycle time by 50 percent. Read the full case study here:
http://www.solidworks.com/sw/docs/SW_WP__CAD_CAM.pdf

### Opportunity #2: Reduction in lead times, design time, programming time, and rework

**Case example: Using CAD/CAM to automate design and part programming**

"CP-Carillo, a leader in the production of pistons and rods for the power-sports and motor-sports racing industries, is leveraging the Applications Programming Interfaces (APIs) of the integrated SOLIDWORKS CAD and CAMWorks CAM solution to fully automate the design and part-programming of its products. This integrated, automated approach reduces overall lead time by 85 percent, including a 95-percent reduction in design time, a 75-percent drop in CNC programming time, and a 20-percent decrease in scrap and rework."
Read the full case study here: http://www.solidworks.com/sw/docs/SW_WP__CAD_CAM.pdf

### Opportunity #3: Improved time to market and exceptional design

**Case example: Software allows for easy modification in record time**

KTM, Europe's largest manufacturer of motorsports vehicles, engineers everything in-house. By using PTC's Creo software, the company is able to design faster and smarter by connecting its digital design to physical products. This allows them to "quickly take any design and easily modify it … (they) can design, simulate, optimize, and modify every aspect of the complete bike in Creo, and this can all be done in just a few hours, compared with the weeks and months it took previously."

The blog post gives results for the KTM 690 DUKE as an example:

- Developed in record time, just 22 months from first concept to start of production, a 15% reduction in time-to-market compared to the previous generation.
- Lightest weight in it class, with the most powerful engine.
- Highest fuel efficiency in its class, with a 10% improvement in fuel consumption compared to the previous generation.

Read the full case study here: https://www.ptc.com/en/case-studies/ktm



## Build the Business Case and Begin Implementation

In this section, we'll outline the steps to take in implementing strategies and tactics of CAD/CAM systems within your company, beginning with awareness and change management, through establishing partnerships and building use cases that will save you time and money. We understand that the idea of implementing a CAD/CAM platform may be very different from what you may be accustomed to, and that the prospect of this degree of change to your communications and operations is daunting and frightening. It is our hope that, through the following content and previous look at the benefits of CAD/CAM systems, you'll feel more comfortable exploring how you can utilize these technologies to better connect with your internal and external information flows to ultimately increase your product and service sales.

**Making Your Case**

Here are some key takeaways from a blog post related to paperless moldmaking, which can be achieved with the help of CAD/CAM platforms:

***Achieving Real Cost Savings with Paperless Moldmaking*** from www.moldmakingtechnology.com: "While the paperless manufacturing environment can clearly reduce costs through the elimination of printed drawings and machine instructions, the real cost savings from a paperless approach comes from a streamlined process with fewer steps and faster time to market."

- 3-D software for tool design can be much faster than traditional paper drawing-based methods
- Using the same CAD model for tool design and NC programming can save significant data conversion times and support fast design updates.
- Advanced data display on a 3-D CAD model can support rapid collaboration between supplier and customers.

Read the full article here, including example calculations of costs at the end:
https://www.moldmakingtechnology.com/articles/achieving-real-cost-savings-with-paperless-moldmaking

Here is another online source to help you understand your business case:

***The CAD Upgrade Handbook*** by Chad Jackson of engineering-matters.com and Life Cycle Insights with PCT Creo
"While innovation progresses in the CAD industry, many engineering and IT managers watch with a mix of excitement and trepidation about a CAD upgrade … Make no mistake: the promise of greater productivity, cost savings and better design is fairly self-evident. Along with those hopes come valid questions and fears."

Read the full article here:
http://www.lifecycleinsights.com/wp-content/uploads/publications/PTC-CADUpgrade-v06.pdf



## Build the Business Case and Begin Implementation *(continued)*

**What to Look for in a CAD/CAM Platform**

You've made your case. Now what? Here are some online resources to help you when choosing your platforms.

- 9 Criteria for Choosing a 3D CAD System, via Solidworks. www.solidworks.com/sw/docs/Top9_WP_2010_ENG_FINAL.pdf. This whitepaper by mechanical engineer, author, and consultant L. Stephen Wolfe is a compilation of nine criteria that users of 2D CAD should consider when shopping for their first 3D system.

- 5 Criteria for Choosing the Right CAD software, via Pinterest. https://www.pinterest.pin.com/322077810835637902/ This infographic describes key things to consider in CAD software selection.

