



THE OHIO STATE UNIVERSITY
OHIO MANUFACTURING INSTITUTE

OHIO TECHNOLOGY ROADMAPPING REPORT

Prepared for the Ohio Development
Services Agency

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September 2015

Executive Summary

The global marketplace and technological changes are placing increased demands on manufacturers in the State of Ohio, resulting in a search for approaches to connect industry needs to technical resources. This report outlines the work being conducted on the Ohio Advanced Manufacturing Technical Network by the Ohio Manufacturing Institute with funding from the Ohio Development Services Agency and in cooperation with partners, including the Ohio Manufacturing Extension Partnership (MEP), Ohio Manufacturers' Association, academic institutions and numerous manufacturers.

In the past year, four technology roadmaps for Ohio were undertaken in molding, machining, joining and forming, and additive manufacturing. These technology roadmaps are designed to provide a collective and clear industry-driven focus that can be leveraged by technical centers, technology organizations, MEPs, academia, and government to guide resource allocation and future technological development. Manufacturers involved in these technical processes identified four issues that were of the greatest concern and required support external to the manufacturing supply chain:

1. Workforce
2. Advanced Materials
3. Smart Manufacturing
4. Innovation and Commercialization

This report also outlines the work being done to facilitate manufacturers becoming engaged and connected with the technical resources in the state via the Ohio Advanced Manufacturing Technical Network. The purpose of this network is to provide a central repository of information about the technical resources in Ohio and a means of effectively accessing and utilizing those resources. The Network is designed to create value for both the manufacturers and technical resource organizations by providing an exchange of knowledge, information, value, resources, and expertise.

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The researcher publishing this work acknowledges the contribution made by the State of Ohio as described in Article 8 of this Agreement. Although the report was prepared with financial support from the State, the content of this report reflects the views of Grantee and does not purport to reflect the views of Grantor and/or that of the State of Ohio.

1. Introduction

Manufacturing is a crucial industry sector in Ohio. Even though manufacturing has enjoyed a marked uptick in re-shoring, firms are still facing significant challenges post economic decline. This report outlines Ohio Manufacturing Institute's analysis of technology roadmap results for four manufacturing processes in Ohio: molding, machining, joining and forming, and additive manufacturing under a grant from the Ohio Development Services Agency (ODSA). It also presents the Ohio Advanced Manufacturing Technical Network and the work to link manufacturers with the technical resources in the state.

The purpose of this study is to understand the technological challenges facing manufacturers in Ohio and connecting them to the technical resources provided by support organizations. First, we outline the purpose and structure of the Ohio Advanced Manufacturing Technical Network that describes the resources available to manufacturers operating within the state. Next, the four technology roadmaps as outlined above are examined to understand the technical needs of manufacturers. We then discuss common themes and technological trends resulting from the analysis. The technical resources available to manufacturers in Ohio are considered, including some of the challenges that manufacturers have encountered in partnering with them, and how the Ohio Advanced Manufacturing Technical Network can assist in overcoming these challenges. And in the final section, we present specific recommendations going forward for how to best utilize the network.

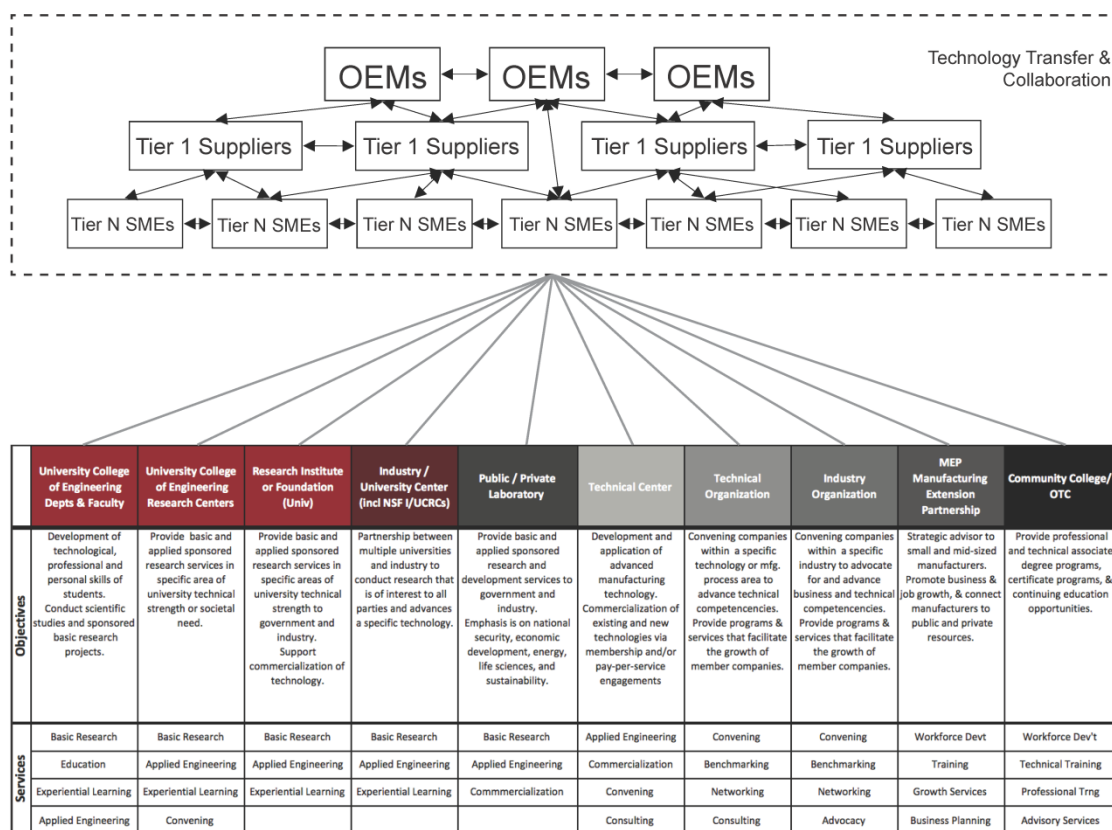
2. Ohio Advanced Manufacturing Technical Network

Many technical resources in the state of Ohio are available to support manufacturers. However, the complexity of the system and the different objectives and roles of the various resources can make it difficult for manufacturers to navigate to access the specific resources that they need. In many cases, manufacturers are not even aware of the existence of helpful resource organizations. Industry partners identified the need for a network that would link manufacturers with the technical resources. This also requires some mechanism for identifying and tracking the technical resources in the state and providing feedback on how these resources should be used and developed in order to continue to support manufacturing in Ohio. The Ohio Advanced Manufacturing Technical Network was developed as a response to these concerns (see Figure 1). Initially, a landscape and utilization of the technical resources was conducted. The resources, which are mostly situated outside of supply chain interactions, have different objectives, strengths and capabilities. Enterprises have engaged each organization within the Ohio Advanced Manufacturing Technical Network at different levels. Figure 2 presents a typology of the technical resources in Ohio, along with their utilization rates by the level of manufacturer. The chart organizes the resources from the more basic and novel engineering research at research universities to industry consulting at Manufacturing Extension Partnerships (MEP) and workforce education programs at community college and technical centers.

