Leveraging Universities to Advance Manufacturing Innovation Through the MEP National Network | PHASE 2
Leveraging Universities to Advance Manufacturing Innovation Through the MEP National Network | PHASE 2

FINAL REPORT
April 30, 2023

Report prepared by the Association of Public and Land-grant Universities for the Manufacturing Extension Partnership, National Institute of Standards and Technology under Grant number 70NANB20H136
Acknowledgements

This report benefitted from the contributions of many. The primary authors were Sheila Martin, Strategic Advisor for Economic Development and Community Engagement at APLU, and Jim Woodell of Venn Collaborative. Diane Palmintera, President, Innovation Associates, originated the project and participated in quarterly meetings, offering her observations on the collective learnings from these gatherings.

The Pilot Project Team members included the following:

University of Louisville Team:
- Dr. Kunal Kate, Associate Professor of Mechanical Engineering, University of Louisville
- Dr. William A. Metcalf, Associate Vice President for Research Development and Strategic Partnerships, University of Louisville
- Scott Broughton, Director, Advantage Kentucky Alliance

Ohio University Team:
- Dr. Jesu ñs Pagán, Associate Professor, Russ College of Engineering and Technology, Ohio University
- Dawn Coleman, Growth Advisor, Ohio Manufacturing Extension Partnership
- Linn Yost, President, Appalachian Ohio Manufacturing Coalition and Owner, Micro Machine Works, Inc.

Northern Illinois University Team:
- Dr. Donald Peterson, Dean, College of Engineering and Engineering Technology and Professor, Department of Mechanical Engineering, Northern Illinois University
- Dr. Mansour Tahernezhadi, Senior Associate Dean and Professor of Electrical Engineering, Northern Illinois University
- Ray Ziganto, Manufacturing Director, Northern Illinois University
- David Boulay, President, Illinois Manufacturing Excellence Center

The profile of TechHelp Idaho benefitted from conversations with Steve Hatten, TechHelp’s Executive Director, and his staff.

Special thanks to Gerson Santos-Leon for his guidance throughout the project, and to Carol Holly, former Director of the Manufacturing Extension Partnership National Network, for seeing the potential benefits of this project and getting it off the ground.
## Contents

**Executive Summary** ................................................................. 1  

1. **Introduction** ................................................................. 5  
   - Objectives ........................................................................ 5  
   - Timeline ........................................................................... 6  
   - Brief Pilot Project Descriptions ....................................... 7  
   - Supporting the Pilot Projects as a Learning Cohort ............ 8  

2. **Models of MEP-University Partnership** ................................. 11  
   - University as SMM Skunkworks ...................................... 12  
   - University Office as Light-touch Connector for SMMs ......... 12  
   - MEP as Front Door to University Technology Assets .......... 12  
   - University as Niche Service Provider ............................... 12  
   - Applied Learning Model ................................................... 13  
   - MEP Advanced Tech Team ................................................. 13  

3. **Examples of MEP Partnerships: Pilot Projects and Other Models** ... 15  
   - University of Louisville Partnership: Applied Learning Model Leading to MEP as Front Door to University .... 15  
   - Ohio University Partnership: Advanced Tech Team Model .............................................................. 15  
   - TechHelp Idaho: MEP as Front Door to University’s Technology Assets, Evolving to Applied Learning Model .......... 28  

4. **Drivers and Barriers to Success in University-MEP Partnerships** ... 38  
   - Setting the Partnership Up for Success .............................. 38  
   - Developing a Shared Understanding of Culture, Roles, and Responsibilities .............................................. 41  
   - Addressing Workforce Development Challenges ................. 43  
   - Keeping the Focus on the Needs of SMMs .......................... 44  
   - Leveraging Assets for Expanding Partnership Opportunities 44  

5. **Conclusions and Next Steps for the MEP National Network** ......... 46  
   - Next Steps for the MEP National Network: Using the Toolkit 47  

6. **Introduction to the MEP-IHE Partnership and Collaboration Toolkit** .... 48
Executive Summary

The National Institute of Standards and Technology’s Hollings Manufacturing Extension Partnership (NIST MEP) is interested in exploring how universities can develop and scale partnerships with MEP programs to increase the capacity of small and medium sized manufacturers (SMMs) to adopt technologies that are key for their success in the evolution to Industry 4.0.

Industry 4.0 refers to the fourth industrial revolution—the next phase in the digitization of the manufacturing sector. Industry 4.0 includes a suite of technologies that are disrupting the manufacturing value chain. They include the following:

- Data and connectivity technologies such as cloud computing, blockchain, and sensors;
- Analytics and intelligence technologies such as advanced analytics, machine learning, and artificial intelligence;
- Human-machine interaction such as virtual reality, augmented reality, robotics, and autonomous guided vehicles; and
- Advanced engineering such as additive manufacturing (3D printing) and nanoparticles.

This report provides findings from a pilot project that paired three universities with three MEP Centers. The project aimed to enhance the competitiveness of SMMs and the effectiveness of the MEP National Network in the United States by:

- Identifying and describing innovative and successful examples of collaboration between MEPs and universities with the goal of new technology adoption, particularly of Industry 4.0 technologies, by SMMs.
- Assessing and articulating the factors that contribute to the success of these examples.
- Applying the knowledge of those success factors to build tools and reference materials that can help to scale the successful examples for use by more university-SMM-MEP partnerships.

The pilot project took place from August 2020 to December of 2022. The three project teams were:

- The University of Louisville (UofL) and the Advantage Kentucky Alliance (AKA)
- Northern Illinois University (NIU) and the Illinois Manufacturing Excellence Center (IMEC)
- Ohio University (OU), Ohio MEP Southeast Center, and the Appalachian Ohio Manufacturers’ Coalition (AOMC)
Throughout the project, the project team assessed the progress of the partnerships and their work with SMMs through monthly check-ins. The teams gathered once per quarter to share what they were learning from their partnerships and share resources and tools for resolving challenges.

As we gathered information from each of the teams on their pilot project experiences, a set of key points began to emerge as the teams reflected on their experiences, both in the moment and as the project came to an end. Those key points fall into five categories:

- **Set the partnership up for success.** Allow time to develop principles of partnership prior to rushing into the work with manufacturers. This includes identifying what each partner believes will be the drivers and barriers to success.

- **Develop a shared understanding of culture, roles, and responsibilities.** This can be essential to ensuring that the three-way partnership doesn’t damage existing relationships and leads to success for the SMM.

- **Identify opportunities to address talent and workforce development issues for the manufacturers.** This is where the missions of universities and MEPs have a natural intersection and can have substantial impact on the success of the manufacturers, the students, and for the regional manufacturing industry overall.

- **Keep the focus on the needs of SMMs.** Although universities and MEPs may have other objectives for the partnership, prioritize the needs of the SMM in the project.

- **Expand the partnership by identifying opportunities to leverage partner assets for greater impact.** Universities have many assets that can be useful to manufacturers and identifying how they might be leveraged for greater impact can lead to rewards for both the university and the MEP.

Partnerships between universities and MEP Centers can effectively accelerate the adoption of Industry 4.0 technologies by SMMs, provided the partnerships are designed and implemented with a focus on the needs and goals of the SMMs. While attending to those needs, keep in mind the following:

1. **Establish principles of partnership.** Partners must acknowledge and accommodate the divergent goals, incentives, and environments of universities, MEPs, and SMMs.

2. **Recognize and attend to the drivers and barriers to successful partnership.**
   The principles of partnership should address issues such as how staff will be trained, how workflow will be managed, and what communication channels will be used.

3. **Recognize that other partners may have assets to offer the partnership.**
   Universities are not the only institutions of higher education that can offer SMMs the opportunity to learn about, adapt, and adopt Industry 4.0 technologies.

4. **Keep in mind the broader goal of a manufacturing sector that is efficiently employing Industry 4.0 technologies.** Partnership work should focus not only on
the benefits to the SMM, but also more generally on the opportunity to advance the adoption of appropriate Industry 4.0 tools across the manufacturing industry.

The project team developed a set of tools designed to address some of the partnerships’ main challenges and identify opportunities for building the partnership for sustainability. We gathered the tools in a toolkit for use by other MEP/University partnerships. The toolkit is available on the APLU website and includes the following tools:

- The **MEP-IHE PARTNERSHIP ASSESSMENT TOOL** offers existing partnerships between institutions of higher education (IHEs) and MEPs a method for assessing the strength of their existing partnership based on characteristics of effective partnerships.

- The **SETTING GOALS FOR IMPROVING YOUR PARTNERSHIP TOOL** helps partnerships that have identified weaknesses in their current partnership develop a timeline, indicators, and responsibility assignments for improving their current partnership.

- The **FORCE FIELD ANALYSIS TOOL** prompts partnerships to describe a future state, including qualities of the ideal partnership as well as positive outcomes for SMMs, and the drivers and barriers to reaching that future state.

- The **GOAL AND METRICS ALIGNMENT TOOL** prompts participants to identify each partner’s goals for the project or partnership.

- The **ENGAGEMENT FUNNEL TOOL** prompts participants to consider issues in choosing partner SMMs.

- The **WORKFORCE NEEDS AND ASSETS TOOL** focuses on the key workforce development needs related to technology adoption.

- The **ASSET AND OPPORTUNITY MAPPING TOOL** prompts partnerships to list both university and MEP assets that can be brought to bear in responding to the “framing question” of “how might we increase the competitiveness of manufacturers in our region by helping them to adopt new technologies?”

- The **FUNDING AND PARTNERSHIP SUSTAINABILITY TOOL** prompts partners to think about potential sources of funding and ongoing revenue that can support the partnership over the long term.

The toolkit also contains links to other resources that assist MEP-IHE partnerships in developing stronger relationships to benefit SMMs.

We suggest that the NIST MEP National Network encourage each MEP Center to use the toolkit that accompanies this report to develop stronger partnerships with regional colleges and universities to the benefit of SMMs and to encourage MEP Centers to share their strategies for cultivating these partnerships. They might also consider offering additional resources to MEPs and their partners to develop and structure these partnerships with a deliverable of a partnership report that includes agreed-to partnership principles and a completed set of tools, including, at a minimum, the **GOAL AND METRICS ALIGNMENT TOOL**, 

---

LEVERAGING UNIVERSITIES TO ADVANCE MANUFACTURING INNOVATION THOUGH THE MEP NATIONAL NETWORK
and the **ENGAGEMENT FUNNEL TOOL**, as described in the toolkit. From our experience, it is very important to put time up front into structuring the partnership prior to launching a project with an SMM.

Finally, the MEP network might consider how it might develop a national partnership network between MEP Centers, community colleges, universities, and workforce boards to ensure that at a regional level, appropriate training on Industry 4.0 technologies is developed and offered to high school students, post-secondary education students, as well as incumbent SMM workers.
1. Introduction

Over the past two decades, the manufacturing industry in the United States has suffered a loss of over 5 million jobs and thousands of manufacturing establishments. Offshoring of production has been financially successful for large multinational companies, but it has led to closure of many of the small- and medium-sized manufactures (SMMs), whose numbers have fallen by nearly 100,000 since the 1990s.¹

While the causes for this decline are many, the factors include stalled manufacturing productivity growth, a loss in manufacturing expertise, and the competitive pressures of a globalized supply chain. Kota and Mahone, in their report Reclaiming America’s Leadership in Advanced Manufacturing, review these factors and note that the survival of SMMs will depend on their ability to adopt the new “Industry 4.0” and other emerging technologies required to regain productivity growth and rebuild American manufacturing.

American universities have an important role to play in the development of new technologies that transform American manufacturing. The technologies of Industry 4.0, including advances in digitization, the use of smart sensors, robotics, simulation technologies, advanced materials, nanomanufacturing, and additive manufacturing techniques, are developed and advanced by university research, often in partnership with industry.

The National Institute of Standards and Technology’s Hollings Manufacturing Extension Partnership (MEP) is interested in exploring how universities can develop and scale partnerships with MEP programs to increase SMMs’ capacity to adopt technologies that are key for their success in the evolution to Industry 4.0.