**Change Management: Building the Case Requires Defining Your Business Requirements**

For most small and medium manufacturers, the prospect of adopting an CAD/CAM platform into your internal and external operations seems risky as it requires "unlearning" the methods and habits that you have used to run your business to this point. And it requires learning new technologies and procedures to remain relevant in a digital age.

There are many ways for you to get started along the path to using CAD/CAM. Check out this blog post by Rachel Burger from Construction Management, *"5 Steps to Get Started with CAD,"* for a succinct overview:
https://blog.capterra.com/5-steps-get-started-with-cad/

You also can use the tips below to make the case for change and immediately begin proving results:

- Understand the business value of CAD/CAM and set goals accordingly. Use our metrics outlined below as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating CAD/CAM into your existing manufacturing processes. This will help in resource planning if you're measuring the right benchmarks out of the gate.

- Focus on one or two key areas (such as a new part or order, or a medium production-volume part) first before adding complexity to your production process and supply chain.

- Focus on getting every employee on board with the benefits of CAD/CAM through peer education. Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision.

- Make them as knowledgeable as you possibly can, taking ownership of CAD/CAM initiatives. Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with new technologies and benefits. See below for more education resources and tips.

- Keep communication lines open during the trial-and-error portion of CAD/CAM implementation. Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to prototyping successful new business processes. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies from CAD/CAM. Breed risk-taking early.

## Build the Business Case and Begin Implementation *(continued)*

Part of change management also lies in understanding and planning for the **challenges you will encounter** in integrating CAD/CAM systems into your existing operations. Below are three challenges we've identified through our research and conversations with manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

● **Challenge 1**: **Time commitment and prioritization**. Many manufacturers, especially those small and medium in size, find it difficult to allocate precious time to adopt new technologies in lieu of other pressing priorities. In order to achieve results from CAD/CAM systems, it takes commitment from both leadership and those responsible for implementation. Start with part-time allocation of one or two employees and grow from there.

● **Make them as knowledgeable as you possibly can, taking ownership of CAD/CAM initiatives.** Innovative companies like GE promote "reverse mentoring" to foster understanding, create mutual empathy, and promote collaboration between disparate generations and team members. In reverse mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with new technologies and benefits. See below for more education resources and tips.

● **Keep communication lines open during the trial-and-error portion of CAD/CAM implementation.** Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to prototyping successful new business processes. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies from CAD/CAM. Breed risk-taking early.

● **Challenge 2**: **Strategic oversight and education**. CAD/CAM systems must be integrated into a manufacturer's overarching operations strategy. This takes foundational education for not only those leading the charge but all employees who are responsible for adopting the new operating system. See below for recommended educational partners.

● **Challenge 3: Budget availability and measurement**. Allocating budget for not only the software, but also support and training is vital. In addition, a few key metrics need to be established to measure the progress implementation and its impact. See the Metrics section below for possible metrics, but the actual selection will depend on your specific business strategy.

**Processes and Frameworks for Implementing CAD/CAM systems**

Integrating CAD/CAM systems into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks below to jumpstart your efforts. The frameworks in this section are presented to aid in your high-level strategic prioritization of CAD/CAM systems, and we recommend you search out specific frameworks for each platform and tactic chosen to guide your implementation.