One of the ways in which resources can be evaluated is the innovation process that they are targeting, or technology readiness levels (TRL), a measure of how close a technology is to

commercialization (market deployment). As assessed on a spectrum from 1 to 9, with 1 being for basic research and 9 being for complete deployment¹, research universities are primarily focused on TRL levels of 1-3. MEPs, on the other hand, generally focus on disseminating current best practices that are at the higher end of the spectrum (in the 7-9 range). The assumption that the closer that a resource is to the commercialization end of the spectrum, the more likely it is to be used by industry is actually very dependent on the type of manufacturer. Major OEMs are far more likely to use R&D resources at every point in the process than are small and medium enterprises. Regardless of the resource or type of manufacturer, the technical resources in Ohio are underutilized by the manufacturing supply chain (see Figure 2). This also means that there is significant opportunity to further help manufacturers in their innovation needs.

Figure 1: Ohio Advanced Manufacturing Technical Network



The Ohio Manufacturing Institute was charged by ODSA to improve the utilization of the vast array of technical resources available in Ohio by helping to make these resources more visible to manufacturers (particularly small and medium enterprises) and also by aligning the resources to the needs of industry. To accomplish these objectives, four specific goals were developed:

1. Develop mid- and long-term technology roadmaps and strategies

¹ This is scale used by NASA and the U.S. military.

2. Develop proposals for collaborative research
3. Evaluate the statewide technical support structure and resources
4. Propose future technical support additions and enhancements

3. Technology Roadmaps

OMI took a novel approach to analyzing the manufacturing industry by choosing to examine key manufacturing processes rather than industry verticals (industry segments). These original six manufacturing processes were:

- i) Molding
- ii) Machining
- iii) Joining and Welding
- iv) Additive Manufacturing
- v) Casting
- vi) Stamping

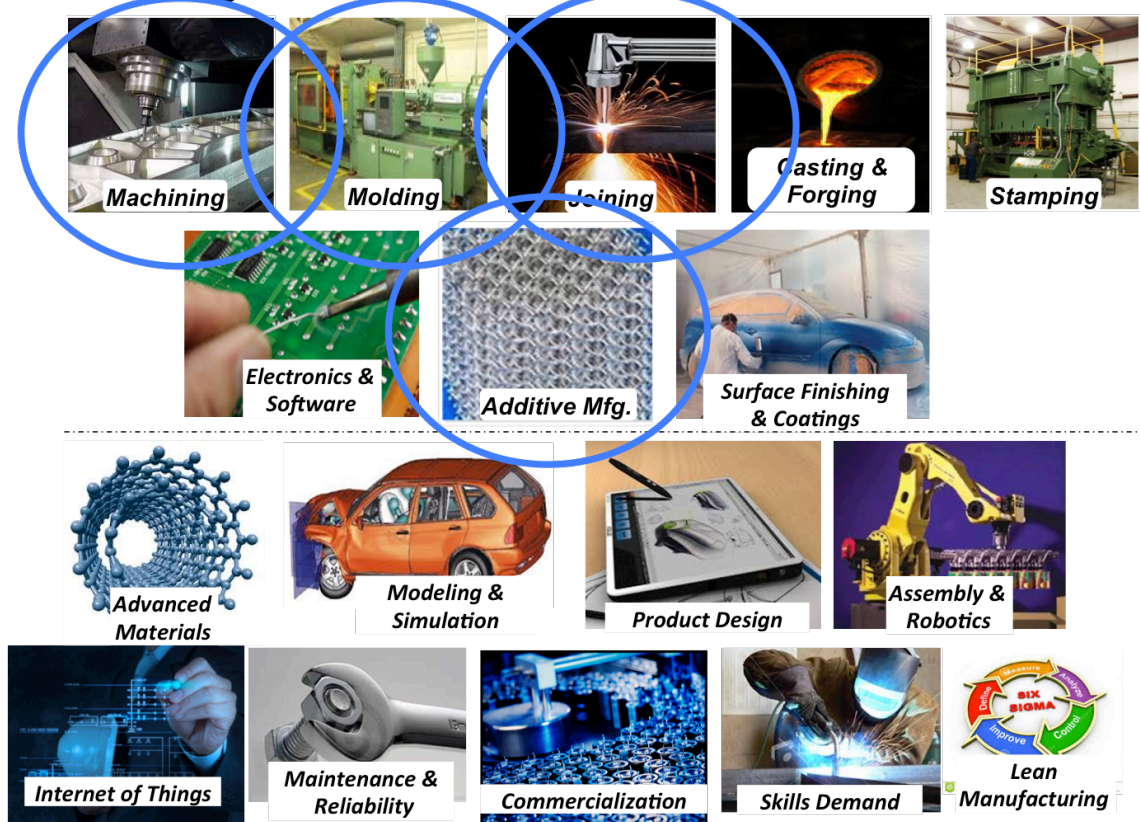
In order to develop a mid- and long-term strategy, four pilot technology roadmaps, three in traditional processes and one emergent manufacturing technology, were undertaken by organizations that understand these areas to determine the industry needs and to develop a collective and clear industry-driven technology strategy (See Figure 2). These were:

- Molding by PolymerOhio
- Machining by TechSolve
- Joining and welding by EWI
- Additive manufacturing by FastLane.

