LEVERAGING UNIVERSITIES TO ADVANCE MANUFACTURING INNOVATION THOUGH THE NATIONAL MEP NETWORK

Partnership and Collaboration Toolkit Guide

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1. Introduction: Manufacturing Competitiveness and MEP-IHE Partnerships

This toolkit guide is designed to help institutions of higher education (IHEs) and NIST MEPs Centers (MEPs) build strong partnerships for the benefit of small and medium-sized manufacturers (SMMs). We suggest that potential partners read through the toolkit guide and use the tools as you consider building a partnership. Take the time to use the tools as a guide to conversations about the following:

- The potential benefits of collaboration.
- The principles that should guide the partnership.
- A vision for the ideal future state of the partnership and a roadmap for getting there.
- Roles and responsibilities within the partnership.
- Methods and processes for identifying and attracting interest from SMMs that might benefit from the partnership.
- Forging a three-way agreement between a university, MEP and SMM.
- Identifying the talent development required to implement Industry 4.0 technology.
- Identifying other opportunities for advancing the partnership’s shared goals.

Why Partner to Advance Manufacturing?

Manufacturing plays a critical role in the U.S. economy’s employment, technological advancement, and international competitiveness. Manufacturing is the major source of commercial innovation in the U.S. and is essential for innovation in the service sector. (Helper, Krugar, and Wial, 2012). According to PWC, most innovative companies grow faster than less innovative companies. While small and medium-sized manufacturers (SMMs) are particularly important to the U.S. economy, accounting for most of manufacturing employment, they tend not to develop new technologies (Atkinson and Lind, 2018) and instead must rely on other sources to develop innovations.

American institutions of higher education (IHEs) develop new technologies that have the potential to transform American manufacturing. Universities and other IHEs are spearheading advances in digitization, the use of smart sensors, robotics, simulation technologies, advanced materials, nanomanufacturing, and additive manufacturing techniques—a group of technologies collectively referred to as “Industry 4.0.” IHEs often partner with industry in technology development, refinement, and testing. The benefits of these innovations are greatest when adopted by manufacturers and others to create new products, to improve the efficiency of production, and to adopt business models that increase the quality of goods and services. Moving advanced technologies to the factory floor where they can improve the productivity of manufacturing and the value of products is critical to the survival of manufacturing in the era of Industry 4.0 technologies.

But SMMs generally underinvest in research and development, innovation, and training. Cost pressures lead to limited resources, and their small scale makes it difficult for them to capture adequate returns from such investments. Furthermore, they may have limited knowledge of the nature of new and improved technologies and how to productively apply it to their company (NRC, 2013).

Alignment between MEP Center and IHE Missions

The MEP has a mission to assist SMMs in advancing their operations and their technology and to encourage continuous innovation. However, MEPs vary widely with respect to their access to expertise in
the area of Industry 4.0 technologies. Universities can help fill this gap by tapping engineering expertise that develops and refines Industry 4.0 technologies for applications in a manufacturing environment. By partnering with HEIs that are eager to assist in the adoption of Industry 4.0 technologies, MEPs can better serve manufacturers and meet their need to understand, adopt, and integrate Industry 4.0 technologies into their processes.

Some HEIs work closely with SMMs to help them adopt new technologies. The history of land-grant universities includes the establishment of engineering experiment stations and industrial extension units that worked closely with local industry, including SMMs.¹ A handful of land-grant universities have been working with SMMs for decades through their industrial extension services, for example, Iowa, North Carolina, Georgia, and Tennessee.² Many of these early industrial extension units later were funded under the NIST Manufacturing Extension Partnership (MEP) and continue to work closely with SMMs.

Relationships between HEIs and SMMs can be difficult to forge. Without a history of relationships or a group of faculty that are enthusiastic about working with SMMs, IHEs may struggle to meet the needs of SMMs. University engineering faculty are often focused on research that advances technology and leads to patents and publications but may not have immediate practical applications in manufacturing. Even where faculty are motivated to help SMMs apply existing Industry 4.0 technologies, they may have difficulty reconciling their core mission and primary incentives—to educate students and conduct groundbreaking publishable research—with their desire to assist in modernizing local manufacturing.