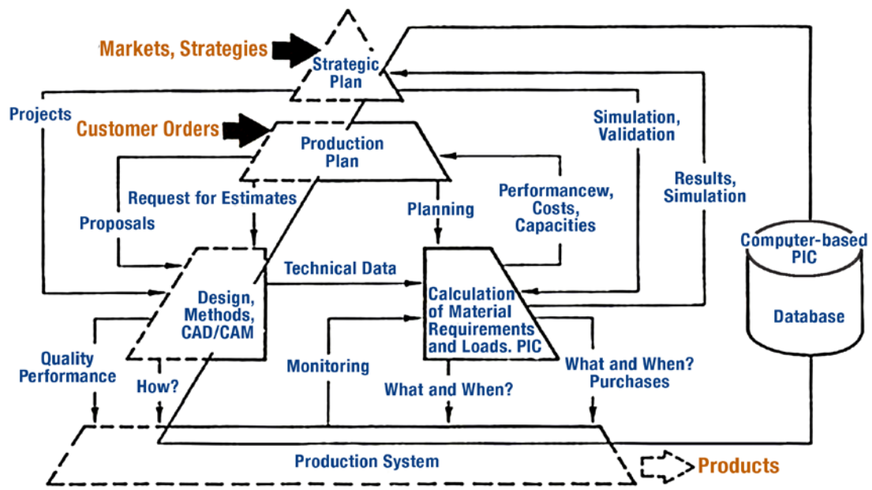


## Build the Business Case and Begin Implementation *(continued)*

**Framework 1: Computer-Integrated Manufacturing** [7]

Note: While it uses the term CIM, the framework encompasses CAD/CAM systems also. According to Wikipedia, "Computer-integrated manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process. This integration allows individual processes to exchange information with each other and initiate actions. Although manufacturing can be faster and less error-prone by the integration of computers, the main advantage is the ability to create automated manufacturing processes. Typically CIM relies on closed-loop control processes, based on real-time input from sensors. It is also known as flexible design and manufacturing."

*Figure 4: Computer Integrated Manufacturing control system* [8]



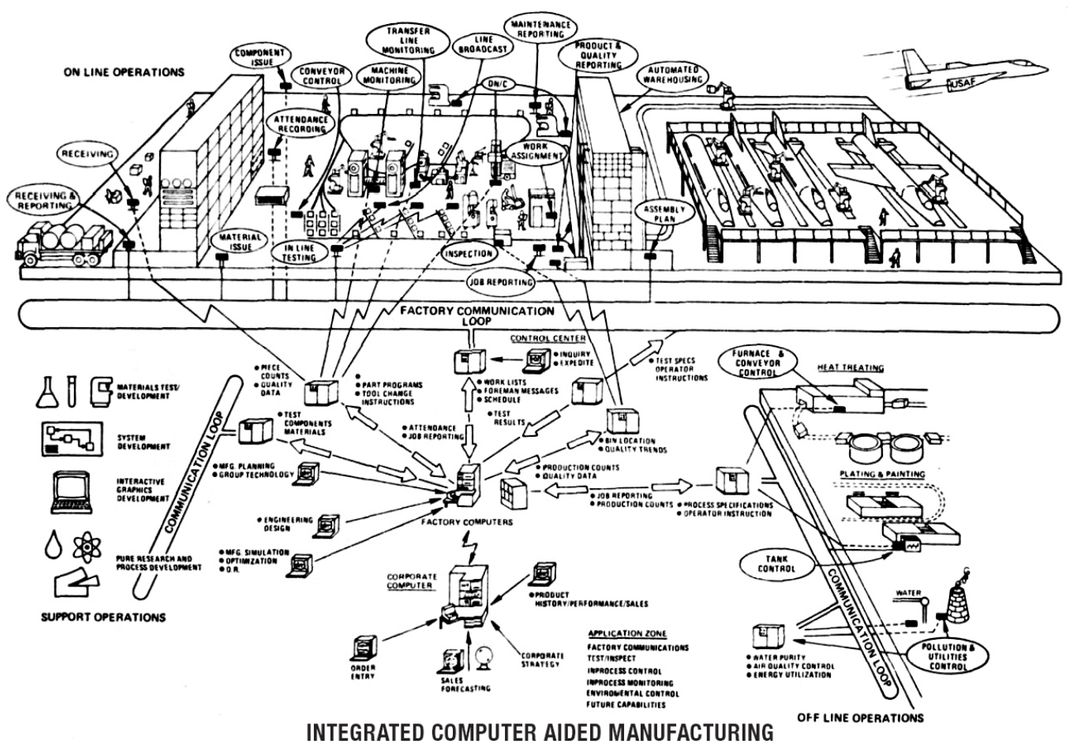

Credit: By Jean-Baptiste Waldner - "CIM: Principles of Computer Integrated Manufacturing", Jean-Baptiste Waldner, John Wiley & Sons, 1992, CC BY-SA 2.5

7 https://en.wikipedia.org/wiki/Computer-integrated_manufacturing
8 https://commons.wikimedia.org/w/index.php?curid=15233023

## Build the Business Case and Begin Implementation *(continued)*

**Framework 2: Integrated Computer-Aided Manufacturing (ICAM)**[9]
According to Wikipedia, "Integrated Computer-Aided Manufacturing (ICAM) is a US Air Force program that develops tools, techniques, and processes to support manufacturing integration. It influenced the computer-integrated manufacturing (CIM) and computer-aided manufacturing (CAM) project efforts of many companies."