Figure 2: Manufacturing Processes (four original technology roadmaps in circles)

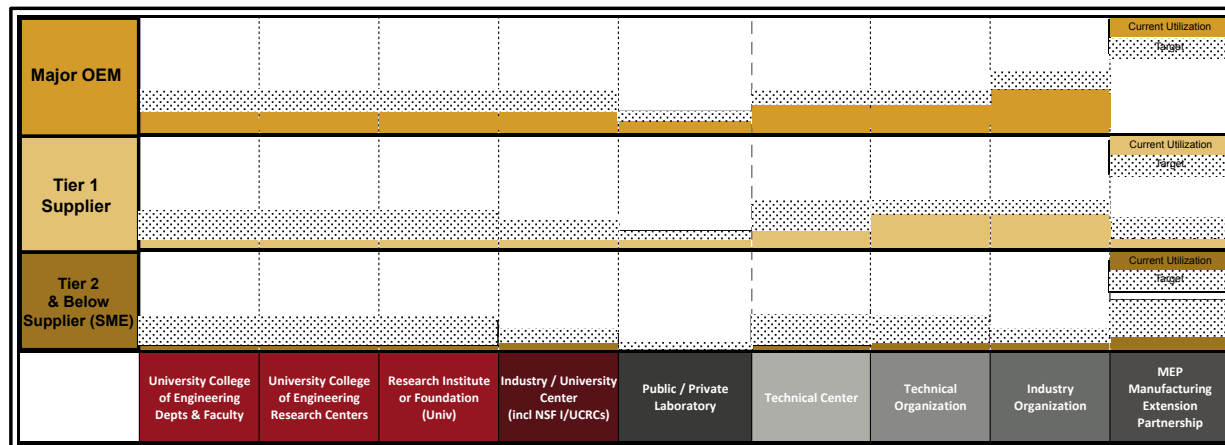
Advanced Manufacturing Technical Network

Manufacturing Processes



In summary the goal of the technology roadmaps is to develop a collective and clear industry-driven strategy that can be leveraged by technical centers, technology organizations, MEPs, academia, and government to guide resource allocations. The results of these roadmaps are to improve alignment between industry needs and state technical resource offerings and to inform, influence and optimize industry and government funding to develop pre-competitive technologies. In order for this goal to be accomplished, the **entire technical support ecosystem must be engaged for industry-wide results**. The next steps are two-fold: for working groups to be identified to convene and pursue additional collaborations, including regional cluster development; and increased networking among manufacturers and state technical resources that lead to direct, effective relationships among entities.

Figure 3: Resource utilization by type of resource and level of manufacturer



Based on research conducted during Phase 1 of the ODSA grant, specific input, processes and output were put in place to guide the approach the different entities used to convene and complete the technology roadmap for each manufacturing process. Each roadmap followed the same basic outline, though each participating organization was able to conduct the roadmap as seemed best for the process they were investigating. The industry and pre-work for each documented the manufacturing process and industry trends through an evaluation of: 1) process technology; 2) product technology; 3) materials; and 4) new industries. Industry technical needs and technical challenges also were identified. The technology roadmaps were supported by a review of the current fundamental and applied research in the field. Each roadmap includes a detailed description of the process followed.

The process the organizations responsible for the roadmaps followed was facilitated and structured in order for industry to:

- Discuss, evaluate, and prioritize trends, critical needs, and challenges
- Develop manufacturing process technology roadmaps
- Identify and prioritize collective research topics/opportunities by
 - Performing SWOT analysis of potential projects
 - Identify/confirm stakeholders
 - Identify potential providers and research entities
- Validate findings with broader range of industry
- Identify and facilitate other potential collaboration opportunities among industry, academia and government
- Summarize and disseminate results to consortium and others

Several important questions come from these results. The first is to understand what manufacturers are requesting from the technical resources; that is, what are the technical needs of

manufacturers in Ohio? The second question is what can then be done to link manufacturers with the technical resources that will address these needs.

The results of these four pilot manufacturing processes roadmaps (referred to below as “technology roadmaps”) are described below and appended to this report.

3.1 Molding (PolymerOhio)

Molding is a process of shaping liquid or pliable raw material into a desired shape, typically by using a rigid frame or mold. The process uses a variety of material, including: thermoplastics, thermosets, rubber, ceramics, concrete, and various metals. There are many different types of plastic molding that shape plastics into desired parts. Injection molding forces melted plastic into a mold to create desired parts. Compression molding presses plastic between two heated molds to form parts. Extrusion molding extrudes thermoplastic pellets into long tubes. Blow Molding shapes plastic with air in a closed mold. Gas-assisted molding uses gas, rather than air, to shape the part. Rotational Molding, also known as rotomolding, turns the plastic at low speeds while being heated using centrifugal force to shape the plastic. Thermoforming forms sheets of pre-extruded rigid plastics through vacuum forming (Piazza and Alexander, 2015d; Plasticmoulding, 2015).

The molding technology roadmap was conducted by PolymerOhio. The full report is available in Appendix A. PolymerOhio interviewed a sample of the over 1500 polymer manufacturers in Ohio, focusing on thermoplastics and thermoset molders. The scope of the technology roadmap was narrowed to ensure that the review could be done in a timely manner. The review by PolymerOhio focused on four technologies: injection molding of thermoplastics; blow molding of thermoplastics; molding of thermoset materials; and molding of rubber. It explicitly excluded: extrusion or pultrusion molding; shape-changing processes like thermo- or vacuum-forming; and specialty processes.

Polymer manufacturers do not easily incorporate new technologies or innovations. Changes come either through customer requests or from vendors. Materials technology are primarily developed and controlled by large chemical companies.

Finding qualified and capable workers at all levels is the biggest challenge for 36 percent of manufacturers interviewed. The next highest reported challenge came from approximately 31 percent of manufacturers concerned about the increasing demands of customers. Customers expect manufacturers to have greater capability and to supply perfect parts (zero defects) faster. At the same time, there is greater competition, so manufacturers must operate as leanly as possible. Thus, it is not surprising that 28 percent of manufacturers identify financial pressures and the ability to reduce costs as a significant challenge. Only five percent of manufacturers looked at specific and specialized technology needs as one of their priorities.

Other technology roadmaps published in the United States have indicated workforce training and development is an important issue for the molders (Piazza and Alexander, 2015d). R&D and innovation are viewed as critical for the long-term success of the manufacturers. Strengthening manufacturing networks, creating partnerships between manufacturers and universities, and providing

them with support are also considered crucial. Some states are using incentives, subsidies, and tax credits to strengthen manufacturing and create a “pro-business” environment.

3.2 Machining (TechSolve)

Machining is the process of removing material and shaping a work piece using machining tools, such as turning tools (e.g., lathes), milling machines, grinders, and drilling tools, cutting tools (e.g., saws and shears), boring, polishing, and finishing tools (Thomasnet, 2015). Metals are typically the material of choice, followed by plastics, rubber and paper.

The technology roadmap for machining was managed by TechSolve with the research support of the Maxine Goodman Levin College of Urban Affairs at Cleveland State University. The Machining Technology Roadmap report is in Appendix B. Initially, a survey was sent to manufacturers, followed by targeted interviews and focus groups. Respondents to the survey represented a cross-section of industries (including automotive, aerospace, and energy) and level of respondents (including senior-level managers, plant managers, and employees).