MEPs can play a role in brokering relationships between IHEs and SMMs. MEPs know the manufacturing environment in their regions and work with their clients to improve their operations through general operational improvement, workforce development, and automation. They can help SMMs evaluate when a new technology might improve the company’s operations, productivity, or market penetration. Thus, MEPs are often well positioned to understand the opportunities that Industry 4.0 technologies can offer to their SMM clients. To the extent that they are also aware of the capabilities and capacities of local colleges and universities, they may be able to connect their clients to these capabilities to enable SMMs to successfully adopt these technologies. This may also offer opportunities to identify and train students interested in joining these companies to work with these technologies. As described in the companion report to this toolkit, these tools were developed and refined through a pilot project that brought three universities and three MEPs together to work with SMMs to implement Industry 4.0 technologies. Not all the pilots were successful, and our tools are designed to diagnose the types of challenges that may lead to partnership failure.

² https://www.ciras.iastate.edu/history/
2. About Partnerships and Collaboration

“Partnership” vs “Collaboration”

As MEPs, institutions of higher education, and SMMs look to collaborate, it’s important to start with some definitions of terms that may seem synonymous but are distinct: partnership and collaboration.

‘Partnership’ can be used informally to mean any type of cooperation, but is formally used to reflect a business relationship between parties and is typically embodied in a legal document outlining roles, responsibility, financial decisions, governance, etc. Partnerships between colleges and universities and MEPs are not likely to be as formal as a legal business partnership but may be governed by some form of legal agreement, like a Memorandum of Understanding (MOU). While the need for a legal relationship (to codify governance, IP, revenue arrangements for instance) may be necessary, we are generally using ‘partnership’ to mean more informal agreements to work together toward shared goals.

We also use the term ‘collaboration,’ which is also a reference to multiple entities working together towards a common goal. If the word ‘partnership’ is used to refer to the agreement that an MEP and IHE have to work together, ‘collaboration’ might refer to the way in which they undertake the partnership. Generally, we use ‘collaboration’ to refer to the ways that partners work together—the principles and practices of partnership work.

However you and your partners decide to use these terms, make sure all stakeholders understand the relevant distinctions, and are using terms with the correct connotations.

Working Together Effectively

Effective collaboration is essential for achieving common goals, whether in business, education, government, or social sectors. Such relationships are built on shared commitment to collaborative principles and practices. Our work with partnerships between MEPs and universities highlighted the importance of practices like those described here. When undertaking a partnership, consider a discussion among partners about these collaborative principles and practices, how they relate to your work together, and what other practices might be required.

**Clear, shared goals and objectives.** Well-defined goals and objectives that are derived collaboratively, agreed to, and directly relate to the work at hand are an important foundation for collaboration. SMART (specific, measurable, achievable, relevant, time-based) objectives may be one way to achieve this, but whatever mechanism is used, a shared purpose—understood and agreed to by all, and related to the scope of work under consideration, is key.

**Mutual benefit.** Effective partnerships and collaboration are mutually beneficial for all entities involved. Each should receive benefits that align with their objectives and values, and although it is rare that a project will mean exact parity in benefits across entities, there should neither be ‘free riders’ or ‘beasts of burden’ in collaborations. Everybody will be doing something, and everybody will derive some benefit. If that is not the case, ask why that person or organization is in the project.

**Open communication.** Transparent and honest practices in communication, sharing information openly and regularly, is key for effective collaborative work. Systems and formats of communication should work for everyone rather than creating an ‘insiders’ club’ structure in which some people are getting regular updates through their network or a tool they use, and others are shut out. If people don’t use a tool or system that has been used to communicate, (for instance, not signing on to a Slack or other chat channel), don’t blame the people. Instead, adjust the tool set in order to find a way to share information that works more successfully.
Trust and respect. Successful collaborations begin with, and work to foster, a culture of trust and respect. People come together to solve problems and work on projects where they are more than the sum of their parts—MEP, IHE, and SMM collaborations are specifically designed to do things that any one component could not do on their own. There are challenges to this—people and perspectives are different, and organizations of course have varied cultures—but begin from a position of respecting everyone’s intentions, expertise, and ability to contribute. And when challenges do arise—as they will—return to these first principles.