*Figure 5: Integrated Computer Aided Manufacturing*[10]




Credit: By Dennis E. Wisnosky - An overview of the Air Force program for integrated computer aided manufacturing (ICAM). ICAM program prospectus. SME technical paper, Public Domain,

9 https://en.wikipedia.org/wiki/Integrated_Computer-Aided_Manufacturing
10 https://commons.wikimedia.org/w/index.php?curid=27152918



## Build the Business Case and Begin Implementation *(continued)*

**Resources Needed: Technology and Staffing**
Resources required to manage and implement CAD/CAM systems will vary by which area of your business that you've prioritized. As previously outlined, you must create a strategic plan for how ERP platforms will augment or replace your current operational processes. How and where to begin implementing elements of ERP needs to be strategic in order to avoid investing in the latest "bright, shiny technology" or hiring unnecessary talent. Use the following general checklist to assist in the process of planning for your hard and soft costs.

**Software:**
- There is a wealth of systems available, and they are constantly changing.
- You might perform an online search using the term "best small-business CAD/CAM."
- You may want to learn what systems your customers and suppliers are using now or planning for the future.
- Learn how the pricing of the software is calculated. It may be by user or by site. This can be important when looking at the future growth of your company.

**Hardware:**
- You will need to review your current systems and equipment to see how you are currently capturing and sharing data (it may be on paper).
- While most software runs on personal computers, there is usually a need for more processing power, memory, and raphics cards.
- You will need to consider how and who will be supporting whatever equipment you adopt.

**Employees and Hiring:**
- You will most likely need some expert assistance in implementing a CAD/CAM platform. You will also probably like to have that assistance to be on-site and face-to-face for some period of time. You may want to check for CAD/CAM integrators and the software that they support.
- You will need someone within your company to be the "owner" and project lead for the new system. This will require a significant amount of time in the start-up and also be needed to train new or additional people in the future.
- As mentioned in the change management sections above, there will be a significant amount of your and your people's time and energy devoted to this implementation. You will be changing the way your company's work gets done, not just adopting a computer system.




## Build the Business Case and Begin Implementation *(continued)*

**"Quick Wins" to Get Started with CAD/CAM systems**
Here are a few areas on which to focus in order to jumpstart your preparation of CAD/CAM element implementation:

- **Tip 1:** Begin mapping your existing design and manufacturing processes. This is probably the best thing you can do to prepare. There are local and online resources to help with this, many of which are listed in the following section.
- **Tip 2:** Pick out a new part or order to begin your 3D modeling experience.
- **Tip 3:** Connect with a local CAD vendor or community college to try out CAD software.
- **Tip 4:** Find or appoint an internal Project Manager. You will need someone within your company to be the owner of the new system. This is the only way to sustain the implementation and train additional people.
- **Tip 5:** Identify the information bottlenecks where you are losing time. Where are the places that either design or manufacturing have to wait before they can move to the next step?
- **Tip 6:** Ask your customers about their plans for future CAD/CAM systems. While systems are getting much better at exchanging data, it makes sense to be proactive in understanding what is going on in your whole supply chain. You may also find others who are sharing your implementation journey.
- **Tip 7:** Reach out to people in the community. You've already taken the first step by reviewing this Guidebook. Next find opportunities to network with others interested in the same topic through professional organizations or informal gatherings.



## Build the Business Case and Begin Implementation *(continued)*

**Metrics for Success: How to Measure Impact**
When setting your objectives for your CAD/CAM platform, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance against where you are today, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

**How to Measure the Success of Your CAD/CAM Implementation:**

- Lead time to deliver a design
- Lead time to deliver a quote
- Number of engineering changes needed
- Number of downstream quality issues in manufacturing or design
- Number of "rush" shipments
- Actual margin per order

Here some online resources from Solidworks that also offer insight into the measurement process:
*Productivity and Return on Investment from SolidWorks 3D CAD Software*. While this ROI is for a particular software, the measurement principles would be the same for other software. It shows there was a 15-25% productivity improvement on engineering change orders. Read the full case study here: www.solidworks.com/sw/images/content/Other/ROI_ReportSolidWorks_2006.pdf

**How to Measure the ROI of Better Engineering Design**
According to this case study posted by Lucas Leão, "The need to get products to market more quickly is prompting companies to take a closer look at how work is done in CAD. Advanced capabilities within CAD tools can allow companies to remove tedious activities and improve design productivity. This article takes a look into the capabilities of CAD software and how it can be used to improve the engineering design process." Read the full case study here: www.e3seriescenter.com/modern-electrical-engineering-blog/how-to-measure-the-roi-of-better-engineering-design




## Find Help with Assets & Partners

**Advanced Manufacturing International:** Manufacturers want to produce products faster-better-cheaper. At AMI, we provide cost-effective, easy-to- implement digital manufacturing technologies for small to medium size manufacturers (SMMs). Our dedicated industry experts collaborate with SMMs to find their pain points and suggest smart supportable technology solutions. Our broad network of manufacturers, solution vendors, and academia – along with our targeted focus on SMMs – is a powerful combination to help your company achieve great results from smart digital manufacturing technology.