Machining manufacturers are a diverse group. Some focus on consumer products or support other small businesses, while others are connected to larger industry segments, such as aerospace. Thus, finding commonality in their problems and operations can be difficult. Typically machining manufacturers have smaller volume orders and less standardization.

Like other types of manufacturers, machining firms are experiencing difficulties with their workforce. A third of those surveyed indicated that they could not find workers with the skills that they needed, while 19 percent remarked that they could not find employees with enough experience and another 19 percent said that they could not find workers with the right soft skills.

Manufacturers are also confronted with changing customer expectations and pressures to lower costs. They find it difficult to find internal resources to innovate. Most innovation comes externally, often from customer demands or from suppliers making suggestions on product or process improvements. Innovation investments are often for capital expenditures (e.g, buying new equipment), and not development of personnel; 57 percent of manufacturers expect to make this type of investment in the next three years.

The two technically focused issues for machining manufacturers are the integration of new materials and the adoption of advanced computer technologies. New materials such as ceramics and advanced high strength steels and stainless steel require new or modified tooling and techniques. Machining and forming manufacturers are also concerned about integrating advanced computer technologies into manufacturing processes. Smart manufacturing – information networking, monitoring, and connecting – are transforming many aspects of production and logistics. These technologies create the potential to catch and correct production and quality problems quickly. At the same time, they create the needs for computer and technology skills that have not been previously needed.

Other technology roadmaps in the United States have highlighted several issues (Piazza and Alexander, 2015b). Innovation and the development of new technologies are key to continued success and prosperity, as is addressing workforce issues. Another important issue discussed in other roadmaps is energy efficiency and sustainability. Reducing energy consumption and costs can provide a significant competitive advantage to manufacturers. New materials, such as ceramics, high temperature alloys, and advanced stainless steels, provide opportunities for manufacturers to produce new and improved products for customers.

3.3 Joining and Forming (EWI)

Joining and forming are closely related manufacturing processes. Joining is the process of permanently attaching or connecting two components, while forming is the process of shaping and deforming materials to a desired shape (Narayanan, 2015). Joining and forming are common processes in many of the manufacturing industries in Ohio, including automotive, aerospace, and oil and gas (Piazza and Alexander, 2015c). Common joining processes are: welding, riveting, and bonding, while forming processes include: cold working, warm working, hot working of metals, rolling, forging, extrusion, drawing, shearing, bending, thermoforming, deep drawing, and casting. Joining and forming can be done with almost any material, including metals, plastics, ceramics, and composites (ibid).

The joining and forming technology roadmap was developed by Edison Welding Institute (Appendix C). EWI relied on their industrial networks to obtain the data and information for their report. Concurrent to the Ohio technology roadmaps, EWI was selected by the NIST Advanced Manufacturing Technology Consortia (AMTech) to engage a nationwide technology roadmap in this area. Materials joining and forming are critical to manufacturing. There are numerous joining and forming techniques, including: arc fusion and solid state welding; soldering; brazing; adhesive bonding; and mechanical fastening. New materials and products mean that joining and forming are increasingly technologically sophisticated and complicated. Many manufacturers are having difficulty incorporating and developing these new methodologies and materials and are looking for help to do this. Manufacturers generally feel that they lack knowledge about recent technological advances and how to incorporate them into their manufacturing processes and products.

Joining and forming manufacturers concur that a skilled workforce has recently become a critical issue for manufacturers. In particular, the current workforce is aging and retiring at the same time that technical demands of the work are changing. Firms have difficulty gaining access to workers at all levels, entry to professional; many have inadequate science/math skills, while those entering the workforce from universities have too theoretical of an education. The number of engineering and skilled-trades workers available are not keeping up with demand. Though automation can address some of the shortage of unskilled labor and easing foreign national restrictions will help, the skilled-labor shortage needs to be addressed.

The other issue that manufacturers identified is that the industry codes and standards can actually hinder the adoption of innovations. For many manufacturers that run small production batches incorporating innovations into this process may be cost prohibitive.

Nationally, roadmaps about the challenges facing joining and forming manufacturers focus mainly on the workforce issues (Piazza and Alexander, 2015c). The industry also identifies the importance of facilitating innovation and university-industry partnerships.

3.4 Additive Manufacturing (FastLane)

Numerous definitions exist for additive manufacturing (AM); as it gains visibility as a viable entity in manufacturing processes, a variety of opinions have been espoused about what it represents. The American Society for Testing and Materials (ASTM) International Committee F42 defines additive manufacturing as process of building a three-dimensional model by layering material onto a workpiece (Huang, Leu et al., 2015). Thus, additive manufacturing is commonly synonymous with 3D printing. However, additive manufacturing processes include not only 3D printing (also known as Binder Jetting), but also direct energy deposition, material extrusion (i.e., fused deposition modeling), material jetting, powder bed fusion (i.e., laser sintering), sheet welding, and digital light processing (Weber, Peña et al., 2013). Rapid prototyping is a commonly known usage of additive manufacturing, but there are many other applications.

Coupled with electronic communications and connectivity, additive manufacturing allows for remote design and production of parts, as well as rapid customization of parts. That is, manufacturers can design a component and then create a part in any location that has production capabilities, i.e., a local 3D printer (Bourell, Leu et al., 2009). Manufacturers may also make changes to designs and products in a matter of hours rather than days, months, or even years (Bradshaw, 2011). Thus, AM has the potential to significantly transform the supply chain, logistics and transportation, and inventory requirements.

The additive manufacturing technology roadmap was developed by FastLane (in Appendix D), in which they consulted with experts in the field and conducted an exhaustive literature review. AM is not a core activity for most manufacturers. As of yet, there is little demand for these services, making difficult the identification of distinct additive manufacturing firms or their specific processes. Moreover, many different types of materials can be used in the AM process, including metals, plastics, polymers, and composites. Relatively speaking, the available materials are limited (Guo and Leu, 2013). Additive manufacturing is generally a design and prototyping tool that some manufacturers make use of, while others do not. Its use is emerging for production parts, spearheaded by companies like GE with their purchase of Morris Technologies.

As additive manufacturing is a relatively new technology, there is a lack of standardization in the field and familiarity with additive manufacturing technologies, processes, and applications by traditional manufacturers. AM enhances what a company is already doing and is typically not the only thing that a manufacturer does (serves as an enabler). There are limited types of materials for large-scale production. Most of the awareness of the techniques and tools of AM come through the workforce, although those in the business do not see additive manufacturing technicians as a major hire. More of the workforce are predicted to be engineers who have AM specialization/interest.