This report provides findings from a pilot project that paired three universities with three MEP Centers to test models of University-MEP partnership.

OBJECTIVES

The goals of this project were to enhance the competitiveness of small and medium sized manufacturers (SMMs) and the effectiveness of the MEP National Network in the United States by:

- Identifying and describing innovative and successful examples of collaboration between MEPs and universities with the goal of new technology adoption, particularly of Industry 4.0 technologies, by SMMs.

• Assessing and articulating the factors that contribute to the success of these examples.
• Applying the knowledge of those success factors to build tools and reference materials that can help to scale the successful examples for use by more university-SMM-MEP partnerships.

TIMELINE
Phase I of this project began in 2019 with a preliminary exploration of the relationships between MEP Centers and universities. This assessment found the following:
• There is noteworthy interest among MEPs and universities in strengthening university-MEP partnerships with the goal of helping SMMs adopt helpful Industry 4.0 technologies.
• A variety of university-MEP-SMM collaborations facilitate technology adaptation and adoption by SMMs. These collaborations take many forms and support technology adaptation and adoption in many ways.
• A variety of partnership exemplars exist, including three-way MEP-University-SMM partnerships as well as partnerships between universities and SMMS that do not include MEPs but could serve as examples for MEP partnerships. Other exemplars include several universities and/or community colleges partnering with non-university-based MEPs as well as partnerships with intermediaries such as state agencies and Manufacturing USA.
• Partnerships between MEPs and universities face challenges related to awareness of information about university assets and the needs of SMMs; a perceived lack of incentives, lack of funding and capacity for partnership; and differences in time horizons.

We began Phase II in August of 2020. We designed the project to build on the information gathered in Phase I by (a) expanding the depth and breadth of the information gathered in Phase I; (b) developing and implementing pilot projects to investigate and document success and scale factors; and (c) preparing and disseminating tools that will help MEPs and universities work together to promote the adaptation and adoption of technologies to advance the competitiveness of SMMs.

After some additional research about innovative examples of university-MEP partnerships, we issued a request for proposals from MEP-university partnerships interested in the pilot. In a competitive process, we chose three projects for funding.

The pilots took place between July 2021 and December 2022. Throughout the project, we held monthly check-ins with the pilot project participants to document the project’s progress, talk through issues that may have come up during the month, and offer resources.
and ideas. We also held quarterly meetings that brought together all pilot participants to share ideas about how to improve the partnership, discuss partnership issues, and test out tools that we later refined and included in the toolkit.

**BRIEF PILOT PROJECT DESCRIPTIONS**

Below, we provide a brief introduction to each of the pilots. Additional information about the pilot projects and their results is provided in Section 3, Examples.

**The University of Louisville/Advantage Kentucky Alliance**

The University of Louisville leveraged a newly formed partnership with the Advantage Kentucky Alliance (AKA), the MEP Center in Kentucky. Their project aimed to assist Kentucky SMMs who might benefit from the adoption of 3D printing technology (also known as additive manufacturing). They planned to target SMMs in the automotive and aerospace industries who require mold manufacturing for product development. Their aim was to reduce time-to-market and assembly time for these SMMs. They used an applied learning model that assigned student capstone teams to assist two manufacturers in adopting the 3D printing technology. Companies were drawn to the collaboration either because they could no longer obtain the part (legacy part), or because they needed to quickly prototype a new part as part of a product redesign. AKA helped to identify the companies that were interested and the parts that were good candidates for the technology through value stream analysis. The MEP also managed the relationship with the company to ensure that communication was strong and that the project progressed.

**Northern Illinois University/Illinois Manufacturing Excellence Center**

Northern Illinois University (NIU) built on a 25-year history of partnership with the Illinois Manufacturing Excellence Center (IMEC, the Illinois MEP Center) to propose a pilot project that would strengthen and extend the current applied learning capstone model in the College of Engineering and Engineering Technology (CEET). The pilot project funded a dedicated Manufacturing Director (Ray Ziganto). Mr. Ziganto served as a link between SMMs and the engineering teams in the Multi-disciplinary Senior Design program. The Director worked hand in hand with IMEC to assess the practical engineering needs of the SMMs—particularly with respect to Industry 4.0 technologies, and in particular, AI, and to ensure long term assistance with implementation and optimization of technology adoption. IMEC sought to enhance its service and outreach capabilities through this partnership to promote Industry 4.0 technology adoption while building a workforce at NIU with practical hands-on experience working with the SMMs to implement these technologies.
Ohio University/Ohio MEP Southeast and the Appalachian Ohio Manufacturers Coalition

Ohio University (OU) proposed to partner with the Ohio MEP Southeast, operated by OSU South Centers, as well as the Appalachian Ohio Manufacturer’s Coalition (AOMC). This partnership addressed engineering and technology challenges to SMMs by helping them to adopt digital twinning technology. Digital twinning would allow SMMs to perform engineering validation of new technologies such as robotics, Computer Numerical Control machines (CNCs) and automated systems used for factory automation prior to purchasing physical components or interrupting current manufacturing processes. They planned to target members of the AOMC to test the partnership through the pilot project. As the project evolved, and as described in Section 3, the partnership ended up being solely focused on the university’s work with AOMC and SMMs—the MEP, largely due to staff and leadership changes, did not continue its participation.

SUPPORTING THE PILOT PROJECTS AS A LEARNING COHORT

APLU Project coordinators, Sheila Martin and Jim Woodell, stayed in touch with each grantee by two types of regular meetings.

- Monthly check-in meetings with the participants at each of the three sites. Sheila Martin facilitated these monthly calls with the Advantage Kentucky Alliance and University of Louisville and Jim Woodell conducted the monthly check-in meetings with Northern Illinois University and IMEC, as well as with Ohio University and the Appalachian Ohio Manufacturers Coalition (AOMC),
- Quarterly meetings with all participants.

Monthly Meetings

For the monthly meetings, a representative of each of the partnerships completed a monthly check-in form letting us the status of partnership development. We asked them these questions:

- Over the past month, what has been fun or rewarding about this project?
- What have you learned over the past month?
- Challenges overcome: Is there anything that was holding you back that you worked through over the past month?
- Challenges remaining: what challenges are you still facing?
- How can we help resolve these challenges?
- What are your plans for the coming month?
- Did you create any materials to support the project (artifacts) over the past month?
We asked them to upload the artifacts from the partnership work during the previous month. (These varied, encompassing promotional material, diagrams of partnership, planning documents etc.)

The project coordinators (Sheila and Jim) read through these monthly narratives prior to the check-in meeting. In addition to learning what was going on at each partnership site, we provided guidance and helped to brainstorm ideas for advancing and troubleshooting challenges. In a broader sense, these calls also promoted a sense of forming a cohort for collaborative learning among all the partners at each site.

**Quarterly Meetings**

We conducted quarterly meetings with all groups together to celebrate accomplishments, discuss topics common to all sites, and learn from one another. These were held in October 2021, January, April, July, and October 2022, with a final quarterly in December of 2022.

In the first quarterly meeting, October 2021, we set the stage for the ongoing partnership development work and for the conversations we would have throughout the initiative during the monthly and quarterly meetings. Participants each shared both what they were “feeling confident about” regarding the partnership, and also what they were “feeling less confident about.” After participants shared responses to these prompts, the group engaged in conversation about what they saw as the priority issues for ongoing focus. Following the meeting, we produced a summary memo outlining the key issues. This memo was used to determine a “learning agenda” for the partnership initiative, and, in particular, four focus areas—each to be explored in one of the 2022 quarterly meetings.

Here are the topics for each of the quarterly meetings:

- **Topic 1: Engagement.** The engagement topic would explore a variety of issues, including identifying SMMs to work with and planning for the SMM engagements (to include outreach mechanisms, roles of the university and the MEP, criteria used to determine good fit, and decision-making protocols).

- **Topic 2: Partnership Cultivation and Management.** The partnership cultivation and management topic would focus largely on the partnership between the university and the MEP. Issues to be addressed included development of partnership principles, identification of key staff, workflow and communication processes, aligning timelines, setting goals, and metrics for measuring success.

- **Topic 3: Talent and Workforce Development.** The talent and workforce development topic would address such issues as the relationship of workforce issues to technology adoption, and university and MEP resources for workforce education and training.

- **Topic 4: Asset Mapping.** The asset mapping topic would include an assessment of the different types of engagement that partnerships might handle, identification of
technology and innovation categories needed by local SMMs, costs and resources for each partner, and identification of assets across the broader ecosystem.

Each of these topics became the focus of one of the quarterly meetings in 2022, during which the agenda centered on a tool that we created for the partnerships that they used to think through and visualize specific aspects of the topic. We created these tools as PowerPoint templates. Participants in each partnership filled in the templates and prepared to present their completed tool at the relevant quarterly meeting, and these presentations scaffolded the discussions. We have aggregated these tools, along with other partnership tools, in the accompanying *MEP-IHE Partnership and Collaboration Toolkit*, which we introduce in Section 6.

These meetings were lively and productive, with a good exchange of experiences and ideas across the three partnerships. Outcomes from these meetings were discussed by Jim and Sheila, and provided insights listed below as well as a basis for the toolkit contents, as noted.
2. Models of MEP-University Partnership

In this section, we explore different models of MEP-University partnership, identify which models were employed by the pilot projects, discuss other models not part of the partnership, and investigate the strengths and weaknesses of these models for assisting SMMs in adopting Industry 4.0 technologies.

We began Phase 2 of this project having identified six models of University-MEP partnership during Phase 1, as described in Figure 1 and further described below.

<table>
<thead>
<tr>
<th>Model Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>University as SMM Skunkworks</td>
<td>University helps identify &amp; assess SMM technical problems and opportunities</td>
</tr>
<tr>
<td></td>
<td>University develops technical solutions for SMM</td>
</tr>
<tr>
<td></td>
<td>MEP connects SMM to skunkworks office</td>
</tr>
<tr>
<td>University Office as Light-touch Connector</td>
<td>Central university office provides connection and hands off SMM to potential university partner (department, lab, or faculty)</td>
</tr>
<tr>
<td></td>
<td>MEP connects SMM to university office</td>
</tr>
<tr>
<td>MEP as Front Door to University Technology Assets</td>
<td>MEP is embedded in university</td>
</tr>
<tr>
<td></td>
<td>Connects SMMs to university partners and manages project</td>
</tr>
<tr>
<td>University as Niche Service Provider</td>
<td>University provides specialized service to large number of SMMs</td>
</tr>
<tr>
<td></td>
<td>MEPs and other organizations refer SMM to university</td>
</tr>
<tr>
<td>Applied Learning Model</td>
<td>Faculty member arranges capstone projects that solve SMM technical issues</td>
</tr>
<tr>
<td></td>
<td>MEPs may play role in identifying SMM projects and ensuring satisfaction</td>
</tr>
<tr>
<td>MEP Advanced Tech Team</td>
<td>MEP specialist is familiar with technology assets at universities, Manufacturing USA Institutes, National labs, and other technology sources</td>
</tr>
<tr>
<td></td>
<td>MEPs utilize the Advanced Tech Team for specialized understanding of tech assets</td>
</tr>
</tbody>
</table>

Figure 1. Models of University-MEP Partnership
UNIVERSITY AS SMM SKUNKWORKS

In this model, universities work with SMMs as a skunkworks team on technology solutions that the SMMs are unable to develop on their own (skunkworks typically refers to an R&D project created by a small group outside the normal channels and structures in an organization). The projects might be brought to the university directly by the company, or in partnership with an intermediary such as an MEP. The result might be the adoption of a new material, a new device or process, or integration of a new piece of equipment into the manufacturing process, for example. The university might receive payment, at least in part, through state or federal funding programs.