**Coursera:** Provides universal access to the world's best education, partnering with top universities and organizations to offer courses online. Every course on Coursera is taught by top instructors from the world's best universities and educational institutions. Courses include recorded video lectures, auto-graded and peer-reviewed assignments, and community discussion forums. When you complete a course, you'll receive a sharable electronic Course Certificate.

**Economic Development Administration:** The U.S. Economic Development Administration is designed to establish a foundation for sustainable job growth and the building of durable regional economies throughout the United States. They offer resources at the national and regional level and have opportunities for government funding.

**Hiring Solutions:** Robert Half Technology specializes in placing application development, systems integration, information security, infrastructure management, networking, database development, help desk and technical support professionals in project, contract-to-hire and full-time positions.

**Manufacturing Extension Partnership (MEP):** MEP is a public-private partnership with Centers in all 50 states and Puerto Rico dedicated to serving small and medium-sized manufacturers. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in positions to develop new customers, expand into new markets and create new products.

**Manufacturing.gov:** Manufacturing.gov is a national advanced manufacturing portal and information clearinghouse high-lighting the Manufacturing USA program. Formally established in 2014, Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

**Manufacturing USA:** Manufacturing USA is a network of regional institutes, each with a specialized technology focus. The institutes share one goal: to secure the future of manufacturing in the U.S. through innovation, collaboration and education. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. Each institute is designed to be a public-private membership organization that provides vision, leadership, and resources to its members.

**NAM Manufacturers Marketplace:** NAM lists hundreds of thousands of leading manufacturers in the U.S., representing small and large manufacturers in every industrial sector and in all 50 states and Puerto Rico. They offer a comprehensive search capability to help you identify and engage with the possible partners for unique supply chain needs.

**NIST:** The National Institute of Standards and Technology (NIST) is a measurement standards laboratory, and a non-regulatory agency of the United States Department of Commerce. NIST's mission is to promote innovation and industrial competitiveness. NIST's activities are organized into laboratory programs that include Nanoscale Science and Technology, Engineering, Information Technology, Neutron Research, Material Measurement, and Physical Measurement.

**Udemy:** A global marketplace for learning and teaching online where students are mastering new skills and achieving their goals by learning from an extensive library of over 55,000 courses taught by expert instructors.



## Appendix

**Glossary: CAD/CAM Terms**
Definitions provided for educational purposes as described by the source unless otherwise noted.

This Wikipedia article provides a good overview of the CAD landscape and the common definitions that surround it: https://en.wikipedia.org/wiki/Computer-aided_design

Should you need a more detailed listing of specific terminology used in CAD/CAM systems, see this extensive listing from the University of Virginia: http://people.virginia.edu/~rlk3p/classes/dram718/Reference/Glossary/Terms.html

**Application:** A computer program. A CAD application, also called and add-on or plug-in, can carry out complex tasks specific to a particular drawing problem. CAD applications run in tandem with the CAD software to perform specialized or automated tasks. Some examples of CAD applications specific to theatre include programs to automate the drawing of construction drawings and light plots.

**Arrowhead:** The part of a dimension or leader which points to an object or extension line. Arrowheads usually can be drawn automatically in several styles or shapes.

**Attribute - AutoCAD**: Information or data about a drawing object which can be hidden or appear in the drawing as text. Often this information can be extracted from the drawing and used in a spreadsheet or other program.

**Attribute - Vectorworks**: Color, Pattern, or Marker Style of an object.

**Bezier curve:** A curve defined by endpoints, tangent lines, and control points at the ends of the tangent lines. Altering the length and angle of tangent lines alters the shape of the curve.

**Bitmap:** A pixel based graphic or image inserted in a drawing. Bitmaps can be sized but not edited with most CAD programs.

**Block:** (AutoCAD terminology), see symbol.

**CAD:** Computer-aided design. Common CAD programs include: AutoCAD, Vectorworks, Microstation. Programs differ greatly in features, complexity, cost, and hardware requirements.