Ultimately, an organic diffusion of this technology has resulted rather than a company going out and looking for that particular tool. As a nascent technology, AM is right on the edge of “cool technology” transforming to an integral process; movement from research environment to production environment is still being predicted. Other technology roadmaps have highlighted the transformative potential of additive manufacturing (Piazza and Alexander, 2015a). They also discussed the need for standards and best practices.

3.5 Summary

The findings from the four initial roadmaps can be summarized as the following:

- Finding an appropriately trained and skilled workforce is the largest overall challenge
- Many manufacturers are unfamiliar with new materials and technologies or have challenges in introducing them to the production floor
- The business environment is now based on the increasing demands of customers expecting instant gratification, personalized products and zero defects
- Reducing the cost of production to gain a competitive edge has become even more of a priority for manufacturers
- Manufacturers are feeling increased pressure to up the speed of product development, prototyping, and commercialization (& developing networks to exploit new opportunities)

The roadmapping project was focused primarily on traditional manufacturing processes that have etched longstanding and well-worn pathways within the supply chain. The lone exception in additive manufacturing offers a springboard into how new technological trends are taking hold on the factory floor. The next section outlines the transformative and disruptive technologies and issues that manufacturers will face in the next five years as we enter a period of rapid change in the manufacturing environment.

4. Common Themes and Technological Trends

The manufacturing supply chain has changed significantly in the past thirty years. The de-verticalization and decentralization of the supply chain has pushed many of the responsibilities for design, quality management, and even integration down to the suppliers. Manufacturers are being driven to increase the speed of their product development, prototyping, and commercialization. At the same time, customers are cutting costs and demanding that suppliers do the same. Thus, manufacturers are pressured to be more productive while working on increasingly narrower profit margins. Greater globalization means that domestic manufacturers are competing with companies with significantly lower labor and regulatory costs. These are the realities of doing business in today’s manufacturing environment.

Manufacturers have been forced to adopt advanced technologies to ensure that their productivity and quality allow them to compete and stay profitable. At the same time, manufacturers are looking for policymakers to mitigate some of the risks that exist in the global marketplace, from not having enough skilled workers and mitigating the financial risks and uncertainties of capital investments,

to navigating the risks of technological changes and competitiveness. Though governments absolutely have a role in helping manufacturers, economic and technological success is really a partnership between the public and private sectors.

4.1 Workforce

Workforce issues are by far the greatest concern for manufacturers overall. Many small and medium manufacturers are operating with slack resources, resulting in human capital development, recruitment, and personnel management taking a substantial amount of core productivity time, especially during periods of growth. This makes workforce issues particularly salient and frustrating.

Many manufacturers accept that they will need to train and develop employees in house. However, it can be difficult to locate potential employees who have even a basic literacy with machines and manufacturing operations. Many potential employees have never been exposed to the skilled trades. That is, they are not even familiar with basics of machine safety, reading a print, or part tolerances. Manufacturers have difficulty finding training programs that address these fundamentals. Another problem is that employers can also find it challenging to train employees who then move to other manufacturers when they become a little more skilled.

For manufacturers, this is a central and core issue. The final report will outline the training and workforce development resources available within the Ohio Advanced Manufacturing Technical Network.

4.2 Advanced Materials

One consistent technical concern identified by manufacturers is new materials. Generally, materials can be classified as metals and alloys, ceramics, polymers, and composites (Askeland, Fulay et al., 2011; Kagermann, Wahlster et al., 2013). There have been significant advances in materials in recent years, from the development of nanomaterials to lightweight composites. Advanced materials are precisely manufactured so that new properties and structures are developed (DAMADEI, 2015), such as materials that are more flexible, more heat resistant, stronger, lighter (etc.). These properties allow manufacturers to make new products. At the same time, they require modifications to the design and manufacturing processes that may be challenging for smaller firms.

Manufacturers have many questions about the properties of new materials, as well as how to manufacture and use them. For instance: How do they work in existing machines and processes? Are new skills needed to work with these materials? How do you assemble and use them? How do you form them? What are the additional costs to adapt machinery to new properties? How do you join them? Do they degrade over time? What new applications and products can be made with them? How do new materials interact with other materials? Do they corrode other parts? What are their thermal properties?

Manufacturers may have both general and specific questions about advanced materials. That is, they may want to investigate a material class generally or they may be presented with the need to

incorporate a new material (or a new property of some material) into their existing process in order to meet a particular customer's request. Often a manufacturer will not have advanced knowledge that they are going to have this need. The material supplier can certainly be of assistance in describing some of the properties and uses of the material, but this cannot address every situation. In addition, new materials are developing that have not been commercialized for production. Thus, having a basic knowledge base and skills in advanced materials is foundational to being able to utilize them. Few manufacturers are capable of having this expertise in house.

4.3 Smart Manufacturing

Smart Manufacturing, or the Smart Factory, is another important emerging trend. The proliferation of sensors, automation, information technologies, data analytics, and Internet connectivity (the Internet of Things) allow manufacturers to monitor and optimize their operations in new ways to connect and track their administrative as well as the production processes in real time. With dramatic reductions in the cost of robotics and increased functionality, manufacturers are able to connect their machines to create an integrated, intelligent internal supply chain. Firms will be able to proactively manage production, maintenance, logistics, energy usage, and quality on the factory floor. These advances will also require new ways of working, with more collaborative factory and administrative operations and virtual, mobile work (Kagermann, et al., 2013). As companies incorporate these new technologies and processes, manufacturers who have not done so will be at a competitive disadvantage in the global marketplace.

4.4 Innovation and Commercialization

Being able to commercialize new discoveries and innovations is not a new problem. However, as manufacturers feel greater pressure to speed up the pace of their operations and to cut costs, the additional time and funding that used to exist for investments in these innovations and discoveries is gone. Many manufacturers are concerned about their ability to commercialize and capture the value of innovations. Some manufacturers are concerned about developing new ideas that may fail in the marketplace, while others would like to expand into new markets.

Substantial research into the factors that promote innovation and commercialization exist. According to a study by the Production Innovation Economy group at MIT, the degradation of the US industrial ecosystem (skills and equipment infrastructure) is the largest challenge to innovation and manufacturing (Berger, 2013). The innovation ecosystem provides the workforce, the ideas, financial resources, and the industrial spillover that enables firms to innovate and prosper. Many of the supporting components of the industrial ecosystem were damaged as companies reduced their domestic investments, shifted their focus to short-term financial returns, businesses and policymakers ideologically rejected industrial policy, regulation, and market intervention, and large companies reduced internal innovation capabilities (Atkinson and Ezell, 2012). With the weaker industrial ecosystem, firms are having greater difficulty innovating (Berger, 2013). Building the industrial ecosystem must be a priority. The Ohio Advanced Manufacturing Technical Network is designed to help address this issue.