UNIVERSITY OFFICE AS LIGHT-TOUCH CONNECTOR FOR SMMS

In this model, a university office provides SMMs access to faculty and other resources at the university. The office might be corporate relations or outreach. The university office conducts concierge match making services, directing SMMs to the right resource, by working to understand the SMMs challenges and finding the appropriate resources at the university. A variant of this model is one in which the university office provides referrals not only to university assets, but also to statewide technology assets. This model is typically light touch—that is, the assistance might end once the hand-off is made, with little or no follow-up. Because of this light touch, there is risk that the SMM will not get the service it needs. In most cases, the Connector service is paid for by the university; if a project results from the connection, the SMM is usually charged a fee.

MEP AS FRONT DOOR TO UNIVERSITY TECHNOLOGY ASSETS

In this model, the MEP is embedded at the university and provides conduit to the university services and expertise. The contact is initiated through multiple channels; moreover, the MEP’s understanding of the state’s manufacturing economy and its deep knowledge of university assets are key to the success of this model. The model provides a broad range of technical services. The services may be paid for by a combination of federal, university, state, and industry funds. This is a much higher-touch model than the one above—the MEP tries to ensure that the SMM finds a good fit at the university.

UNIVERSITY AS NICHE SERVICE PROVIDER

In this model, the university has a facility or a service that meets a very specific need of many manufacturers in the state. Examples include materials testing, energy audits, or food safety testing. Referrals might be made by the MEP, or manufacturers needing the service may find the service through an industry association or their own. When the results of the service suggest needs for technology upgrades at the manufacturer, these may be
implemented. Universities often charge a fee for these services; they may be subsidized or paid in full through a university or government funding program.

**APPLIED LEARNING MODEL**

This model pairs students, either graduate or undergraduate students, with a project for a manufacturer, usually with a faculty mentor and sometimes an industry mentor. In some cases, the MEP may help to identify industry projects for the university; in other cases, faculty who have existing relationships with manufacturers help to develop the projects. In some cases, the state provides funding to enable the students and/or their professor mentors to be paid.

**MEP ADVANCED TECH TEAM**

This model is represented by the relationship between the MEP Advanced Tech Team and several universities and Manufacturing USA. The MEP Advanced Tech Team is a small group of MEP representatives who understand small manufacturers and become familiar with emerging technologies and resources relevant to SMMs. They work with other MEP agents to field technology questions and identify technology resources at universities, federal labs, and Manufacturing USA Institutes. This model is similar in some ways to the University Office as Light-touch Connector, except that those identifying the technologies are deeply familiar with SMM needs. They work with the SMMs and additionally hand off information to an MEP who is in close geographic contact with the company for a broader, value-added level of service. There is follow up to ensure that appropriate services are provided.

There are many variations on these models. In some cases, universities are using several of these models to interact with SMMs, and some, but not all, include MEPs as partners. Most of the MEP-university relationships that seem to be working well fall into one of these general models.

By observing the pilot projects, we have learned that the models embodied by MEP-university relationships often evolve over time, changing from one model to another or combining elements of different models. This may reflect a maturing and deepening of the partnership, as occurred in the Kentucky pilot, described below. Or it may reflect a turnover in staff that makes the initial model unworkable, as happened in Ohio. It could reflect a change in the assets available to either institution that allows an additional dimension to be added to the partnership, such as a new lab, testing facility, or training program. Or it could reflect a shift in priorities that either emphasizes or deemphasizes the partnership.
The descriptions of the partnerships from our pilot projects illustrate how these university MEP partnerships may fall somewhere in between these models and as well as how they may evolve over time. We also describe another MEP-University model from TechHelp Idaho.
3. Examples of MEP Partnerships: Pilot Projects and Other Models

UNIVERSITY OF LOUISVILLE PARTNERSHIP: APPLIED LEARNING MODEL LEADING TO MEP AS FRONT DOOR TO UNIVERSITY

The University of Louisville Partnership/AKA project team included the following members:

- Dr. Kunal Kate, Associate Professor of Mechanical Engineering, University of Louisville.
- Dr. William A. Metcalf, Associate Vice President for Research Development and Strategic Partnerships, University of Louisville.
- Scott Broughton, Director, Advantage Kentucky Alliance

Motivations for Partnership

For UofL, the motivation to work with industry was two-fold. The first objective was to offer students an applied learning experience to improve their understanding of how their research will be applied, and to provide a hands-on experience that will improve job placement. The university also expected the faculty working on the project to benefit from learning about companies and the industry and deriving personal satisfaction from seeing companies implement the technology. Finally, the university leadership is committed to economic development for Kentucky, and the faculty believed that this technology could help SMMs improve their competitiveness. This program was part of a larger program at the UofL to assist companies in growing their business through federal technology development opportunities, including funding through Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, the Minority Business Development Authority (MBDA), and SBA’s Growth Accelerator Fund Competition (GAFC).

For AKA, the partnership with UofL allowed them to provide SMMs the opportunity to accelerate new product development for SMMs using 3D printing technology. More importantly, the MEP saw the potential for a longer-term partnership to take advantage of the broader technology assets of the university.

As the project began, AKA was housed at Western Kentucky University (WKU) but had little interaction with WKU faculty or technology assets. By the end of the pilot project, UofL had applied for and won the right to host the Kentucky MEP, with the attendant
opportunity to deepen the partnership for the benefit of SMMs throughout the State of Kentucky.

**Partnership Model and Principles**

The UofL/AKA team initially planned to structure the partnership as an applied learning model, with two separate student teams employed to assist the company—one working on the engineering aspects of the project with UofL and one working on value-stream mapping with AKA. Over time, this model transitioned into a MEP as Front Door to University Technology Assets model, as the MEP became more familiar with the larger suite of services that the university could offer SMMs. Locating the MEP at the UofL means that the Kentucky MEP can leverage a wide variety of university facilities and faculty for the benefit of their client SMMs. The pilot project team credited the partnership built during the pilot project with their success as the new site of the Kentucky MEP.

**Determining Principles of Partnership**

As the pilot team members began working together, they developed principles of partnership to guide their collaboration. These principles were not explicitly stated up front but became apparent as they proceeded. The principles included the following:

- The primary objective of the partnership was to improve the competitiveness of the businesses.
- The students working on the project would gain exposure to the manufacturing environment and an opportunity to solve real-world manufacturing problems. This would improve their employability, but this is a secondary, not a primary, objective of the project.
- It was important that AKA staff understand the 3D printing technology so that they could effectively work with the SMMs to determine which companies and which parts might be good candidates for the technology.

**Identifying and Selecting Partner SMMs**

The team worked together to determine a process for selecting SMMs they would work with. There were several principles that they used to determine this. They were looking for companies with the characteristics (fit factors) listed below. We used the SMM Engagement Funnel Tool (see Figure 2) to talk through the process and the fit factors.

- The business management team has a proactive mind set.
- The business has an immediate need or situation that can be aided by applying the 3D printing technology.
- The business has the resources (staff and funding) to take advantage of the program.
• The business management has a desire and expectation that the program will result in a change in their operations.

After determining these fit factors, AKA and UofL trained several AKA staff on the technology so that they could conduct outreach to potential participants and bring those that seemed like a potential fit to UofL to learn more about the technology and the process.

<table>
<thead>
<tr>
<th>SMM Engagement Funnel</th>
<th>Tactics</th>
<th>Tools, Artifacts</th>
<th>Partnership Issues</th>
</tr>
</thead>
</table>
| Identification        | • Initial strategy meeting with AKA and UoL  
• Internal prospect discussion with partners to identify potential fits  
• Brainstorm on “perfect fit” of client | • Development of cloud-based prospect document | • Outlining partner responsibilities |
| Outreach              | • Social media release  
• Incorporation of education on outreach activities  
• AKA team engagements | • Original write up by UoL, discussing grant opportunity  
• Press release by UoL/AKA  
• Facebook, LinkedIn  
• Development of educational white paper on program  
• Training session for AKA team members | • Need for increased communication  
• Regularly scheduled update discussions  
• Development of easily understood documents/training materials |
| Selection             | • Requirement of prospect being responsible for a task  
• Initial preliminary discussion with prospect  
• UoL tour  
• Prospect onsite meeting to finalize strategies | • 1 page qualifying prospect-filled out document  
• History of work and experience with main stakeholders at client | • Anticipated alignment of facility tours  
• Businesses needing to work at the speed of businesses |
| Fit                   | • Proactive mind sets of business management team, have a current situation/need that program alleviates, businesses having resources (workforce/money) to take advantage of program, have a real desire and EXPECT to CHANGE business after program culmination. |

**Figure 2. SMM Engagement Funnel**

**Building and Managing Relationships with SMMs**

The UofL/AKA partnership started by working on a list of manufacturers that would be interested in learning about and possibly applying 3D printing to their manufacturing process. They co-developed an information sheet that the AKA team used to explain the opportunity to companies. A sign-up sheet gathered information of potential participants, and AKA worked with the companies to help them assess whether the technology might be helpful and for which parts. The team described the process for identifying candidates using the engagement funnel pictured in Figure 2. The prospective partner companies toured the 3D printing lab at UofL and held discussions with UofL faculty and AKA.

AKA was primarily responsible for outreach to potential companies, making the business case for the application of the technology—and, once the company was on board, managing communications between the university team and the company to keep the project moving.
UofL was responsible for working with the student team to develop a prototype part that could be integrated into the company’s workflow.

We asked the pilot participants to use the “force field analysis” tool (see Section 6 and the MEP-IHE Partnership and Collaboration Toolkit) to surface both drivers and barrier to a “future state” in which an ideal partnership had been developed and SMMS were achieving positive outcomes. Upon reflection regarding the ideal partnership, the team described it as follows:

- The partnership generates a shared set of goals for collaboration.
- The partnership develops a common understanding of responsibilities for moving toward those goals.
- Each partner brings assets to the partnership that both value, including know how, financial resources, equipment, ideas for new grants to support the project, staff to vet SMMS, staff that can develop financial viability models, and student teams.
- Partners share credit for the accomplishments achieved from the partnership.

They also described the drivers leading to that ideal partnership state, and the things they are doing to support those drivers:

- Developing a partnership agreement that values the contributions of both partners.
- Developing an agreement about how they will vet potential SMMS for the technology and how the company will be introduced to the university.
- Training MEP staff on the technology so they are comfortable talking about it with SMMS.
- Working toward aligning start times for projects to ensure that full teams of undergraduate and graduate students and the supervising faculty can be on board as project launches.

However, there were barriers that prevented the partnership from reaching its full potential and stalled the project:

- Miscommunication about expectations regarding timelines and company vetting process.
- Inability to recruit and onboard students for the project until the beginning of semester.
- Metrics for universities (students, research funding) don’t align with MEP metrics (short term impact for SMMS).

Keeping in mind these differences in expectations, metrics, and timelines is important as MEP/university partnerships develop their principles of partnership. We address these challenges in the “lessons learned” and in the toolkit.
Meeting Workforce Needs of SMMs

One of the key barriers to adoption of Industry 4.0 technology adoption by SMMs is training the company’s workers to use the technology and integrate it into the company’s process. We encouraged the pilot projects to do some forward thinking about how these needs would be addressed and what each of the partners could bring to that effort. For instance, what were the training needs associated with implementation of the 3D printing solution developed for their project? We also asked them to consider what longer-term needs were necessary as the company implemented the technology more broadly across the company.

In the case of the UofL/AKA partnership, the partners identified the SMM needs specific to the current projects as follows:

- Training on advanced manufacturing technologies.
- Training on assessment of market needs.
- Understanding how to transition specified parts to the 3D printing technology and how to integrate it into their workflow.
- Training on application for SBIR and STTR grants, which would allow them to bring capital into the process of reinventing specific parts.

More general, longer-term workforce training needs included the following:

- Developing a pipeline of talent familiar with the 3D printing technology for the company.
- Training on supply chain management and how the supply chain might be improved through 3D printing.
- A jointly developed certificate program that would demonstrate understanding of the 3D printing technology.

The partners further identified how each of them could contribute to meeting these needs. This helped them to think about a longer-term partnership around education and training for SMMs related to 3D printing technology.