Flexibility and adaptability. Things change and part of the reason we emphasize principles and practices of effective collaboration is that changes should not undermine or derail the partnership. The more collaborative partners are, the more able they will be to flex and adapt to changes. New circumstances require new approaches, as do the inevitable changes at organizations, for instance when someone leaves or joins a team. The need for flexibility to respond to such changes should be built into the work and anticipated from the beginning.

Diversity and inclusivity. Diversity in individuals’ backgrounds, experiences, and perspectives bring strength to projects, and an inclusive mindset should be key to how the collaboration is built and operates.

A culture of evaluation. There is a very human tendency in any collaborative project to begin ‘gung-ho’ and then fall into a pattern that is more characterized as muddling through than direct progress. This is particularly likely when change or friction accompany the agreed upon work. People retreat to their corner, put their head down, and the project becomes ‘entities that dwell apart’ like a family that has nothing to say to each other at dinner. The way to avoid this is to commit to regular self-evaluation and project evaluation, in which not only the work products, but also the nature of the collaboration, is discussed regularly. Questions like “what is working? What is not working? How would I describe the culture of the project? Why might I be wrong in my perception of the project? What struggles do I have? What assets do I have that are not being tapped?” It is important that this culture of evaluation embraces reflection as well as critique. When looking at progress toward goals and necessary improvements, avoid the temptation to evaluate only what others have done to advance or impede that progress. Change happens only when everyone communicates openly about what is going on, and people trust others’ intentions.

Timelines and calendars. Different organizations work with different types of timelines (product launch deadlines versus semester schedules, for example) and different organizations may therefore see the way projects unfold over time in fundamentally different ways. A shared culture of timelines and agreed upon tracking systems and calendars will improve the chance for collaborative success. Multiple tools, and unspoken assumptions about the nature of deadlines can trip up a project, so discussions early on about how timelines will be handled, updated, and revised when problems occur should take place. It also is in the best interest of everyone involved to go into such discussions without a preconceived notion of one ‘best’ system. Each organization will have its own approaches—what is needed is something that works for the whole collaboration and is interoperable with calendars and timelines that are organization specific.

Create a Principles and Practices Document

One way to set the stage for success in collaboration is to create a document that outlines the principles and practices for partnership and collaboration. Use the characteristics above to start the discussion and adapt them to your project. Such a document can provide common ground for the work ahead, and also surface any potential differences in vision or approach before they arise in the form of dysfunction based on a lack of alignment. Colleges and universities, MEPs, and SMMs are very different organizations.
Expecting alignment around principles of collaboration to emerge naturally—without intentional focus discussions—is not realistic.

**Collaboration Frameworks**

There is a body of evidence-based research on working together that may be useful in supporting your collaborative work. Several frameworks are described below, with links to more information. Each of these frameworks may have different kinds of benefit for partnerships and collaboration among colleges and universities, MEPs, and SMMs.

- **Collective Impact.** Collective Impact refers to multiple organizations, sectors, and communities working together to address complex social problems. The framework includes five core components: a common agenda, shared measurement, mutually reinforcing activities, continuous communication, and backbone support. Read more: [What is collective impact?](#)

- **Open Innovation.** Open Innovation focuses on collaboration through knowledge sharing between organizations, individuals, and communities. The framework encourages organizations to work together to develop new ideas, products, and solutions, and to share knowledge and resources to achieve shared goals. Read more: [Open Innovation](#)

- **Design Thinking.** Design Thinking is a human-centered approach to problem-solving that emphasizes collaboration and creativity. The framework begins with bringing people together to understand the needs of users, and then takes the collaborators through steps in which ideation, prototyping, testing, and iteration bring forth and refine potential solutions and processes. Although the Design Thinking methodology grew out of industrial and product design research from Stanford Design School, it has now been applied—and validated—for a much broader range of types of collaborations. Read more: [What is Design Thinking?](#)

- **Strategic Doing.** Strategic Doing is an open-source discipline for designing and guiding complex collaborations by following simple rules. This methodology enables leaders to generate solutions to wicked problems, and it is a field-tested practical approach to leverage networks and ecosystems quickly. The methodology emphasizes a focus on partners’ consideration of the questions “What can we do together? What should we do together? What will we do together?” and short, 90 to 180 day sprints focused on “pathfinder projects” that help the collaboration advance toward a greater goal. Read more: [Do More Together with Strategic Doing](#)

We encourage you to consider these methodologies as well as any other approaches you have used in your context. You may find that multiple frameworks and approaches are required for your collaborative work.