5. Connecting to the Technical Resources

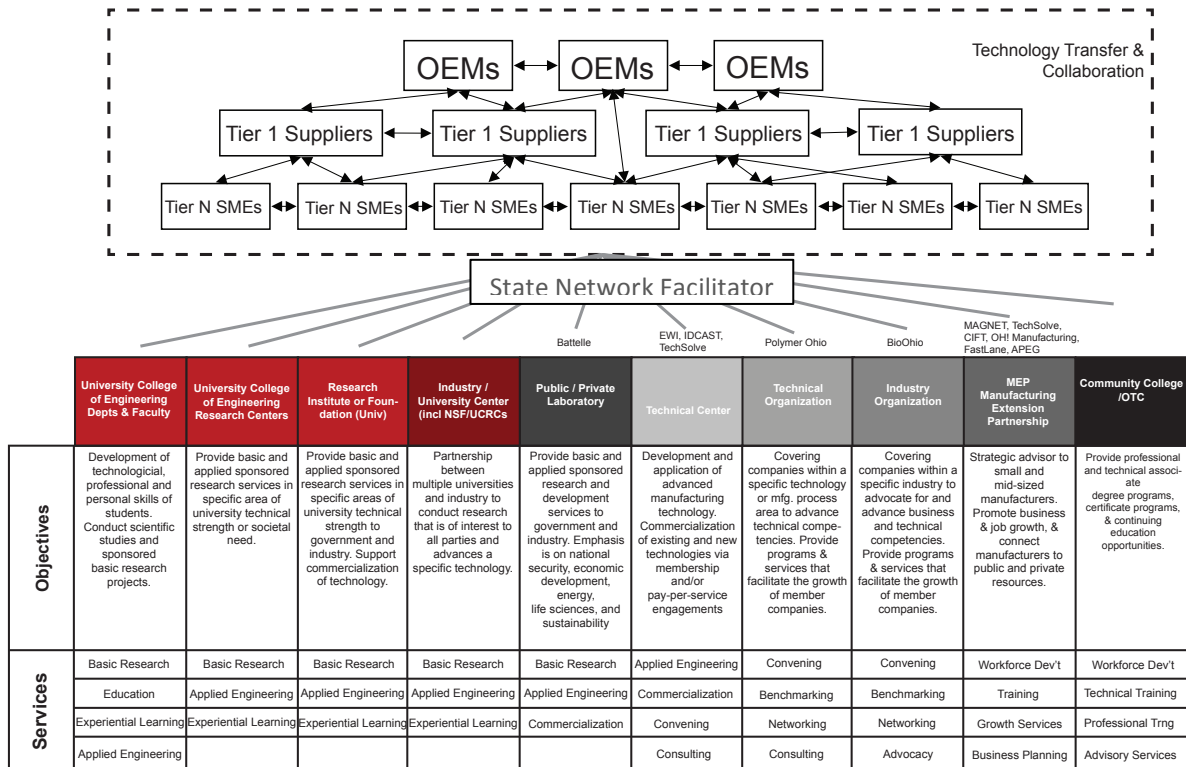
With its status as a national manufacturing powerhouse, the diverse and substantive resources in the state fulfill different aspects of manufacturing and innovation support. All the resources organizations are needed to support manufacturing firms of all sizes and technical processes. Facilitating coordination among providers in Ohio's technical resource network with manufacturing firms would go a long way in easing the above-mentioned issues within the supply chain and meeting manufacturers' needs in the state. In other words, codifying a value exchange to make technical connections happen and facilitating the demand to drive the exchange toward solutions is required for the Ohio Advanced Manufacturing Technical Network to flourish.

Manufacturers, particularly small and medium firms, have indicated that it is difficult to identify specific resources that can help them with their problems. They are constrained by resources and when presented with a problem, they need to spend substantial time trying to figure out where to get needed help. Some manufacturers have also become quite skeptical about attempts to develop networks or solutions that will support manufacturers. They feel that these have been tried before and are not confident that the long-term support or appropriate mechanisms will be installed.

What is clear from the technology roadmaps conducted and feedback received is that a facilitator was a critical component to the network (see Figure 4), as was an up-to-date (and dynamic) asset or resource map. In addition, the facilitator would identify clear entry points for manufacturers to navigate the state network, thereby preventing them from spending significant amounts of time and effort in searching for themselves. In addition, facilitators connect the manufacturers to "super users" to identify the specific solution to the problem or issue. The super user then interfaces with the appropriate resource to ease navigation for the manufacturer. The facilitator will work with the super users and each of the resource organizations to ensure that processes are transparent and available in a timely manner to manufacturers – and that specific problems are addressed while being alert to the different strengths of the resource organizations.

As highlighted in the beginning of the report, utilization of technical resources by manufacturers has varied significantly. There are reasons for this. The network's success requires that these resources be coordinated effectively. This requires a detailed knowledge of the different resources, commitment by the senior management at these resource organizations, and an asset map that is updated continually. In order to understand the challenge of this task and the proposed solution, we briefly discuss the different types of assets in the state and some of the challenges that have existed in using those resources.

Figure 4: Ohio Advanced Manufacturing Technical Network



5.1 Technical Resources

i. Research Universities

Research Universities can be very difficult for manufacturers to engage with, particularly for small- and medium-sized enterprises (SMEs) with neither the resources nor time to try to navigate through the university system. Entry points can be unclear and they may encounter colleges, departments, and faculty at research universities focused on the development of technological, professional and personal skills of their students rather than industry service. Faculty members in particular are engaged and rewarded for scientific and engineering research, both curiosity-driven and industry sponsored. This research is typically government funded. Often, industry-funded projects must be quite substantive in order to make them worthwhile for university engagement. These types of projects are simply cost prohibitive to many (if not most) companies. University faculty are also promoted on their publications and student development. Thus, the dissemination of new knowledge is an important aspect of much of the research at universities. Faculty members also typically work on longer-term projects, with 3-5 years being common.

Companies, on the other hand, are necessarily concerned with the protection of intellectual property and preserving their competitive advantage over other companies. They are focused on short-term returns and profitability. Few companies can afford to wait 3-5 years for results or to invest in speculative research. These different objectives and timeframes can create barriers between faculty

members and manufacturers. University engagement mechanisms are simply not aligned with industry expectations (contracting, pricing, project management, speed of business).