Identifying Opportunities to Meet the Broader Technology Adoption Needs of SMMs

As the partnership progressed, we asked each of the pilot teams to reflect on how they might partner in the future to meet the broader needs of SMMs for the adoption of Industry 4.0 technologies. We asked the pilot teams to consider the following question: *How might we increase the competitiveness of manufacturers in our region by helping them adopt advanced manufacturing technologies?*

In the case of the UofL/AKA partnership, the pilot team identified a number of strategic opportunities to partner to address this longer-term issue. They included the following:
• Strategic Opportunity #1: Establish SMM, MEP, University and Community partnerships to create new product market opportunities that advance regional entrepreneurship and manufacturing.

• Strategic Opportunity #2: Set up and run a 3D printing manufacturing accelerator with partners identified in strategic opportunity # 1.

The partners brainstormed about how they might move forward with these opportunities, identifying the key steps and milestones, who would be responsible for making progress on each of them, the key questions that needed to be answered to make progress, and the results expected at each milestone.

**Pilot Project Results**

The pilot project worked with two manufacturers to develop designs for parts that would be created through metal 3D printing. The two companies, Monticello Tool and Die and Lexair, Inc., continue to work with UofL to refine the design of the parts that they have identified as candidates for 3D printing.

The primary impacts of the projects have been as follows:

• Both companies have been educated about how additive manufacturing can change their business model in the future.

• Both companies are realizing the benefits of 3D printing in their business. Monticello will embed 3D printing into their value stream, using the technology to replace legacy parts that are no longer otherwise available and significantly reducing costs for the part. They are working toward additive manufacturing for more parts that will further reduce their costs.

• Lexair is using 3D printing to improve the design of the parts for more capacity and improved function.

• The partnership between the MEP and UofL was key to making this technology transition happen at this time. Without the MEP, the companies would not have worked with UofL. The MEP was essential to the management of the relationship, project scheduling, and communication.

• The pilot project led the UofL to apply to NIST MEP to become the host of the Kentucky MEP. this meant moving the MEP from Western Kentucky University, which had no cooperative relationship with the MEP (other than hosting them in their space), to UofL. The pilot project helped both the university and the MEP recognize the potential of the partnership for better serving the needs of SMMs with respect to both technological adoption and workforce development.
**CHALLENGES**

Like any new partnership, the UofL AKA partnership encountered some challenges. For example, the faculty working with the student teams on one of the projects did not fully understand how the part in question would be used. This impeded the faculty member from fully understanding the key specifications necessary for the 3D printed part. Communicating up front about those requirements would have saved a lot of time. This points to a more general issue among university-MEP partnerships: faculty don’t necessarily have manufacturing experience that would prompt them to ask the right questions to ensure that a technology solution will meet the company’s requirements and fit into the company’s manufacturing workflow.

A second challenge, one that is also common to university-MEP partnerships, is the tension between the company’s timeline and the reality of a university’s academic calendar and academic process. Students cycle in and out of the capstone program, and this turnover was challenging. New students had to be trained and the process was interrupted and delayed.

**ADDRESSING THE CHALLENGES**

The team has learned that it is critical to give both students and faculty an opportunity to learn about the part and the manufacturing process up front to ensure that they understand the product requirements both for its use and how it integrates into the workforce. A liaison working within the university who has extensive manufacturing experience and has worked with MEP (Scott Broughton) is bridging this gap and ensuring that the university team understands the conditions and requirements of the project. The team is also working on identifying a better model for handing off the project from one student team to another by providing more continuity through the use of graduate students that stay with the project over the longer term while undergraduates cycle in and out.

**Sustainability of the Partnership**

The partnership between UofL and the AKA has evolved as the MEP has physically and contractually relocated from Western Kentucky University to the University of Louisville. Since this shift, the partnership has evolved in structure to look more like, “MEP as front door to the University Technology Assets.” During 2022, Scott Broughton moved from AKA to UofL’s Office of Research and Innovation as Director of Manufacturing Engagement. He is familiarizing himself with all that the university has to offer manufacturers so that he can better connect manufacturers’ needs to UofL solutions. With the Kentucky MEP moving to UofL, the MEP will be able to bring their client SMMs to the university and, through Scott, connect them with the technical, training, and recruitment resources they need to adopt Industry 4.0 technologies.
OHIO UNIVERSITY PARTNERSHIP: ADVANCED TECH TEAM MODEL

The Ohio University project team included the following members:

- Dr. Jesús Pagán, Associate Professor, Russ College of Engineering and Technology, Ohio University
- Dawn Coleman, Growth Advisor, Ohio Manufacturing Extension Partnership (MEP)
- Linn Yost, President, Appalachian Ohio Manufacturing Coalition (AOMC) and Owner, Micro Machine Works, Inc.

Motivations for Partnership

Ohio University, the lead applicant, in collaboration with The Ohio MEP Southeast operated by the OSU South Center proposed a partnership to support SMMs. The partnership was to be supported by the Appalachian Ohio Manufacturer’s Coalition (AOMC), Washington State Community College, and Building Bridges to Careers, a nonprofit that runs programs and events for the Mid-Ohio Valley and houses a makerspace and small business incubator. Ohio University aimed to address challenges that SMMs have to overcome while implementing new technologies such as robotics, CNC machines, and automated systems used for factory automation. It did this by applying Industry 4.0 digital tools to create digital-twin virtual machines.

The Ohio Center’s effort was motivated by an opportunity in advanced manufacturing created by the advent of digital twinning technology. This technology creates a digital model of a manufacturing process that can be tested and refined before physical components are constructed or purchased. One of the key Industry 4.0 technologies, digital twinning holds the promise of greatly improving manufacturing systems and outcomes as systems can be tested and validated, iterated, and refined with much more flexibility in a shorter time, and at a lower cost than through other methods.

There are two fundamental challenges associated with implementing digital twin approaches in Ohio, however, and both relate to workforce development. The first question is where will SMMs already implementing or planning digital twin approaches (and associated technologies such as robotics and CNC machines) find the talent to operate these systems and provide technical support? The second question is whether the region’s educational organizations are ready to support the necessary talent development to fill this need, and if not, how will they develop this capacity?

The heart of the proposed work was to create pilot programs with partner organizations in which digital twin projects were planned and implemented in industry higher ed collaborations with an eye to assessing both the effectiveness of the technology solutions and the relevance for workforce development questions. They were also looking for insights on how digital twinning projects should be scoped with respect to time, resources, and budget, how risk can be managed, and how quality can be measured. The work
also aimed to set the stage for partnerships across the MEP participants for broader implementation of digital twinning and development of associated talent pipelines to work in Industry 4.0 jobs.

**Partnership Model and Principles**

The OU/Ohio MEP/AOMC partnership at first fit the Advanced Tech Team Model. OU was to prepare the MEP specialist to help them become familiar with the digital twinning technology assets at Ohio University, and with the benefits of such technology. The Ohio MEP was to develop specialized understanding of the digital twinning technology to be able to present that information to manufacturers.

The Ohio partnership ended up straying from the model when it became clear that the Ohio MEP was facing resource and bandwidth constraints. Ohio University then focused its partnership development efforts on the AOMC, which did to some extent take on the role of developing an understanding of the technology to be able to talk with manufacturers about it.

**Determining Principles of Partnership**

For guidance on developing appropriate principles of partnership, the OU/Ohio MEP/AOMC partnership turned to work produced by IASA, an international association of technology architects. Their Associate Engagement Model outlines four categories and 12 principles for effective engagement: 1) Value (categories, measurement, prioritization), 2) Coverage (scope, context, portfolio), 3) Governance (standards, maturity, target state), and 4) Quality (testing, architecture analysis, quality attributes). Because the IASA model provides guidance about how enterprise architecture teams can be effective in their engagement on digital transformation projects, the Ohio partnership adopted this framework to guide the partnership focused on digital transformation of manufacturing with digital twinning.

**Identifying and Selecting Partner SMMs**

All members of the Ohio team were asked to participate in identifying SMMs to work with. Tools were available, including regional surveys, website news and highlights, and email newsletters, that could help partners with the identification of prospective SMMs to work with. Outreach tools included Microsoft teams to conduct visits (during the pandemic) and demos of the digital twinning software, Simumatik. The partners encountered challenges during the identification and outreach stages, however. The partners all had overlapping regions, so they needed to figure out how to not duplicate outreach to constituents and stakeholders. The partners also needed to figure out ways to build a bond, given that they were all working on multiple regional activities. Another challenge was determining who would lead the outreach efforts.
The partners identified “fit factors” that they would look for in SMMs to gauge their readiness to participate in the digital twinning work. They found that the SMMs that would be most likely to benefit from the work would be those that: 1) were able to participate in regular communication, 2) had a project to implement that was feasible given the expertise and tools available from Ohio University, 3) had some exposure to digital twinning software tools, and 4) were willing to explore new ideas.

**Building and Managing Relationships with SMMs**

The Ohio partners were unable to complete the “force field analysis” to surface drivers of and barriers to a “future state” in which an ideal partnership had been developed and SMMs were achieving positive outcomes. However, they did share that they initially faced a number of barriers creating an effective partnership, and they also reported on a number of drivers that supported partnership development work after overcoming some of the initial hurdles. Between the time that Ohio University approached the MEP about partnership and the time that the grant began, a number of staffing and leadership changes occurred at the MEP. By the time the grant was awarded, OU was still trying to (re)build relationships with the MEP and establish roles. There were significant barriers created around key staff and relationships. Once the project was underway, further challenges arose around workflow and communication when it became clear that the staff of the MEP, focused largely on lean manufacturing process training and consultation, did not have the technology expertise to become versed in digital twinning to the extent that they could describe the technology and its promise to prospective partners. The MEP eventually dropped out of the partnership activity because of limited bandwidth to participate in activity that wasn’t within their skill set.

Meanwhile, OU and AOMC developed a strong working relationship and were able to leverage a number of drivers supporting advancement toward a strong partnership and positive outcomes for SMMs. OU and AOMC were able to coordinate their activities and develop communication and workflows that allowed for effective exploration of relationships with SMMs around digital twinning (see Pilot Project Results below).

**Meeting Workforce Needs of SMMs**

The Ohio partners (which, by this time in the project, included only Ohio University and AOMC) recognized a number of education and workforce needs among Ohio manufacturers which would need to be addressed for further technology adoption by SMMs in the state. These needs ranged across CNC machining, computer aided design (CAD) and computer aided manufacturing (CAM), programmable logic controllers (PLC), and robotics. To address all of these needs, the partners determined that the main university assets were the curriculum, labs, and expertise. What the university would need from the MEP (or in this case, the AOMC) to enlist these assets in addressing workforce needs, where four things: 1)
access to clients, 2) planning activities and motivation, 3) sharing resources, and 4) support and problem solving.

Similarly, the Ohio partners were able to identify a straightforward set of assets and collaboration needs on the part of AOMC. The partners agreed that most significant asset that AOMC brought to the table was relationships with manufacturers. The only thing that AOMC would need from OU in order to leverage those relationships would be shared meetings and events. A more detailed analysis of assets and collaboration needs would be required, of course, to catalyze deep partnership activity focused on the workforce needs of manufacturers, but the Ohio assessment of needs and assets was elegant in its simplicity and got to the heart of what’s possible when universities and their partners in manufacturing collaborate around each other’s assets.

Identifying Opportunities to Meet the Broader Technology Adoption Needs of SMMs

As the grant period was approaching a close, partners were encouraged to consider how they might leverage assets of both the university and the MEP to explore a strategic opportunity that would keep them working together. Partners were provided with a tool on which to map assets of both the university and the MEP, across four types of assets—network, skill/knowledge, physical, and capital. Partners were then asked to combine 3–6 assets to create a strategic opportunity that would be feasible to undertake right away, and for which both short-term outcomes and long-term impacts were known. Finally, partners presented a short-term action plan for implementing the strategic opportunity.