**CADD:** Computer-aided design and drafting.

**Cartesian coordinates:** See coordinates.

**Center point:** The defining point at the exact center of a circle, arc, regular polygon or ellipse.

**Chamfer:** A diagonal line which connects points on two intersecting objects such as an angled corner. The chamfer tool is an editing tool.

**Class:** A category of objects (Vectorworks) to which objects can be assigned and then manipulated as a group.

**Color:** A property of any drawing object which defines the color in which it appears on the screen and (possibly) the color in which it is printed. Color is often associated with an object's layer or class assignment and can be used to determines how that object will appear on a printout with regard to line thickness and line type.




## Appendix *(continued)*

**Component:** (Generic CADD terminology) See symbol.

**Constraint:** A drawing tool which limits drawing to a particular point, line or angle. Some common constraints are snap to grid and ortho.

**Control points:** Points determining the path and shape of a Bezier curve.

**Coordinates:** A system of numbers used to locate a point or object in a drawing. In the Cartesian coordinate system 2 numbers x and y are used to describe the location of a point in the horizontal and vertical dimensions respectively. 3D CAD programs add the z coordinate which describes distance in the third dimension. In the Polar coordinate system a point is described by a distance and an angle where 0° extends horizontally to the right.

**Cursor:** The screen symbol or icon which represents the current mouse location relative to the drawing window or viewport. The cursor may appear as crosshairs or another symbol based on which command is active.

**Curve:** A complex entity created by the definition of endpoints of spline curve sections. Note, the type of curve you use determines the types of editing tools or functions that may be performed on it. See also Bezier curve.

**Datum:** A temporary coordinate point set by the user which can be used as a snap point or reference point when drawing.

**Dimension line:** A line, usually with an arrow indicating the direction and distance of a drawing dimension. See also extension line.

**Drawing database:** The central part of a CAD drawing. A list of all objects which exist within a drawing along with all parameters and definition points.

**Drawing units:** See units.

**Drawing window:** See viewport (AutoCAD).

**DXF:** Drawing exchange format created by Autodesk. An ascii text file format describing drawing data and settings to translate drawings between programs and formats. Note: DXF is not a standardized format and different programs convert or ignore different entities found in a DXF file.

**Edit:** The process of modifying a drawing object or entity.

**Editing tools:** A class of drawing commands used to modify drawing entities or objects. Common edits include: trim, rotate, move and stretch.

**Ellipse:** A CAD drawing object defined by a major axis, minor axis and centerpoint. An ellipse may also be constructed out of arcs and line segments. An ellipse created in this way is not mathematically a true ellipse but is an easier object to edit.

**Environment:** The over-all setup of a CAD program including all drawing settings, colors, units, tool palettes, etc. comprise the drawing environment.



## Appendix *(continued)*

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## Appendix *(continued)*

**Explode (AutoCAD):** A common command which break objects apart into their component pieces. Explode most often works on symbols, breaking them back into their component pieces. In some CAD programs other entities are explodable such as text lines, polylines, or other complex objects.

**Extension line:** The line which extends from a measured line or object to the dimension line, showing the extent of the measured distance.

**Fillet** (Rhymes with skillet): An arc connecting endpoints of two intersecting lines or objects, often a rounded corner.

**Fill:** A complex object defined by a series of points or a bordering object such as a circle or polyline which fills the defined area with solid color. The display of a fill is highly dependent upon the display or printer/plotter being used. See also hatch.

**Font:** The typographic style property of text. Fonts may be drafting style (one line thickness) or typographic such as that being used in this document. Fonts are commonly managed by the operating system, not the CAD program and can be difficult to translate from one computer to another or one CAD program to another.

**Grid:** A drawing tool which is usually a pattern of regularly spaced dots or lines which make the alignment and drawing of objects easier. A snap to grid tool constrains or locks all drawing to grid points only.

**Group:** A collection of objects which can be manipulated as one object.

**Handles:** See object handles.

**Hatch:** A complex object defined by a series of points or a bordering object such as a circle or polyline which fills the defined area with a repeating pattern of lines. Hatches have a scale property which determines the size and density of the repeating pattern. See also fill.

**Layer:** A property of any drawing object. Usually objects are organized onto different layers for organizational purposes and ease of drawing, viewing and editing. Layers often can be named and can have default colors or other properties associated with them. Vectorworks Layers have the added ability to have associated properties of scale, view, and projection. These added properties of Vectorworks layers are similar in function to AutoCAD paperspace.