On average, about 50 percent of research university engineers have conducted any work with any industry. Scientists are even less likely to deal with industry, with only 30 percent of life scientists, 22 percent of physical scientists, and 23 percent of math and computer scientists interacting with companies (Schuelke-Leech, 2011).

Many universities have begun to recognize the difficulties of getting faculty members to work with industry as part of making their research relevant and applicable to industry problems, and in commercializing faculty research. Universities have tried to improve the engagement of faculty and the university with industry through university research centers (URC). University research centers provide basic and applied research services in specific areas. Faculty members affiliated with an URC are much more likely to be involved with industry (Boardman and Bozeman, 2007; Boardman and Ponomariov, 2007; Bozeman and Boardman, 2010). Research Institutes or university foundations are another connection point to industry. Multiple inter-university partnerships and industry engagement teams work together to advance basic and applied research services in specific areas, such as actively developing and commercializing technology developed at the universities.

Similarly, National Science Foundation-sponsored Industry-University Research Centers (I/UCRCs) (NSF) specifically link university faculty and resources with industry. These I/UCRCs focus on partnerships between multiple universities and industry wishing to conduct research in a specific area. Funding by the NSF is limited and the centers are expected to become self-supporting through industry-focused research.

University resources and research centers are more likely to be used by major Original Equipment Manufacturers (OEMs), rather than other levels of manufacturers. University programs have been instituted to support research interactions with SMEs, which have been less likely than larger manufacturers to use university resources.

ii. Public-Private Laboratories

Public-Private Laboratories, such as those at Battelle and NASA-Glenn, provide basic and applied sponsored research and development to government and industry. Given their focus, these institutions are typically the least utilized by manufacturers, particularly SMEs. Often these institutions' charge is to engage in government projects or on large manufacturers in specific industries, such as national security or energy; their services usually include high overhead rates and are typically not feasible for small manufacturing projects. This is changing as government funding supporting these programs is reduced, with an increase in private labs publicly offering their technologies for industry use.

iii. Technical Centers

Technical Centers are intended to develop and apply advanced manufacturing technologies. They are focused on the development and application of advanced manufacturing technology and specialize in

the commercialization of existing and new technologies, similar to Germany's Fraunhofer system. They are usually funded by through membership and/or pay-per-service engagements. Ohio examples are EWI, TechSolve machining laboratory, and IDCast. These organizations provide a multitude of industry-oriented services in specific industrial areas.

iv. Technical and Industry Organizations

Technical Organizations and Industry Organizations help manufacturers either by addressing specific problems, technologies and processes or by helping manufacturers more generally compete and grow as businesses. Technical and industry organizations, such as PolymerOhio and BioOhio, are funded via memberships and/or pay-for-service contracts, with some government support. The organizations also include trade organizations, such as the American Foundry Society. Since these organizations are dependent on voluntary participation and funding by their members, they are much more inclined to focus on the short-term needs of their members and policy issues and in providing specific services that manufacturers are willing to pay, with some exceptions.

v. Manufacturing Extension Partnerships (MEPs)

The Manufacturing Extension Partnership (MEP) program was established and funded by the federal government through the National Institute of Standards and Technology (NIST) at the U.S. Department of Commerce (NRC, 2013) with additional financial and programmatic support from the state government. The MEP program is specifically targeted towards serving small- and medium-sized manufacturers. MEPs are designed to be a strategic advisor to SMEs and to promote productivity, business development, supply chain management, lean manufacturing, workforce training, and job growth (ibid). Ohio has six MEPs: (1) APEG in the Southeast; (2) Magnet in the Northeast, (3) CIFT in the Northwest, (4) FastLane and (5) TechSolve in the Southwest, and (6) PolymerOhio in Central Ohio. MEPs have the specific mission of helping manufacturers to address manufacturing problems (MEP, 2015). They offer customized technical solutions, Lean and SixSigma consulting, product commercialization and customized training to their customers.

vi. Community Colleges and Technical Centers

Approximately 23 Community Colleges and 51 Ohio Technical Centers statewide are focused specifically on workforce and skills training. The entrance requirements and tuition fees are typically lower than those at research universities and the time-to-degree completion is shorter. They serve a substantial portion of the industrial workforce by providing professional and associate degree programs, certificates, programs, and continuing education. These educational institutions are responsive to changing workforce skills demands and offer some advisory services to companies.

Community colleges dominate the design and delivery of industry-focused training programs, certificate, and degrees (Weaver and Osterman, 2014). They often will work with a larger manufacturers or industry to develop programs that respond to the specific needs of that stakeholder. However, they often have fewer resources than some of the other institutions for longer-term ventures.

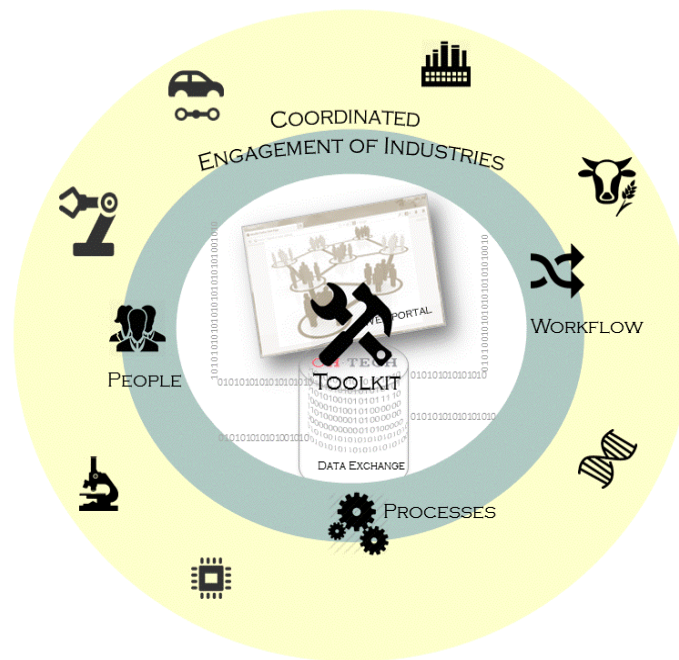
5.2 Resource Database and Asset Map

Providing individual roadmap input and vetting the initial report drafts, manufacturers consistently discussed the need for a mechanism that would allow them to access the resources available in the state in a more user-friendly and responsive manner. Currently, resources are decentralized and utilized only because of previous use or recommendations by other manufacturers. As mentioned earlier, gaps exist in finding an effective means of linking industry needs to the resources in the state, as well as funding and developing those resources in response to changing industry needs. At the same time, significant opportunities can be made available to assist manufacturers in becoming more productive, innovative, and globally competitive.