**The Collaboration Continuum**

Arthur R. Himmelman, a nationally recognized expert on systems change collaboration, has developed a tool to clarify and benchmark different levels of collaboration, conceptualizing them as a continuum that includes these stages:

- **Networking.** Organizations or individuals exchange information and resources but do not collaborate on specific projects or initiatives.
• **Coordination.** Organizations or individuals work together to achieve a common goal but maintain their autonomy and decision-making authority.

• **Cooperation.** Organizations or individuals work together to achieve a common goal and share decision-making authority.

• **Collaboration.** Organizations or individuals work together to achieve a common goal and share decision-making authority, resources, and risks.

• **Co-Production.** Organizations or individuals work together to achieve a common goal and share decision-making authority, resources, risks, and benefits.

This collaboration continuum was created in a context of community organizing and social change efforts but has been adapted and adopted more widely. Some organizations have added additional levels to the continuum or modified the wording of the existing levels to better reflect their organizational context, culture, and problem to be solved.

You may find the continuum useful in various ways. You might use it to map out the current and potential level of collaboration in your partnership, recognizing that not all partnerships need necessarily reach the “Co-Production” level to be successful. What’s important is that partners discuss the appropriate level of collaboration for their goals. If partners decide to work toward higher levels of collaboration, the framework can be used to create a roadmap for that effort.

Also, you might consider how the characteristics of successful collaboration outlined above can be mapped to this continuum. For instance, as you move from networking to collaborating, trust increases, and leadership and decision making reflect that trust.

Read more: [Collaboration for a Change](#), by Arthur Himmelman, and [Understanding the Collaboration Continuum](#), by the Teagle Foundation

**Learning from University Engagement Practices**

As stakeholders build and nurture partnerships and collaborations in the advanced manufacturing context, they may find that principles and practices from university engagement—the ways in which an institution interacts with other entities in their region across the broadest range of activities—offer valuable models and strategies. Here are ways that a higher education institution may already be connecting and collaborating:

• **Community Engagement.** IHEs engage with local communities by listening to stakeholder concerns and working together with community members to co-create solutions. Other community-based activities likely already underway at IHEs you are working with include community-based research, service learning, and outreach programs.

• **Engagement with Business and Industry.** There are likely existing partnerships with businesses and industry in areas other than manufacturing (for instance, internship programs, or entrepreneurial education activities programs in a business school). There may be practical expertise that can help support manufacturing partnerships.

• **Engagement with Local and State Governments.** IHEs, particularly public institutions, often connect to government entities through advisory committees, research projects, funding, or outreach relationships.

• **Engagement in Professional Networks.** IHEs are typically members of state, regional, and national membership organizations, and participate in meetings, serve on committees, and
undertake other volunteer leadership roles. There may be resources, as well as consulting services, documents, or professional development on collaboration and partnership that are available through these networks.

University Engagement Principles

University engagement with communities was mentioned above. Established approaches in university engagement with communities and business/industry/entrepreneurs can help manufacturing partnership. Here is an overview of principles drawn from university community engagement to consider in your partnership.

- **Listening to partner and community needs.** Partnerships should strive to listen to the needs and concerns of all partners, stakeholders, and customers. This needs to be intentional, with regular engagement activities (public forums, surveys, field research, for example).

- **Building solutions through co-creation.** It is important to recognize that external stakeholders bring assets as well as needs to collaboration. Successful collaborations bring all stakeholders into the project development and delivery process. To be sure, different organizations have different roles, but it is important that everybody be able to look at the project and process and know that they had a part in creating it.

- **Engaging in multi-way knowledge exchange.** Collaboration should provide pathways for knowledge sharing across the entire partnership—and make clear that all parties have things to contribute and things to learn.