The Ohio University and AOMC partners combined the following assets:

- AOMC—a network of six manufacturing leaders across Southeastern Ohio (network asset)
- AOMC—manufacturing/business, workforce development, education (skill/knowledge asset)
- AOMC—virtual operations (physical asset)
- OU—West Union Street Office Center; Central Classroom building (physical assets)
- OU—a network of six university-based manufacturing, innovation, and entrepreneurship experts (network asset)
- OU—Athens campus (physical asset)
- OU—staff and faculty expertise across five university units focused on engineering, technology, innovation, and community engagement (knowledge/skill asset)

Building on partnership work already underway, Ohio University, AOMC, and other partners throughout the region are working to combine these and other assets to create a Technology Center in Advanced Manufacturing for the Greater Ohio River Valley, serving the Appalachian regions in Kentucky, Ohio, Pennsylvania, and West Virginia. In regular
meetings with the Ohio University and AOMC partners, they pointed to a significant outcome of the APLU/MEP project being that it helped to serve as a platform upon which they could further conversations about the technology and advanced manufacturing center. While there may have been challenges in developing the partnership around digital twinning, the collaboration between OU and AOMC has helped to advance the vision for this broader regional asset.

**Pilot Project Results**

The partnership set out to work with multiple SMMs on digital twinning. Two firms began conversations to work with OU on a digital twinning demonstration. Unfortunately, one firm was unable to continue conversations because of difficulties raised by the proprietary nature of their manufacturing process that negated their ability to provide information needed to model the process in a digital twin. The other of the two firms, however, did work with OU on a digital twinning demonstration. OU worked with RXQ Compounding, a drug compounding firm, to develop a digital twin of a clean room environment and dispensing system that pumps liquid into a syringe. In this case, the digital twin was a simulation of a proposed system to automate a process currently carried out by a human working with process elements under a hood. The digital twin demonstrated how the process could be automated with robotic and digital control equipment, which could result in significant cost savings and operating efficiencies.

OU and AOMC also realized significant results that will help in their ongoing efforts to build the manufacturing innovation ecosystem in Southeastern Ohio, the Ohio River Valley, and the Appalachian region. Outcomes identified by partners included:

- The project created a depth of knowledge around digital twinning, and a proof of concept that will demonstrate the value of this Industry 4.0 technology to manufacturers in the region.
- The partners developed a clear idea of what’s required with regard to staff time and training to support development of a digital twin.
- An opportunity was established to develop education and training for students in an emerging technology of critical importance to manufacturing innovation.
- Ultimately, the partners report that the project’s largest impact has been to provide an entry point for broader conversations across the region about developing the regional manufacturing innovation ecosystem. These conversations and the deepened relationship that have come with them will be central to efforts to establish the Technology and Advanced Manufacturing Center that is envisioned by partners in the region.

Ohio University continues conversations with the MEP, despite the difficulties that arose around engaging the MEP in the current project. The MEP is an important part of the
development of the manufacturing innovation ecosystem in the region and will play a role in the new Technology and Advanced Manufacturing Center mentioned above.

**CHALLENGES**

The most significant challenge faced by the partners on the project were issues related to staffing and leadership of the MEP. Because of shifts at the MEP and their staffing and resource limitations, it was difficult for OU and the MEP to develop the necessary ongoing partnering activities to support joint efforts to reach out to and engage SMMs in digital twinning projects. The partnership faced a more challenging process than expected with regard to assessing SMMs fit for this kind of project, which limited the number of manufacturers they were able to engage in development of a digital twin. A final challenge related to the proprietary nature of some manufacturing processes, which made it difficult to apply digital twinning at all because of concerns that the manufacturer would need to reveal too much in order to build the digital model.

**ADDRESSING THE CHALLENGES**

The relationship between OU and AOMC significantly mitigated challenges raised by changes at the MEP and the change in the MEP’s role in the project. Because of the close relationship, AOMC was able to work with OU to reach out to manufacturers and help in educating manufacturers about the technology and in assessing manufacturers’ fit and readiness for this type of project. Because of the broader ecosystem relationship-building that happened through this project, partners are engaging in wider conversations and planning for development of ecosystem-wide assets like the Technology and Advanced Manufacturing Center. This will address the limitations around bandwidth and resources as the partners move forward with collaborators across the region.

**Sustainability of the Partnership**

The broader collaborations stimulated and strengthened by the current project represents the greatest hope for sustained partnership and collaboration between OU and AOMC, and also with the Ohio MEP. Though the MEP was unable to engage as hoped on this project, they are communicating regularly with OU and others about ecosystem development and will play a role in development of the Technology and Advanced Manufacturing Center.
NORTHERN ILLINOIS UNIVERSITY PARTNERSHIP: APPLIED LEARNING MODEL

The NIU/IMEC project team included the following members:

- Dr. Donald Peterson, Dean, College of Engineering and Engineering Technology and Professor, Department of Mechanical Engineering, Northern Illinois University
- Dr. Mansour Tahernezhadi, Senior Associate Dean and Professor of Electrical Engineering, Northern Illinois University
- Ray Ziganto, Manufacturing Director, Northern Illinois University
- David Boulay, President, IMEC

Motivations for Partnership

The NIU-IMEC effort was motivated by a desire to strengthen and extend existing programmatic activities at both organizations in a synergistic way that tapped substantial existing resources to improve technology adoption and implementation in specific, Industry 4.0 practices at small and medium-sized manufacturers (SMM) in the metals sectors. The specific programmatic activity at the heart of this site was the applied learning model using capstone classes at the NIU College of Engineering and Engineering Technology (CEET).

Specific elements of the project included the following:

- Strengthening and extending the existing applied learning model in the NIU College of Engineering and Engineering Technology (CEET).
- Establishing a dedicated Professor of Practice in Manufacturing (PPM) role, and linking this role to SMMs, to other collective activities, and to the IMEC.

The ultimate motivations were to strengthen the partnership linkages, improve learning models, and successfully provide Industry 4.0 know-how to SMMs.

WHY THE METALS INDUSTRY?

Although metal manufacturing (including fabricated metal, machinery, and other specialties) constitutes the largest manufacturing sector in Illinois, many companies in the sector lack expertise in Industry 4.0, including, but not limited to, A.I., robotics, smart machining, and additive manufacturing. Additionally, metals manufacturers are strong feeders to other Illinois SMMs in aerospace, automotive, and agricultural industries. Thus, improving the competitiveness of this industry is important to broader supply chains.

GOAL AND OBJECTIVES

The work was guided by three broad objectives:

1. Develop and transition new advanced manufacturing Industry 4.0 technologies and practices.
2. Educate and train the workforce for technology adoption and sustainability.
3. Expand the Industry 4.0 adoption by SMMs in Illinois.

**Partnership Model and Principles**

The NIU/IMEC partnership fits the Applied Learning Model. NIU and IMEC have long collaborated on applied learning capstone projects, through which students at NIU CEET work with companies on a real-world problem. IMEC helps both in identifying potential companies’ projects as well as ensuring that the capstone being undertaken is strategic, namely that it has the potential to lead to lasting improvements in technology adoption and optimization.

NIU also has a multi-disciplinary senior design project (MDSP) capstone as part of the bachelor’s degree curriculum. Students work on teams to take on a design challenge for a client and are mentored by faculty and industry professionals.

The key focus of this work was creating a Professor of Practice in Manufacturing (PPM), who would be the key link for NIU, IMEC, and companies, working hand-in-hand with IMEC to assess needs of companies, and coordinate projects to achieve long-term improvement in understanding and adoption of Industry 4.0 practices. At the same time IMEC enhanced its service and outreach capabilities through the stronger partnership created by the PPM.

**Determining Principles of Partnership**

The NIU and IMEC teams responded actively to prompts to review examples of principles of partnership and to consider what such principles might look like for their own partnership. In conversations about the development of the partnership, the NIU/IMEC team noted that it would have been helpful to have had a conversation about principles before the work began, as this would have strengthened their ability to partner more closely and achieve mutual benefit.

Using examples provided by APLU, the team members identified four core principles for the NIU/IMEC partnership:

- **Respect and Equality**: The relationship between partners is characterized by mutual trust, respect, authenticity, and commitment. Principles and processes are established, especially for decision-making and conflict resolution, with clearly defined expectations and roles for all involved.
- **Communication and Transparency**: Partners make clear and open communication an ongoing priority in the partnership by striving to understand each other’s needs and self-interests through regular communication.
- **Proactive Planning**: Partners create the strategy and tactics and collaborate on the timely execution to achieve the agreed upon, mutually beneficial goals.
• **Future Direction:** Partners must plan for sustaining the success and growth of the partnership over time.

Further definition was provided for each of these principles in a one-page draft set of principles. The principles were not finalized as the day-to-day work of the capstone projects overtook broader planning activities such as the development of partnership principles. As noted above, the NIU/IMEC team agreed that development of principles would have helped more if it had been undertaken before the work of the partnership was underway.

**Identifying and Selecting Partner SMMs**

Because NIU had been offering the multi-disciplinary senior design project (MSDP) for a number of years, they had developed tactics to identify and reach out to prospective SMMs partners, and they also had a proven selection process. In partnership with IMEC, they were able to expand their promotional reach, but the partnership struggled to fully engage both parties in the engagement effort. The partners noted that because of the grant award timing, there was not enough time to resolve roles and responsibilities prior to engaging with SMMs. Therefore, IMEC didn’t end up playing much of a role in selecting companies for MSDP engagements, and even after selection had taken place, the mutually beneficial collaboration model was still a work in progress.

The partners did agree on a set of “fit factors” that should be in place for SMMs to fully participate, and for the partners to share responsibilities. Because of the academic year calendar, SMMs had to be prepared to work on a 9-month project timeline. They also needed to have enough of an idea or existing project/problem that something could be more fully developed during this window. These fit factors were in place for the MSDP before the NIU/IMEC partnership on this grant project. The third fit factor would support mutual engagement with the SMMs by the partners: SMMs should be able to benefit from IMEC’s support pre- or post-project. However, it’s not clear that this fit factor was used heavily in the selection process because, as noted above, IMEC did not end up playing a significant role in selection.

**Building and Managing the Partnership**

NIU/IMEC partners identified the following descriptors of the future state of an ideal partnership and positive outcomes for SMMs:

- Partners establish a set of guiding principles to inform their working relationship and desired outcome for SMMs.
- Partners agree on the tactics, methods, roles and responsibilities to engage with SMMs.
- SMM value delivery is scalable, and process driven.
- The partnership is self-funded.
- Resources (value) are easily accessible by SMMs.
• Benefits to SMMs are known, tangible, and measurable.
• Partnership generates a shared set of goals for collaboration.
• Partnership develops common understanding of responsibilities for moving toward those goals.
• Each partner brings assets to the partnership that both value, including knowhow, financial resources, equipment, ideas for new grants to support the project, staff to vet SMMs, develop financial viability models, and supervise students.
• Partners share credit for the accomplishments achieved from the partnership.

The NIU/IMEC partners identified a number of drivers supporting movement toward the future state described above. These included a partnership agreement that acknowledges and values the contributions of each partner, agreement on “best fit” SMMs that will most fully leverage the contribution of the partnership, and aligning start times for projects to ensure that full teams of undergrad and graduate students plus faculty can be on board as the project launches. Some drivers identified by the partners seemed to be aspirational—that is, they hadn’t been implemented, but they felt they should have been.

The partners also identified barriers to creating the future state described above, and many of these related to misalignment between the university and MEP—misalignment that would likely have been avoided with more time to focus on partnership development at the beginning. Barriers identified by the partners included: Misalignment of jointly positioning human resources at MEP and University, lack of alignment between MEP and University for a “one-stop shopping framework” for SMMs, misunderstanding about commitment of resources required, and the fact that success indicator metrics for MEP and university do not align (metrics for universities, such as students, research funding, don’t align with MEP metrics, such as short term impact for SMMs).

The force field analysis conducted by the NIU/IMEC partners underscored the need for more time at the front end to work out partnership principles, operating procedures and workflow, and alignment of expectations and processes. Many of the drivers are issues that take time to address, and the barriers were mostly created by the lack of time at the front end to address and strengthen the drivers.