As an initial step to a complete resource database and asset map, OMI has been working to build databases of both the manufacturing needs through the technology roadmaps and the resources that exist within the state. A statewide project OMI is supporting is led by the Ohio Department of Higher Education with the goal of developing a resource database and innovation exchange among research universities and industry. Three universities (The Ohio State University, Case Western Reserve University, and the Ohio University) are founding partners of a pilot project that provides information about faculty expertise, equipment, and research facilities available at these institutions. Once the resources have been identified, an online interface highlighting these resources is being developed that allows the user to easily engage and interact with the universities. The university resource database provides the foundation for a subsequent network that will incorporate all of the technical resources in the state. The university innovation exchange is intended to include an online web portal for industry use.

As discussed above, effective coordination is needed in these activities, as the tool will only be as good and the facilitators and super users supporting the system. Figure 5 shows a representation of the coordination needed to help manufacturers connect to the people, processes, equipment, and facilities that can help them solve their problems.

Figure 5: Coordinated Engagement of Industries with State Technical Resources



5.3 Creating Value

i. For Manufacturers

The Ohio Advanced Manufacturing Technical Network aims to be a value-add for both manufacturers and the technical resource organizations. For manufacturers, the network provides a mechanism for them to connect with available resources to address their specific technical issues and concerns and offers an information, knowledge, and expertise exchange on technology trends and innovations. As a noncompetitive forum, the network allows manufacturers to leverage resources and collaborate. The network provides access to industry-friendly faculty experts, laboratory facilities and equipment.

ii. For Technical Resource Organizations

Each of the technical resources also receives value from being involved in the network, from increased membership, service provision, and revenues. **Having multiple organizations, with their respective strengths, work together on an industry problem could increase efficiencies and innovation in the process.** Universities and community colleges can increase student enrollment and revenues through testing services and facility-usage fees (i.e., labs and equipment). The network also provides a conduit, as an example, for universities to engage in real-world projects and opportunities both for faculty and students, ensuring that research is relevant to industry. As academia is forced to change in response to changes in state and federal funding support and changing student needs and demands, universities in particular, will need strong connections to business and manufacturing.

Likewise, technical resources with required metrics to serve manufacturers are looking for avenues to increase their membership and services. Participation in the Ohio Advanced Manufacturing Technical Network provides another avenue for engaging with their customers and clients.

6. Recommendations

The purpose of this report has been to outline the findings of the technology roadmaps undertaken on four manufacturing processes and to present an overview of the state technical resources and the challenges of their greater utilization by manufacturers. More broadly, the report aims to provide the basis for the continuing discussion and development of the Ohio Advanced Manufacturing Technical Network to support manufacturing in the state.

This report and its recommendations have received substantial input and vetting from manufacturers throughout Ohio. Thus, this report is a reflection of the needs, concerns, and recommendations of industry. Specific recommendations include:

1. Develop the Ohio Advanced Manufacturing Technical Network

Simply stated, manufacturers are extremely time and resource constrained. For many manufacturers, the need to be price competitive makes it impossible to keep any resources in house that are not essential to daily operations or employees that underperform. Even with manufacturers that produce more specialized products, competition is tough. With the relatively low cost of transportation and the speed of communication, manufacturers compete with firms nationally and globally. Thus, manufacturers often do not have the time and ability to look for entry points to access the technical resources of the state, even if these resources could ultimately make them more productive or competitive. In other words, today's production demands are more urgent than investments in future productivity. Thus, it is imperative that any statewide program designed to help manufacturers tackle these challenges effectively and appropriately.

In gathering manufacturers' responses to this report, we learned that any efforts to facilitate the state technical resources must be user friendly and relatively transparent. Manufacturers need direct help navigating through the resources. Thus, a network of super users who directly interface with a manufacturer to assess their individual needs and point them to the right resources is crucial. This will mean assisting the manufacturers in identifying the specific issues to be addressed, coordinating with the technical resources on behalf of and with the manufacturer, and ensuring that the issue is resolved. In addition, statewide network facilitators are needed to ensure that resources are coordinated and the problems addressed in a timely and effective manner by organizations with the relevant resources. Initially, this will likely be a labor-intensive process, particularly as the resource database is being filled out and the relationships are being established. There is no way to automate the relationship management that will need to take place.

2. Technology Roadmaps

The common technical concerns identified by the technology roadmaps were (1) advanced materials; (2) smart manufacturing; and (3) innovation and commercialization. Technology roadmaps for each of these areas are being planned in order to more fully understand the issues involved in these technology areas and how the Ohio Advanced Manufacturing Technical Resource Network can help address the unique issues associated with them.

3. Develop detailed asset map and resource database

An important component of the Ohio Advanced Manufacturing Technical Network is engaging different technical resources in the network to more fully support manufacturers. All of the onus cannot be placed on external stakeholders, manufacturers, or even the facilitators to engage the technical resources. Instead, each of the technical resource organizations must be educated about the network and must be committed to participating in it. This will require collaboration and incentives.

Returning to the example of research universities, incentivizing faculty members and university administration to respond to the needs of manufacturers may mean carving out better entry points. An educational campaign about the network, its goals, and the advantages to the resource organizations to become more engaged will be necessary.

Specifically, there needs to be:

- Specific points of contact in each resource organization
- Awareness within each resource organization of the network and the rules/roles of engagement
- A mechanism that will allow manufacturers to use the resources. This will require that costs are specified, transparent, and reasonable; that intellectual property protections are built into the service contracts; that contracts are simple and streamlined; and that technical support is available when the manufacturer needs it (in terms of hours and days, not weeks or months)

4. Pilot study

As an initial solution gathered from industry vetting of the roadmapping, OMI will facilitate the resolution of specific problems facing two to three manufacturers by connecting them with organizations within the Ohio Advanced Manufacturing Technical Network. In addition, OMI will convene the organizations to work together to provide solutions. This will help to identify difficulties and barriers that users may encounter and identify streamlined pathways that may be used for future firms that require assistance. In addition, we will develop a more detailed regionalized list of available resources within the state to support the initial advanced manufacturing technical resource map.

7. Conclusion

Ensuring the effective coordination and provision of assistance to manufacturers will take work. For some of the resources, this is a new way of doing business.. There is recognition of the need and the desire to engage with manufacturers, but also recognition of the formidable challenges to reach success. Many of the external reports and literature reviewed for this report discussed the need for effective collaborations and partnerships for success in manufacturing and regional economic development. We have provided an industry-vetted set of recommendations to drive this process. The Ohio Advanced Manufacturing Technical Network is the essential foundation for successful collaboration to support manufacturers in Ohio.

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