- **Promoting a capacity building mindset.** Sustainable partnerships build on the capacity of the stakeholders as well as the way the partnership itself planned. An example of stakeholder capacity development might be a workforce training initiative, and for the partnership itself, capacity building might be an intentional succession planning model.

- **Centering innovation and entrepreneurship.** Higher education institutions are increasingly embracing innovation and entrepreneurship mindset—both in engagement contexts and across the institution at large. Engagement activities that build on this approach can embed creative problem solving into their work.

Tools for Assessing and Improving Your IHE-MEP Partnership

To help you put to work some of the ideas we’ve outlined here, we have prepared two tools that you might find useful in taking stock of your current partnership—or assessing a future partnership once it’s underway—and making plans for improvement.

- MEP-HEI Partnership Assessment Tool

- Setting Goals for Improving Your Partnership or Collaboration Tool
3. Cultivating and Managing Partnerships

In our work with three university partnerships with MEPs, we learned that the work of cultivating and managing the partnership takes time and intention. We identified five dimensions of partnership that collaborating organizations might consider as part of this work: principles of partnership; key staff and relationships; workflow and communication; aligning timelines; and goals and metrics. We helped participating partners examine these dimensions to envision a future state for the ideal partnership, and the drivers of and barriers to achieving that ideal future state.

Force Field Analysis Tool

The tool we used with partners was an adapted version of a tool called a “force field analysis.” This decision-making tool helps partners to examine the forces that are driving progress toward an outcome, and also the forces working against such advancement.

You can access the force field analysis tool here. Following are instructions for completing it.

Using this tool, you will conduct a force field analysis for achieving a future state of “The Ideal University-MEP Partnership,” which we will define broadly as a partnership that creates positive technology adoption outcomes for small- and medium-sized manufacturers.

First, in the blue column, list 3 – 6 characteristics of the ideal partnership. What does that partnership look like? Does the ideal partnership include shared resources? Shared vision? Revenue generation? No right answers here—you should fill in what you and your partners think are the key characteristics of the ideal partnership, and for creating positive outcomes for SMMs.

Next, in the green cells, identify as many key drivers for the future state as you can. If the blue column describes “where our partnership is going,” the items in the green part of the table represent “what’s going to get us there.”

Finally, in the orange cells, identify as many potential barriers as you can. These items are “what is getting in our way (or might get in our way) as we work on getting there.”

Consider addressing the following dimensions in your drivers and/or barriers. Your drivers and barriers might address other dimensions as well. Use icons to indicate which dimensions each driver/barrier relates to:

- partnership principles
- key staff, relationships
- workflow and communication
- aligning timelines
- goals and metrics
4. Engagement with SMMs

In this section of the toolkit, we offer suggestions and tools for determining how partners will work together to achieve the aims of the partnership.

Aligning Goals

Before beginning to work with SMMs, the HEI/MEP partnership members will benefit from clarifying their shared interests in working with SMMs. This requires setting goals for the partnership and describing each partner’s incentives for reaching those goals.

For example, the shared goal might be, “Convert ten percent of SMMs in the automotive industry in this region to using 3D printing for parts that are causing delays in their supply chain.”

The IHE might list two incentives for reaching this goal. The first might be that they want real-world opportunities for students in the industry. These opportunities can lead to stronger job placement—a metric used to evaluate the engineering school. The second might be to improve the overall competitiveness of the industry in the region to advance economic success for the region (and therefore the HEI).

The MEP might be incentivized toward this goal because it contributes to the MEP’s overall mission of improving manufacturing competitiveness in the region. Their more specific reason for advancing 3D printing technology might be because they want to understand how this technology can be transferred to other manufacturing sectors. Finally, success for the SMM will translate into positive metrics for the MEP at the end of the year.

Being transparent about the motivations for working with SMMs can eliminate misunderstandings later. For example, while the project timeline might benefit from substituting an MEP staff member for a student who is working on a value chain analysis for the project, it is at cross purposes with one of the HEI’s primary motivations. Clarifying which goal is paramount will help the partners decide whether to take this course of action.

The Goal and Metrics Alignment Tool

This tool will help you clarify these goals and see how your incentives are aligned. It will also help you specify how each organization, the college or university, the MEP, and the SMM, will contribute to the effort, the outcomes and impacts that will benefit each, and the metrics that each organization will use to track their impact for their key stakeholders.