**Meeting Workforce Needs of SMMs**

We asked the pilot participants to reflect on what they had learned about the workforce needs of the participating SMMs. The NIU/IMEC assessment is included in Table 1. Relationships with the SMMs have clearly created an understanding of the array of workforce needs faced by the manufacturers. Assets from both the university and the MEP can be brought to bear on these needs, but significant collaboration and partnership needs remain. While some of the kinds of collaboration identified in the outer columns on the table—“Align & leverage marketing and outreach efforts,” for example—were taken up as part of this partnership effort, many of the collaboration issues were identified as barriers.
by partners, and/or were identified as partnership issues that simply needed more time for development on the front end of the partnership.

Table 1. Workforce needs of the partnership.

<table>
<thead>
<tr>
<th>Collaboration Needed by University with MEP</th>
<th>University Assets</th>
<th>SMM Talent and Workforce Development Needs</th>
<th>MEP Assets</th>
<th>Collaboration Needed by MEP with University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs, Assets, Collaboration Directly Related to Current Partnership</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Align &amp; leverage marketing and outreach efforts (plant tours, job fairs, etc.)</td>
<td>In-house marketing &amp; communications team</td>
<td>Broader access to students for Internships, MSDP, &amp; Full-time employment. R&amp;D needs</td>
<td>Sophisticated marketing resources and outreach platform, webinars</td>
<td>Fully engage within IMEC/MEP constraints.</td>
</tr>
<tr>
<td>Merging of processes for recruiting of SMMs</td>
<td>Multiple industry &amp; community contact points</td>
<td>Single point of contact to assess needs &amp; present options, “One-Stop-Shop”</td>
<td>Multiple field resources, current needs survey data,</td>
<td>Mapping of IMEC resources with NIU faculty, admin, student, &amp; lab resources.</td>
</tr>
<tr>
<td>Jointly identify &amp; share case studies and testimonials to demonstrate ‘best practices’ and pre/post impact</td>
<td>Past SMM projects (including Industrial Systems Engineering projects)</td>
<td>Increase awareness of NIU &amp; IMEC R&amp;D services and Advanced Manufacturing applications for SMMs.</td>
<td>Hundreds of documented &amp; SMM engagements/yr with known impact, technical staff,</td>
<td>Jointly identify &amp; share case studies and testimonials to demonstrate ‘best practices’ and pre/post impact</td>
</tr>
<tr>
<td>More General, Longer-Term Needs, Assets, Collaboration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create a financially sustainable model</td>
<td>Revenue generating opportunities, (Research, SMM sponsored projects)</td>
<td>Long-term partnership with NIU/IMEC for workforce needs (reflective of one-stop shopping)</td>
<td>Marketing &amp; Field Resources</td>
<td>Create a financially sustainable model</td>
</tr>
<tr>
<td>Create/administer a pre &amp; post impact assessment for SMM clients</td>
<td>Engineering Department students, faculty, and staff resources.</td>
<td>Measurable Outcomes in terms of ROI</td>
<td>Existing assessment tools, Field Resources</td>
<td>Need to be involved at all stages of SMM engagement</td>
</tr>
<tr>
<td>Identify staff resources responsible for collaboration &amp; assisting with program execution</td>
<td>MFG Director &amp; other staff resources</td>
<td>Staffing &amp; resource pipeline, engineering skills, future talents</td>
<td>Internal resources, field staff, 3d Party resources.</td>
<td>Compelling ROI to more fully engage</td>
</tr>
<tr>
<td>Identify training needs of SMMs</td>
<td>Engineering Department Faculty, Grad/PhD students, and staff resources.</td>
<td>Re-Skilling current workforce to adapt to Advanced Manufacturing Practices</td>
<td>SMM access, survey capabilities, workforce workshop data/trends</td>
<td>Create/deliver prioritized training curriculum that syncs with the needs (duration, location, timing) of the SMMs</td>
</tr>
<tr>
<td>Identify the friction points typically experienced by SMMs in the recruiting process</td>
<td>NIU CEET Placement Office, Student clubs and professional associations, Faculty &amp; staff resources, current recruiting/career programming &amp; timing</td>
<td>Best Practices to attract &amp; retain Gen Z workforce for SMMs</td>
<td>SMM access, survey capabilities, workforce workshop data/trends, other partner &amp; 3rd party resources</td>
<td>Summarize &amp; share current resources, programming and data related to placement activity, student preferences, etc.</td>
</tr>
</tbody>
</table>
Identifying Opportunities to Meet the Broader Technology Adoption Needs of SMMs

As the grant period was approaching a close, partners were encouraged to consider the ways in which they might leverage assets of both the university and the MEP to explore a strategic opportunity that would keep them working together.

The NIU/IMEC partners combined the following assets:

- IMEC—manufacturing leaders on board (network asset)
- IMEC—training webinars (knowledge/skill asset)
- IMEC—conference center (physical asset)
- NIU—transdisciplinary faculty (network asset)
- NIU—regional economic development industry council (network asset)
- NIU—expertise in Industry 4.0 technologies (knowledge/skill asset)

From the combined assets, the partners envisioned an Industry 4.0 and Economic Development Summit. With existing facilities, intellectual capital, and other resources, the partners felt that such a summit would provide the short-term outcomes of networking and showcasing IMEC and NIU capabilities and innovative ideas. The Summit would have the longer-term impact of creating roadmaps for diffusing and adopting Industry 4.0 technologies across SMMs in the region.

Pilot Project Results

During the pilot project, the NIU MSDP worked with eleven manufacturers on various technology solutions. Three of the manufacturers in the cohort of clients—Bonnell Industries, Borg Warner, and Cast Products—came to the MSDP through the coordinated promotion and outreach of the NIU/IMEC partnership.

The primary impacts of the projects have been as follows:

- Bonnell Industries has increased the efficiency of their industrial leaf vacuum system through improved impeller design and use of a smaller horsepower engine.
- Borg Warner worked with students on a component reduction exercise for a valve used in one of their emission devices, which made the envelope smaller and drove improvements in cost and efficiency.
- Cast Products created an automated test station integrating a number of sensors, reducing the time for a test process that normally takes a couple of days to 45 minutes.
- For the partners, there were outcomes that promised to improve future endeavors to collaborate.
- The partners developed principles of partnership, allowing them to be more communicative and more able to be supportive of each other’s vision and goals.
• The manufacturing director position funded by the grant (a role filled by Ray Ziganto) helped facilitate ongoing conversations and relationships with manufacturers, and the intention is to continue this position with proceeds from MSDP projects.
• The manufacturing director particularly helped by enabling the university and MEP to have one interface with SMMs—someone that could talk about a range of issues related to process, R&D, technology, prototyping.
• The partnership created a foundation on which NIU and IMEC can showcase more of their assets and outcomes; getting more exposure to SMMs and bringing other assets to bear on the needs of the SMMs.

**CHALLENGES**

The primary challenge facing the partners was the short timeframe at the beginning of the grant period in which to develop the partnership and work out all issues related to staffing, communication and workflow, roles, goals and metrics, etc. NIU and IMEC agreed that had there been more time at the front end, they would have had more success in developing and implementing a model for jointly serving SMMs. Specific challenges included difficulty in working out the financial management for the project, challenges facing manufacturers in working with the academic year timeline, and multiple misalignments in approach and expectations between NIU and IMEC (which could have, again, been resolved with more time for a partnership development runway).

**ADDRESSING THE CHALLENGES**

The partners are confident that the tools that were part of this effort will help them to strengthen the relationship between the university and the MEP. They agree that a goal should be to develop the broader partnership between NIU and IMEC, using resources like the principles of partnership and tools like the asset-based strategic opportunity identification, to help establish a foundation for program- or initiative-specific collaboration in the future.

**Sustainability of the Partnership**

The intention of this collaborative effort was to generate enough new clients and revenue for the MSDP to enable the partnership to hire a manufacturing director on a more permanent basis. They did not achieve this goal during the grant period, but NIU is committed to establishing the permanent position. The person who served as the manufacturing director for this project, Ray Ziganto, moved into a position at IMEC after the grant funds were exhausted. The broader partnership between NIU and MEP will be sustained (IMEC maintains ongoing partnerships with Bradley University, NIU, SIU Carbondale, and the University of Illinois Chicago) through regular joint activities. The partners that undertake more work on the foundations of partnership could vastly strengthen future collaborations on specific programs or initiatives.
TECHHELP IDAHO: MEP AS FRONT DOOR TO UNIVERSITY’S TECHNOLOGY ASSETS, EVOLVING TO APPLIED LEARNING MODEL

TechHelp Idaho, the Idaho MEP Center, did not participate in the pilot project. However, we include it here because it serves as a useful model of an MEP that is embedded at a university and is partnering within its own institution as well as across other institutions. We gathered information about TechHelp through a site visit, conversations with staff, and from their website.

Located at Boise State University, TechHelp Idaho offers a variety of programs for manufacturers, including the following:

- **Operational Excellence**: TechHelp facilitates operational improvement by applying tools such as Lean, Lean 6 Sigma, and other kinds of quality management training.
- **New Product Development**: TechHelp can assist with design, prototyping, and 3D printing of prototypes for new products.
- **Food Manufacturing Excellence**: TechHelp has programs specifically targeted to the food processing industry, including food safety processes, product development, process improvement, and other programs.
- **studio/Blu**: studio/Blu is a new product development program working with faculty, students, and industry to design, develop, and prototype products, test the market, and design branding for market success. This program also exposes students and companies to each other, developing a workforce pipeline of students who have experience bringing a product from idea to fruition.
- **Funding**: The program also includes opportunities for startup company funding through The COBE Funding Accelerator, a partnership between the Boise State College of Business and Economics (COBE) and VentureCapital.Org (VCO).
- **New Markets**: TechHelp also hosts a PTAC (Procurement Technical Assistance Program) and export assistance program that helps manufacturers reach into new markets.
- **Cybersecurity**: TechHelp works with manufacturers to offer cybersecurity resources including information, training and developing solutions for Idaho manufacturers.

**University Partners**

TechHelp Idaho is a partnership among three universities:

- **At Boise State University**, TechHelp partners with both the College of Business and Economics and the College of Engineering, which hosts the New Product Development Lab.
- **University of Idaho** hosts a TechHelp manufacturing specialist at their research park in Post Falls. U of I Cooperative Extension partners with TechHelp to manage the food industry program in Twin Falls.
Idaho State University’s Center for Entrepreneurship and Economic Development in Pocatello hosts TechHelp outreach to manufacturers in Eastern Idaho.

TechHelp also has a partnership with the Idaho Manufacturing Alliance and hosts an Economic Development Administration (EDA) University Center, which provides funding for the new product development lab.

Motivation for Partnership

TechHelp’s mission is to “be the catalyst for strengthening Idaho manufacturing—accelerating its ongoing transformation into a more efficient and powerful engine of innovation driving economic growth and job creation.” Its partnerships with Idaho State and the University of Idaho provide an opportunity to serve areas of the state far from Boise, and to build on the connections and expertise of University of Idaho’s Cooperative Extension program to serve the important food processing industry.

Building partnerships within Boise State required TechHelp to develop strong alignment with the mission of the university to “engage students through learning and research opportunities that improve the intellectual vigor, cultural vitality, and health of our communities.” Identifying opportunities to serve these two missions has helped TechHelp raise visibility and support within the university and provide a strong pipeline of students prepared to contribute to the success of Idaho industry.

Partnership models

Like many MEPs located at universities, TechHelp serves as a “front door to the university’s technology assets.” By partnering with University of Idaho and Idaho State University, TechHelp is able to leverage the expertise on those campuses as well as those at Boise State to bring greater resources to its clients. However, TechHelp goes beyond typical “Front Door” function to provide in-depth services to SMMs and other businesses, as described below.