**Leader:** A line with an arrowhead and attached text pointing at another object.

**Leader line:** The line portion of a leader connecting the shoulder to an arrowhead.

**Line:** A CAD object defined by two endpoints.

**Line type:** A property of any line, circle, curve, or arc. Line type describes a repeating pattern of lines and spaces. Lines may be solid, dashed, alternate, etc. The additional property of line type scale determines how often in a given distance a pattern of lines and spaces repeats. Scale may or may not be affected by the scale of the drawing view.

**Line width:** A property of any line, circle, curve, or arc. Line width describes how thick a line or other object appears on the screen or on a printout. Different CAD programs use different schemes for achieving line width.

**Locus:** A drawing object with a single reference point and no physical dimension.



## Appendix *(continued)*

**Macro:** A sequence of commands recorded and saved for easy playback. Well designed macros can save a great deal of drawing time. See also script and application.

**Major axis:** The longer axis of an ellipse.

**Manual entry:** The process of entering points manually by typing coordinates as opposed to clicking within the viewport or workspace.

**Markers:** A line marker is used to mark the end points of lines.

**Minor axis:** The shorter axis of an ellipse.

**Move:** A drawing editing tool which moves objects or selection sets to a new drawing location by changing all definition points by a given distance.

**Nested:** Objects inside of other objects. Symbols may be nested within other symbols. Drawing commands can be nested or executed while other drawing commands are active. Macroprogramming objects can be nested in terms of their control structure.

**Object handles:** In a windows CAD program the handles which appear when an object is selected. Handles often allow objects to be stretched, rotated, or moved. Note: in AutoCAD handles refer to arbitrary names assigned to each drawing entity in the drawing database so that macros and applications may refer to specific entities directly.

**Offset:** The distance between two objects. Offsets are often used to draw parallel lines or determine the location of a dimension. In AutoCAD a command which creates a duplicate of an object at a specified distance.

**Origin:** The point in a drawing with the x,y coordinates of 0,0.

**Ortho:** Short for orthagonal. Usually refers to objects placed horizontally or vertically within a drawing. Ortho mode is a constraint which limits all drawing to regular 90° angles. In some CAD programs other ortho angles and modes may be set.

**Pan:** The process of altering the drawing view by moving the viewpoint laterally relative to the drawing.

**Polar coordinates:** See coordinates.

**Polygon:** A complex object composed of three or more straight lines in a closed figure. Polygons are treated differently by different CAD programs. Often a polygon is simply a closed polyline entity.

**Polyline:** A complex object composed of two or more lines, curves, or arcs which have contiguous endpoints. A closed polyline or polygon has its endpoints joined into a closed form. Polylines are more difficult to edit than a form drawn with individual line segments, but offers some advantages when editing or building surfaces and 3 dimensional objects.

**Primitive:** The simplest drawing objects from which all objects are built. Common 2D primitives include: point, line, circle, arc, and ellipse.

**Prompt:** A program message often located on the programs status line.




## Appendix *(continued)*

**Radial copy:** Also Duplicate Array (Vectorworks). An editing command which creates multiple copies of objects by copying them around a centerpoint for a given angle.

**Real scale:** Objects in a CAD program a drawn at full scale or 1:1. See scale.

**Redraw:** The process by which the video display is updated cleaning up any unwanted marks or construction points. See also regenerate.

**Reference points:** Points associated with drawing objects which allow an object to be selected, grouped, and manipulated. Reference points are often not visible. One example is the reference point of a text line which is often found at the lower left hand corner of the text line. To select a text entity it is often necessary to click near this invisible point or include it within a selection window.

**Regenerate:** The process by which the view updated from the drawing database cleaning up any unwanted marks or construction points. Similar but more comprehensive and time consuming than a redraw. Note: on some CAD packages these processes are synonymous.

**Relative coordinates:** Drawing coordinates which when manually entered are interpreted as relative to the last point entered. In AutoCAD relative coordinates are entered by preceding the coordinate pair with the @ sign such as @2,3.

**Resolution:** The clarity or degree to which individual elements can be discerned on a monitor or print/plot. Common monitor resolutions include 600x800 and 1280x1024 measured in pixels. Common laser printer and plotter resolutions range from 300x300 to 600x600 dots per inch. Resolution of these devices determines how accurate a printout will be or how accurate an object will appear on the screen. The actual resolution of objects saved in the drawing database is usually much higher to insure a high degree of accuracy. When drawing objects are viewed on screen or plotted their size and position is rounded to the nearest dot at the resolution of a given device.