You can use this tool at the start of the partnership, prior to any specific SMM or project being defined. In this case, the inputs, activities, and outputs will be more general to the partnership. As you define specific projects within your partnership, you can use the tool to define more specific problems to be solved, goals to be advanced, and the activities, outputs, outcomes, and metrics that will be produced by the project.

Instructions for the Goal Alignment tool

As with the other tools in the toolkit, partners should work on the goal alignment tool collaboratively as they talk through the issues.

- In the “Problem Statement” box, enter the broad outlines of the problem the partnership will attempt to solve.
• Then identify the goals of the MEP and the college or university in entering into the partnership, along with goals that SMMs will have for working with both the MEP and the HEI.

• In the “resources/inputs” column, identify in broad terms what resources each brings to the partnership.

• In the “Activities” column, identify what each partner will do to advance the goals. This may differ for each specific engagement with an SMM, but in general, as the partnership is launching, a general idea of activities and roles is helpful. We will talk more about this below.

• In the “outputs” column, describe what each entity expects to produce from the partnership.

• In the “outcomes” columns, identify short term and long-term outcomes that will benefit each of the stakeholders. These should be related to the problems statement and the goals that each entity has identified for the partnership.

• In the Metrics box on the bottom, identify how each entity will measure the impact of the partnership.

Assigning Roles

While the goal alignment tool helps each partner identify their goals, resources, activities, outputs, and outcomes, it is also important to clarify roles and responsibilities and to ensure that the partnership runs smoothly. This is especially important in identifying how the MEP and the college or university will each interact with the SMMs. For example, they will need to determine how they will identify how to target SMMs that might be a good fit for working with the IHE and the MEP, given the goals of the partnership, the assets and technologies being offered, and the goals of the MEP and the college or university.

They will also need to determine a strategy for reaching out the SMMs, describing the partnership and its potential benefits, and how to engage with the project.

Finally, they will also need to determine how they will select from among those interested, the SMMs they will work with. This will require developing a set of “fit factors” - characteristics of SMMS that are a good fit for the project.

The Engagement Funnel Tool

The Engagement Funnel tool offers IHEs and MEPs an opportunity to articulate strategies and roles for identification, outreach, and selection of HEIs as well as the “fit factors” they will use to finalize this decision to work with a particular SMM.

Instructions for the Engagement Funnel

As with the other tools, the engagement funnel should be collaboratively developed by the MEP and the HEI. Fill in the template as follows:

• Identification:
  - In the “Tactics” column, list the methods you will use to identify what the universe of possible SMMS that should be targeted for the project.
• In the “Tools” column, identify tools you will use to identify the universe of SMMs (for example, a database) and any tools or materials you will use to identify and evaluate the universe of SMMs that should be contacted.

• In the “Partnership” column, describe issues that could come up as you work through this identification. For example, who owns the CRM or database you will use to identify the SMMs, and who can access it? If you have to purchase a database, who will pay for it?

• Outreach:
  
  • In the “Tactics” column, identify methods you will use to promote the opportunity and reach out to SMMs. For example, you might use social media and a link to a sign up to receive more information or incorporate a discussion of the opportunity into client visits by the MEP, or an article in a trade publication, or conduct webinars.
  
  • In the “Tools, Artifacts” column, list the tools you will use to conduct the outreach and promotion—for example, a flier or a web-based description, or the article.
  
  • In the “Partnership Issues” column, list the issues that might come up as you sort through roles and responsibilities for the outreach. For example, who is the lead outreach partner? How will queries be handled?

• Selection:
  
  • In the “tactics” column, identify methods you will use to make the selection of the SMMs to participate. For example, will might invite them to campus to present their company and their needs to a group that includes students, faculty, and MEP. You might engage in a conversation that allows you to assess the SMM “fit factors” - those factors that determine whether the SMM is a good fit for the project.
  
  • In the “Tools, Artifacts” column, lists the tools you will use to make the final selection. For example, a written proposal by the company, an assessment of the MEPs history with the company, etc.
  