Meeting Workforce Needs of SMMs

As workforce development has become a more urgent need for Idaho’s manufacturers, TechHelp has found that involving students in their work has strengthened both the mission of the MEP and of the university: for the MEP, assisting manufacturers and for the university, offering students learning opportunities that contribute to positive outcomes such as retention, graduation, and success in the workforce. The partnership model has shifted as the goal of student success has risen to become as prominent and the manufacturing service goal.
Manufacturers and industry startups need students with a variety of backgrounds. studio\Blu attracts an interdisciplinary set of students who work together on an industry-led project. They learn how to apply the skills they are learning in the classroom to these real-world problems in collaboration with students with different sets of skills and experience. One primary benefit to students is that they gain exposure to potential employers that may lead to positive student outcomes. They are more likely to stay in school, complete their degrees, and find success in the workplace. These positive student outcomes across disciplines further builds partnerships across the university and with faculty from different university departments.

Student centrality has become a unifying factor for partnerships across campus with TechHelp. Students in the MBA program are working to build connections across programs that had been siloed: for example, tying the funding accelerator—a partnership with venturecapital.org—with the product design lab.

TechHelp’s ability to unite and serve these two missions as they have developed the studio\Blu concept has facilitated partnerships across the university and attracted broader support from university leadership as they demonstrate the effectiveness of student involvement in their projects for important student success metrics.

**Meeting the broader needs of SMMs**

TechHelp’s studio\Blu provides access to a broad set of services for manufacturers—advanced technologies, equipment, and a space for collaboration for students, faculty, and industry. One of the unique features of studio\Blu in the context of MEPs is the degree to which it encourages interdisciplinary collaboration to meet the challenges of developing a new product while training students in the process of bringing a product from idea to market. This more closely models the real-world requirements of new product development in manufacturing—one in which product designers, product and process engineers, and marketing managers work together to ensure that a new product meets customer demands and can be manufactured efficiently.

**Partnership Sustainability**

The sustainability of TechHelp’s partnerships across the universities and departments has been an ongoing issue that they are working to address. Currently, the partnerships depend on personal relationships and commitments, rather than institutional arrangements built on a long-term plan for improving outcomes for all partners. After suffering partnership setbacks due to turnover in personal connections, TechHelp is moving toward more formal partnerships to ensure sustainability through the articulation of common long-term goals.
4. Drivers and Barriers to Success in University-MEP Partnerships

As we gathered information from each of the teams on their pilot project experiences, a set of key points began to emerge as the teams reflected on their experiences, both in the moment and as the project came to an end. Those key points fall into four categories:

- **Set the partnership up for success.** Allow time to develop principles of partnership prior to rushing into the work with manufacturers. This includes identifying what each partner believes will be the drivers and barriers to success.

- **Develop a shared understanding of culture, roles, and responsibilities.** This can be essential to ensuring that the three-way partnership doesn’t damage existing relationships and leads to success for the SMM.

- **Identify opportunities to address talent and workforce development issues for the manufacturers.** This is where the missions of universities and MEP’s have the greatest intersection and can have the greatest impact on the success of the manufacturers, the students, and for the regional manufacturing industry overall.

- **Keep the focus on the needs of SMMs.** Although universities and MEPs may have other objectives for the partnership, prioritize the needs of the SMM in the project.

- **Expand the partnership by identifying opportunities to leverage partner assets for greater impact.** Universities have many assets that can be useful to manufacturers and identifying how they might be leveraged for greater impact can reap rewards for both the university and the MEP.

We address each of these categories of key takeaways below.

**SETTING THE PARTNERSHIP UP FOR SUCCESS**

**Drivers and Barriers**

The partners in this project identified drivers of and barriers to success in developing a partnership and realizing positive outcomes for manufacturers. A summary of the drivers and barriers identified by partners is included in Table 2, and a brief discussion of partnership and collaboration considerations follows.
<table>
<thead>
<tr>
<th>Drivers</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partnership Principles</strong></td>
<td>Spell out clear outcomes and timelines in the partnership agreement.</td>
</tr>
<tr>
<td></td>
<td>Confirm that both partners value student engagement; pair student engagement with technology adoption and R&amp;D. Engaging students deepens the SMM–University–MEP interaction.</td>
</tr>
<tr>
<td></td>
<td>Establish principles and expectations before taking action. Hammer out principles and expectations between university and MEP before involving SMM, between MEP/university partnership and SMM before involving students or multiple researchers. University and MEP should also hammer out internal expectations and principles before engaging each other in partnership development. Make no assumptions—make sure that all expectations are reflected in partnership principles and agreement.</td>
</tr>
<tr>
<td></td>
<td>Develop an understanding of SMM fit. Partners agree that SMMs will be assessed for fit with the partnership project, or whether they should work with either the university or MEP.</td>
</tr>
<tr>
<td><strong>Key Staff and Relationships</strong></td>
<td>Provide technology training for MEP staff, who need to be able to discuss features and benefits of Industry 4.0 technologies with SMMs.</td>
</tr>
<tr>
<td></td>
<td>Manufacturing process and business training for SMM and university, to understand and speak to the business case for the technology.</td>
</tr>
<tr>
<td></td>
<td>Developing the ability to articulate the primary assets and offerings of each partner.</td>
</tr>
<tr>
<td><strong>Workflow and Communication</strong></td>
<td>Access to needed resources. Whether it be grant funds, equipment, staff or faculty expertise, access to what’s needed has to be confirmed. If permission by an external party is necessary, that needs to be secured before relying on it.</td>
</tr>
<tr>
<td></td>
<td>Alignment, clarity of and reference to goals and intended outcomes. MEP and university partners, as well as SMMs, need to be on the same page with regard to understanding the “why.” Each partner might have its own goals and intended outcomes, but there must be some shared goals that all understand, and other goals can’t conflict with the shared goals.</td>
</tr>
<tr>
<td></td>
<td>Mapping of, and agreement on, all key processes, like promotion and outreach, assessing fit, ongoing relationship management.</td>
</tr>
</tbody>
</table>

Continued on page 40
<table>
<thead>
<tr>
<th>Aligning Timelines</th>
<th><strong>Drivers</strong></th>
<th><strong>Barriers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commitment to making timelines work for everyone. Partners have to be as flexible as possible in setting up timelines as well as being transparent about and planning around about milestones that cannot be changed (such as semester schedules or SMMs process commitments).</td>
<td>Not including time for developing the relationships. Without time to work out all dimensions on this chart, lack of credibility and trust will likely undermine efforts. University and business timelines will always be different. The challenge is to find ways to work within constraints rather than insisting that constraints be removed.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Goals and Metrics</th>
<th><strong>Drivers</strong></th>
<th><strong>Barriers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Develop financial goals and metrics as well as technology adoption or other SMM outcomes. Set clear expectations regarding contributions to and revenue from the partnership. Report regularly, using shared terminology and measures, to maintain transparency. Measures for shared goals and intended outcomes are more important than measures tracked by individual partners. MEPs should not expect that the MEP metrics will drive evaluation of success; the university should not expect success to be based only on student outcomes or research impact analytics.</td>
<td>Metrics don't always convince business. Risk averse SMMs may be convinced of long-term benefit from measures that are easy to capture during a project’s timeline. Don’t expect MEP and university metrics to align. Instead, develop shared metrics. Different financial accountability and reporting processes. Alignment may not be possible and finding ways of working with the constraints may be needed.</td>
</tr>
</tbody>
</table>

There are different levels of partnership and collaboration, and not all require high levels of interdependence and shared vision and expectations. Our university and MEP partners found, however, that most effectively serving SMMs did require everyone to be aligned and working together. Key lessons can be drawn from the drivers and barriers identified by these pilot projects:

- It takes time to build and sustain a partnership and you need to plan for and build this time in—on the front end of the project and throughout.
- Overestimate the skills and resources required to keep surprises from creating setbacks.
- Talk about what interdependence looks like—when are responsibilities shared, when are they executed in parallel versus in serial fashion, and what responsibilities can be undertaken autonomously?
- Try to align expectations, processes and timelines, and success measures, but understand that compromise and working within constraints are parts of being effective partners.

This partnership-building exercise helped the partners anticipate barriers, commit to working through them, and to identify creating ways to mitigate the impact of the challenges.
Clarifying Roles and Establishing Principles

We asked participating partners to review a set of principles of partnership we collected from across universities. The example principles related to a variety of different kinds of partnerships, including those between universities and industry. We encouraged partners to consider what it might look like to develop principles for the University-MEP partnership and for the University-MEP-SMM partnership. We were pleasantly surprised at the enthusiasm with which our partners took up this task.

The following principles are not taken verbatim from what our participating partners outlined, but rather are examples of the kinds of principles that MEP-university partnerships might consider, based on what we learned from the participants in this project.

1. Commit to planning for and taking the time necessary to discuss, align (to the extent possible), set, and reflect on metrics, roles, responsibilities, and expectations. It takes time to build trust and the reliability needed for interdependence.

2. Work on building a foundational partnership, not just one focused on the current project. This will serve future project- or initiative-focused partnerships and collaboration.

3. Aim to build on individual partners’ strengths in divvying up responsibilities, and also make sure that partners have relative equal roles.

4. Use the partnership building activity as a way to learn and advance broader ecosystem building efforts. Organizations often come together because they are required to for a grant development or implementation activity. Commit to partnering beyond the grant, whether or not the grant request is successful.

5. Each participant must understand how their own organization works and why, where there are opportunities to mitigate constraints, and how internal assets can be aligned (or not). Each participant must also commit to understanding these dimensions of the other partner organizations, and not expect everything to change. For example, university participants must understand the university’s own structure and processes related to transferring and adapting manufacturing technologies, where there are opportunities to be flexible, and how to make things work internally so that partners have a streamlined experience.

Partners can use the Force Field Analysis tool in the toolkit to think through some drivers and barriers for your own partnership(s), and thereby consider what kinds of principles of partnership are required.

DEVELOPING A SHARED UNDERSTANDING OF CULTURE, ROLES, AND RESPONSIBILITIES

Universities, MEPs and SMMS each have their own cultures driven by institutional mission, incentives, and metrics. A driver for success is understanding these cultures
and how they influence who might best play each role in the three-way partnership. The partners should document and communicate those roles so that the university, the MEP and the SMM all understand who is responsible for each part of a project and how communication and work will flow.

Areas of agreement about these roles and responsibilities might include the following:

- Who identifies and conducts initial outreach to potential SMMs?
- Who is responsible for explaining the potential benefits of the project to the SMM?
- What is the timeline for each important task to be completed, and who is responsible for its completion?
- Who will ensure that the project specifications are consistent with the company’s needs?
- Who will ensure that the workplan is possible within the timeline and resources available?
- Who is responsible for tracking and communicating the project’s status to the company?
- Who is responsible for reporting on project metrics?

Partners can use standard project management tools to achieve alignment among the partners on many of these areas of agreement, provided each partner signs off to signal that they understand their roles and responsibilities.

Prior to signing off, each partner might need to complete some internal homework to make sure that they can meet their responsibilities. For example, the university partner might need to check with those responsible for managing university assets if they plan to leverage them for the project. Is the needed equipment available? Will intellectual property issues pose any challenges? Are there sensitivities or barriers to students working on the project—particularly international students? Timelines and calendars should be reviewed with an eye to where there is flexibility and when other events (such as semester schedules or product delivery milestones) cannot be changed.

Similarly, the MEP partner should have a general understanding of the target technology so they can discuss benefits and features with the SMMs, effectively recruit companies that are a good fit, and act as an effective translator between the university team and the SMM. The university should explain the technology to the MEP representative in terms that are understandable and apply to the needs of SMMs.

MEPs and their university partners need to be able to identify SMMs that can benefit from working with a university to advance Industry 4.0 approaches. Although MEPs in our pilot program were typically the party responsible for initial contact with SMMs, it is clear that before that contact takes place the MEP and university should discuss criteria for the kinds of companies that could gain the greatest benefit. The results of this discussion should
inform an agreement about how to identify companies who are a good fit. During the pilot project we developed a specific collaborative tool for doing this work. It can be used to guide the discussion and to help craft an agreement, both of which increase the chances that an SMM that the MEP identifies as a potential partner will be able to move ahead with the project and reap strong benefits.