**Rotate:** A drawing editing tool which rotates objects or groups of objects based on a center of rotation and an angle.

**Rubberbanding:** A feature of many CAD programs which shows how a line or other object will look before it is actually placed. An example is with the line command. A starting point is selected after which a line appears rubberbanded between the first point and the cursor. As soon as another point is selected the actual line is drawn and the rubberband moves to the next point.

**Scale:**
1) An editing tool which changes the size of an object relative to percentage. Some objects can be rescaled to different percentages in the x and y directions.
2) The relative size at which a drawing is viewed on the screen or printed/plotted. Scale is often represented as a ratio where 1:1 is full scale, 1:12 = 1” =1’-0”, 1:24=1/2”=1’-0” etc.

**Script:** A list of drawing commands which can be typed in a text editor and then loaded and executed with one command. Different scripting methods are supported by different CAD programs. Scripts are useful for performing repetitive tasks such as drawing setups. **Selection set:** One or more objects selected for action with a single command. Often items are selected this way by drawing a window around them or holding down the shift key while selecting them individually.



## Appendix *(continued)*

**Shoulder:** The horizontal part of a leader line.

**Snap:** A drawing tool which locates points exactly by finding an existing point within the drawing database which is closest to a point selected with the on the screen. Some common snaps are: snap to nearest point, snap to midpoint, snap to intersection of two lines, etc.

**Snap to grid:** A drawing constraint which forces all points picked to fall on the current grid.

**Stretch:** An editing tool which moves some of the points which define an object and leaves others.

**Trim:** A drawing editing command which causes one object to end exactly at another. Trim points are calculated mathematically so they are exact. Some complex objects such as curves cannot be trimmed to.

**Symbol:** A collection of drawing objects defined as a single complex entity. Defining and using symbols speeds drawing and makes drawing files more compact. Symbols are also called blocks (AutoCAD).

**Tangent:** A line which intersects a circle, ellipse or arc at only one point. Tangent lines to Bezier curves define the shape of the curve.

**Toggle:** A drawing control or setting which is either on or off. Subsequent execution of the command reverses the state of the parameter. One toggle is the display grid command.

**Units:** Units of measure represented by numbers in a CAD program. Usually units are inches or feet, but can be anything from millimeters to light years.

**Vertex:** A point defining the junction of a segment within a polyline or polygon.

**View:** The graphical representation of the geometry stored in the drawing database which appears in the drawing window or viewport. A view has a center point and a scale or zoom. Multiple views of one drawing may be open in separate windows or viewports simultaneously.

**Viewport:** The window or frame within which a view of the drawing is visible. In some complex CAD programs viewports are considered complex objects and can be placed in drawings. Many programs also support the use of multiple viewports which can simultaneously show different parts of the same drawing. This is especially important when working in 3D.

**Zoom:** The way the view is changed by magnifying or reducing the image on the screen. Zoom scales the view only and does not affect the actual size of drawing objects.


NOTES

OUR EXPERTISE. Our renowned industry experts led the development of many Industry 4.0 technologies and know how to successfully apply the right technology to improve your value stream. They are well-qualified to assess your production and provide expert consultation at a cost that only a non-profit company can offer.

OUR PROCESS. Using lean Six Sigma methods, we work with you to develop a customized fit for your needs. We provide a customized roadmap to integrate our technology into your manufacturing process so that operators and supervisors, planners, and engineers can make better decisions from shop floor to top floor.

OUR TECHNOLOGY. Our product strategy is to offer ultra low-cost solutions coupled with expert consultation. For example, our IoT LIMS™ appliance is a data gateway from your manufacturing floor to our Solution Family™ software. Using open standards like MTConnect™and OPC UA™, our technology is highly versatile, easy to install, and easy to manage.

OUR COMMITMENT. Installation is usually a day and we remain on site to insure proper set-up and for training. Additional help is available by phone or video conferencing. We are also committed to helping you expand and develop your technology applications through additional consulting and technology applications.

OUR COMMUNITY. You will be enrolled in our membership program for one year at no charge. We provide access to product user communities for “peer-to-peer” learning to address the cultural changes to execute a successful digital transformation. In addition, we will continue to offer assistance through virtual meetings and product workshops.

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