  • In the “Partnership issues” column, list the issues related to the partners that may come up during this stage. For example, who will provide the key information needed to make the decision? How will you decide whether a company participates if there is disagreement among the partners?

• Fit Factors:
  
  • In this section, list the factors you will use to determine whether the SMM is a good fit for the project. For example, you might want to ensure that the company is willing to invest time and resources in the project; that the project has potential positive financial impact for the company, and that the company is open to training its workforce on the new technology.
5. Talent and Workforce Development

Understanding SMM Workforce Needs

The workforce needs of modern manufacturers are much different from those of the past. To take full advantage of Industry 4.0 technologies, manufacturers will need to overcome a deficiency in the skills of the current workforce. The manufacturing sector is upskilling, and for many manufacturing jobs, some college education is required as digital skill content of these jobs increases. But non-digital operational skills are also required, as companies adopt technologies such as 3-D printing, advanced materials and robotics (Bonvillian and Sarma, 2021). SMMs, with smaller workforces and training budgets, are challenged to provide the training required to fully adopt these technologies. Partnerships between IHEs and MEP centers can work with SMMs to develop and implement the training required for success with these technologies.

As MEPs and IHEs embark on partnerships to assist SMMs in the workforce challenges in adopting Industry 4.0 technologies, they need to assess the immediate needs of a project as well as the SMM’s longer-term needs. As they jointly assess the needs of the SMM, the partners can identify the assets that the MEP and the IHE bring to the table. For example, HEIs have curriculum in engineering courses that might be adapted for delivery to SMM workers. They might also already have short-term training courses in Industry 4.0 techniques such as 3-D printing, IoT, or robotics. MEPs have training expertise and facilities that might be employed to deliver the training, as well as knowledge of other, related training needs in lean manufacturing, quality and inventory management systems, and energy management.

The Workforce Needs and Assets Tool

This tool can help the partners work together to align their assets and resources toward solving the SMM’s workforce challenges in the short and longer term.

Fill in the template as follows:

- Start with the middle column. Identify 3 – 5 talent and workforce development needs that have become evident and that are related specifically to the focus of the current partnership and technology/technologies. Then, identify 3 – 5 more general, longer-term workforce needs.

- Next, in the second column from the left, identify college or university assets (academic programs, experts, facilities, research, etc.) that can be tapped to help address each of the workforce needs you have identified.

- Then work on the first column at the left. In this column, identify ways in which the MEP can/should partner with the college or university in order to engage the listed college or university assets and make them available to SMM’s to help them address workforce needs.

- Next, focus on MEP assets (staff expertise, relationships, events, facilities, etc.) that can be tapped for each of the identified workforce needs.

- Finally, in the last column on the right, identify the ways in which the University can/should partner with the MEP to engage the listed MEP assets and help deliver on the promise these assets hold for addressing workforce needs.
6. Asset and Opportunity Mapping

The best way to get a partnership going and to sustain it is to do as Teddy Roosevelt once said—“Do what you can, with what you have, where you are.” While additional resources are often necessary to realize ultimate outcomes and impacts, collaborating partners can be surprised by how much they can get done when they simply inventory existing assets and think of creative ways to combine them.

Drawing on lessons from the Strategic Doing approach to complex collaboration, we encouraged university and MEP partners to identify and “link and leverage” assets to establish a strategic opportunity for advancing their partnership. The tool linked below will help you work with your partners to do the same.

First, some important considerations for undertaking this kind of inventory and “linking and leveraging” of assets:

- First, when identifying existing assets, it’s important that you identify assets that participating collaborators have access to and control of—you don’t want to have to ask permission to activate the assets as this will slow down and potentially derail pursuit of your strategic opportunity.

- Next, consider different kinds of assets. Network assets are social assets—connections to and relationships with other individuals and organizations that can be helpful. Knowledge or skill assets are ways that individual collaborators’ expertise can be brought to bear in advancing the work. Physical assets are things like office or gathering space, or special tools or equipment. Finally, capital assets are financial resources.

- To get ready to use the tool, consider hosting a session with collaborators in which everyone lists their assets on sticky notes—maybe using different colors for network, knowledge/skill, physical, and capital assets. Conduct an ideation activity to think of creative ways that assets can be combined.