**ADDRESSING WORKFORCE DEVELOPMENT CHALLENGES**

Workforce development plays a crucial role in adapting and advancing manufacturing technologies in SMMs. Although it might appear to be secondary to a technology adoption project involving the university and the MEP, we found that these concerns were important to the manufacturer as they navigated how they might integrate the technology into their workflow.

Universities and MEPs can work together to address these challenges. The partnerships in our pilot used a specific tool that is included in the toolkit to talk through the following issues:

- What specific workforce development needs might arise as the company begins to adopt and implement the technology within their company?
- How can we align technology advancement and workforce development strategies simultaneously?
- How can we identify and connect the SMM with the most appropriate workforce development resources (including those at community colleges and technical institutions)?

In addition, companies might benefit, at the outset, from an initial workshop that fully explains the technology and the process that will be used to work with the company to apply the technology to their opportunity or challenge. This can accomplish several objectives: first, it can help broaden the number of companies that are exposed to the technology without a big investment of time. Second, it helps companies that might be considering adopting the technology understand how they might integrate the technology into their workflow and understand the training that will be needed. Finally, this kind of workshop might help to manage companies’ overall expectations for the project.

As we worked through these issues, we also considered university students who might be working on the project and how the partners might prepare them to contribute to the project and to derive the greatest benefits from the experience. While students are receiving technical training in the technology, in many cases, they may also need preliminary orientation to the manufacturing environment to be effective (and faculty may need this orientation as well).
KEEPING THE FOCUS ON THE NEEDS OF SMMS

The motivations that MEPs and universities bring to the table may involve more than simply solving the SMMs’ technological and business challenges, but the partnership must prioritize these needs within the partnership. For universities, student experiential learning is important, and brings benefits to the company as well as the student, but students’ needs should not supersede those of the company. Similarly, the university may be interested in licensing a technology or obtaining a grant to test a technology, but the partners should not try to push a technology that will not address a real need or opportunity for the company. This can lead to a lot of wasted time and effort when the company rejects the technology.

University faculty, staff, and students may need orientation to the working environment and pressures facing SMMs. Their environment is very different from that of larger corporations that universities may work with on technology transfer or research contracts. Some universities can offer more expeditious processes for technology licensing for smaller companies to account for these differences.

LEVERAGING ASSETS FOR EXPANDING PARTNERSHIP OPPORTUNITIES

Borrowing lessons learned from work in Strategic Doing—a methodology for starting up and managing complex collaborations (see strategicdoing.net), we encouraged participating partners to think about how they could continue to sustain and build on their partnership. We challenged them to develop a new strategic opportunity that would advance their goals and that would create new opportunities for manufacturers. The partners identified opportunities that hold significant promise for their manufacturing innovation ecosystems:

- Illinois: Host an Industry 4.0 and Economic Development Summit, gathering economic development and manufacturing leaders to explore new opportunities for advancing regional economic development through advanced manufacturing.
- Kentucky: Establish SMM, MEP, University and Community partnerships to create new product market opportunities that advance regional entrepreneurship and manufacturing.
- Ohio: Create a Technology and Advanced Manufacturing Center in the Greater Ohio River Valley, serving the Appalachian regions in Kentucky, Ohio, Pennsylvania, and West Virginia.

The partnerships’ aspirations for these strategic opportunities are impressive given the constraint we presented them; we asked them to identify a strategic opportunity that could be undertaken with only existing assets. These strategic opportunities could not
be dependent on additional resources, whether in the form of funds, networks, skills/knowledge, or physical assets such as facilities and equipment. The partners started by inventorying some of each partner’s existing assets, then explored how assets could be combined to develop a strategic opportunity. This assets-based approach can be highly effective in getting partnerships going and can put partners in a better position to later explore “stretch” opportunities—those that require additional resources.

Critical to implementing these strategic opportunities is a short-term action plan. We asked participating partners to develop a three-month action plan. Each month included a milestone to shoot for, and clearly achievable actions assigned to specific individuals. For each action, the partners identified intended results and the information required. The idea of the short-term action plan is not to “set it and forget it,” but to reassess each month whether the project is on track, whether the partners must take other actions, whether the project has led to the intended results, whether those expectations need to be adjusted, and whether the partners need to obtain new information. Stopping to benefit from key lessons learned is important.

To try this assets-based approach in your own partnership, review and try the Asset and Opportunity Mapping tool provided in our toolkit.

Another key to the sustainability of the partnership was to include senior administrators on both the MEP and university side of the partnership. When planning for more ambitious partnership opportunities that require additional assets, ensure the full support of the university administration and MEP management by bringing them into the process. This also provides some degree of insulation for difficult staff transitions that may happen during the life of the partnership, as a commitment from higher level administrators provides a greater chance that the partnership will survive this kind of turnover.

Finally, keeping in mind the needs, assets, and gaps of the wider manufacturing ecosystem is important to identifying these key opportunities. Universities and MEPs should have a solid understanding of the manufacturing and business landscape of the region and understand the short- and long-term economic development plans and strategies. What other partners might be helpful to capturing these opportunities? Are there organizations other than an MEP, as in the Ohio case with AOMC, that have close ties to SMMs and might add an important asset to the partnership? Are there different higher education institutions, such as community colleges that could advance one of these opportunities? Each region has different strengths among their MEP and other organizations, and these should be considered in determining the goals and strategies of a long-term partnership.
5. Conclusions and Next Steps for the MEP National Network

Partnerships between universities and MEP Centers can effectively accelerate the adoption of Industry 4.0 technologies by SMMs, provided the partnerships are designed and implemented with a focus on the needs and goals of the SMM. While attending to these needs, keep in mind the following:

1. **Establish principles of partnership.** Partners must acknowledge and accommodate the divergent goals, incentives, and environments of universities, MEPs, and SMMs. Establishing appropriate principles of partnership is a first step toward ensuring that these partnerships offer benefits to each of the parties; this becomes the basis for a sustainable partnership. For assistance developing these principles, refer to the toolkit for ideas about structuring a conversation among partners about what these principles should be.

2. **Recognize and attend to the drivers and barriers to successful partnership.** The principles of partnership should address issues such as how staff will be trained, how workflow will be managed, and what communication channels will be used. Acknowledge and work through differences in timelines, goals, and metrics, and identify solutions to barriers that reduce benefits to the SMM.

3. **Recognize that other partners may have assets to offer the partnership.** Universities are not the only institutions of higher education that can offer SMMs the opportunity to learn about, adapt, and adopt Industry 4.0 technologies. Community colleges may have an important role to play in developing curriculum for technicians who work with engineers to ensure that the technology leads to long-lasting benefits to the SMM. Similarly, as exemplified in the Ohio partnership, other entities such as membership organizations can be useful in identifying and networking SMMs to learn from the university, MEP, and from each other. Universities and MEP Centers should be open to these other kinds of partnerships.

4. **Keep in mind the broader goal of a manufacturing sector that is efficiently employing Industry 4.0 technologies.** As mentioned in Section 4, partnership work should focus on the benefits to the SMM, but also more generally on the opportunity to advance the adoption of appropriate Industry 4.0 tools across the manufacturing industry. Workforce training is a key component of the industry’s ability to do this, and partnerships must consider not only how SMMs will adapt its products and processes, but also how colleges, universities, and training programs can produce the workforce necessary to staff SMMs as they move more broadly into Industry 4.0. This may require regional partnerships across the MEP National...
Network, universities, community colleges, other training providers, and state and regional workforce boards.

**NEXT STEPS FOR THE MEP NATIONAL NETWORK: USING THE TOOLKIT**

We suggest that the MEP National Network encourage each MEP Center to use *MEP-IHE Partnership and Collaboration Toolkit* that accompanies this report to develop stronger partnerships with regional colleges and universities to the benefit of SMMs. MEP Centers can reach out to regional colleges and universities to become familiar with their Industry 4.0 assets and can work toward understanding how they might structure a beneficial partnership. If no relationships already exist, one place to start is with the Dean of the engineering college, or with a faculty member who has been visible in the manufacturing community as a resource for advancing manufacturing technology.

The MEP National Network can encourage MEP Centers to share their strategies for cultivating these partnerships. They might also consider offering additional resources to MEPS and their partners to develop and structure these partnerships with a deliverable of a partnership report that includes agreed-to partnership principles and a completed set of tools, including, at a minimum, the **GOAL ALIGNMENT TOOL**, and the **ENGAGEMENT FUNNEL TOOL**, as described in the toolkit. From our experience, it is very important to put time up front into structuring the partnership prior to launching a project with an SMM.

Finally, the MEP National Network might consider how it might develop a national partnership network between MEP Centers, community colleges, universities, and workforce boards to ensure that at a regional level, appropriate training on Industry 4.0 technologies is developed and offered to high school students, post-secondary education students, as well as incumbent SMM workers.
6. Introduction to the MEP-IHE Partnership and Collaboration Toolkit

A MEP-IHE Partnership and Collaboration Toolkit accompanies this report and can be found on the APLU website. Many of these tools were applied and refined during the pilot project. Here is a brief description of each tool.

- The **MEP-IHE Partnership Assessment Tool** offers existing partnerships between institutions of higher education (IHEs) and MEPs a method for assessing the strength of their existing partnership based on characteristics of effective partnerships.

- The **Setting Goals for Improving Your Partnership or Collaboration Tool** helps partnerships that have identified weaknesses in their current partnership develop a timeline, indicators, and responsibility assignments for improving their current partnership.

- The **Force Field Analysis Tool** prompts partnerships to describe a future state, including qualities of the ideal partnership as well as positive outcomes for SMMs. After considering the future state, participants identify both drivers (What kinds of things are we putting in place to create the future state? What are we not yet putting in place but will likely have to?) and barriers (What has gotten in the way, or what we worry might get in the way, of our efforts of creating the ideal partnership—one that creates positive SMM outcomes?). Further, the tool prompts participants to address each of five elements in their force field analysis, and to include indicators of which drivers and barriers were related to each: 1) partnership principles, 2) key staff, relationships, 3) workflow and communication, 4) aligning timelines, 5) goals and metrics.

- The **Goal and Metrics Alignment Tool** prompts participants to identify each partner’s goals for the project or partnership. Then it helps them demonstrate how their different goals are aligned and/or reinforce each other. Finally, it shows how each partner’s activities will contribute to the goals. This tool helps partners talk about which goals should be paramount and how to resolve conflicts among goals.

- The **Engagement Funnel Tool** prompts participants to consider issues in choosing partner SMMs. It asks partners to consider issues at each of four “stages” of engagement—identification, outreach, selection, and fit. It calls for tactics, tools and artifacts, and partnership issues that relate to each of the first three stages. For “fit,” participants identify a set of “fit factors”—criteria that would help them determine whether an SMM was a good fit for engagement.

- The **Workforce Needs and Assets Tool** focuses on the key workforce development needs related to technology adoption. For each identified workforce
need, participants identify both university and MEP assets that can serve the need, and also what each partner needs from the other to leverage those assets. The tool prompts partners to identify the needs, assets, and collaboration issues for both the current partnership and also workforce needs more generally, and over the longer-term partnership between the organizations.

- The **ASSET AND OPPORTUNITY MAPPING TOOL** prompts partnerships to list both university and MEP assets that can be brought to bear in responding to the “framing question” of “how might we increase the competitiveness of manufacturers in our region by helping them to adopt new technologies?” Based on the assets, the partners are prompted to identify strategic opportunities that they might undertake by combining some of the assets. The tool then prompts the partnership to plan for implementation of the strategic opportunity by creating a timeline and roles grid as an action plan. Partnerships are asked to identify two opportunities—one strategic opportunity that can be undertaken with **existing** assets, and another “stretch” opportunity that requires **additional** assets, like funding, to be secured before it can be pursued.

- The **FUNDING FOR PARTNERSHIP SUSTAINABILITY TOOL** prompts partners to think about potential sources of funding and ongoing revenue that can support the partnership over the long term.

The toolkit also contains links to other resources that assist MEP-university partnership in developing stronger relationships to benefit SMMs, while meeting many aligned goals of MEPs and universities.