- After you and your collaborators develop a strategic opportunity that links and leverages existing assets, consider a “stretch” opportunity that might include assets that you still need to chase down.

- It’s important to create a short-term action plan. A strategic opportunity is only as good as the plan for executing, and you should know who’s doing what; understand the ultimate output and intermediate milestones; and stop to reflect on lessons learned, results achieved (or not), and additional information required.

Asset and Opportunity Mapping Tool

This tool will help you to identify and leverage assets to establish a strategic opportunity for advancing their partnership. Below are instructions for using this tool.

- Step 1—Your Framing Question
To begin this exercise, create a framing question that is broad enough to inspire many possibilities, but specific enough that you can generate concrete ideas. An example framing question is provided. Generate one that is more tailored to the needs of your clients.
• Step 2—Mapping Readily Available Assets
Next, identify existing, readily-available assets. These are assets that you are certain can be accessed and deployed for the partnership. Don’t include anything that requires going through a permission chain or is hoped-for (like funding) but not available. Do this by filling in the assets on the table, noting that the different colors refer to different types of assets.

• Step 3—Creating Strategic Opportunities from Existing Assets
Now, look over the existing assets you’ve identified and think of ways you might combine 3 – 6 of these assets (drawing upon assets from both the MEP and the University) to create a strategic opportunity. Record this opportunity on Slide 6. Re-color the “stickies” to match the assets you’ve identified by type (network, skill/knowledge, physical, capital). Create a short title and description and complete the table for the strategic opportunity. Refer to examples provided.

• Step 4—Creating “Stretch” Opportunities That Require Additional Assets
If you would like to create an additional strategic opportunity, but one that requires additional assets (which means you won’t be able to get this opportunity underway immediately), use Slide 8 to do that.

• Step 5—Developing an Action Plan
Now, create a short-term action plan for your strategic opportunity. The first column lists the names of everyone who can participate in advancing the opportunity. Identify milestones for each 30-day period. Assign actions to each person that can be done within a couple of hours each 30-day period. Use the Questions and Results column to record information that needs to be chased down, and key learnings related to each action. Refer to examples on Slide 10. Use Slide 11 to create a short-term action plan for your stretch opportunity if you wish.

7. Other Issues and Resources

Opportunities, Challenges, and Responses
When partners come together to adopt and implement new technologies in manufacturing, there are many opportunities and challenges to consider. Some of these are listed below starting with the general issues that may affect any partner or the collaboration overall, and then by specific stakeholder category.

General Opportunities

**Improved efficiency, effectiveness, and quality.** New technologies have the potential to help SMMs improve many aspects of business operations from concept through delivery: resulting in better company performance and more profitability.

**Increased competitiveness.** Technological innovation holds the promise of offering a competitive edge and may be a differentiator in opening new markets and attracting new customers.

**Improved partnership expertise.** When new technology builds on and taps expertise from all partners (IHE, MEP, and SMM), the overall knowledge of each stakeholder can be increased, both about the specific technology and about innovation adoption in general.

**Strategic opportunities.** Partnership approaches to adopting new technology may provide networking, funding, and business opportunities that are not available to the organizations acting alone.
General challenges (and potential responses) that may affect any partner:

**Difficulty of budgeting for innovation.** Novel technologies typically mean a degree of uncertainty in budgets and timelines, and these unknowns carry risks.

*Response:* build contingencies into budgets and timelines, and work through scenarios and potential responses when challenges change budget realities.

**Resistance to change and change management.** No matter where you sit in the partnership, you may encounter, or be the source of, resistance to change, even when you can see potential value in adopting new technologies. Even when change is widely embraced, managing the disruption that accompanies it can be challenging.

*Responses:* for resistance, consider sharing and acknowledging such resistance, and separating emotional issues for instance, “we’ve always done it this way” from factual issues, for instance, “the risks in implementing this are hard to predict.” As for change management: that is a core capacity of innovative companies and partnerships, be intentional about building it as a strength. The tools in this toolkit are a good place to start.

**Discounting external factors.** Higher education institutions, MEPs, and SMMs all work in their own specific environments with distinct reporting, regulatory, and legal requirements, different IT and privacy policies, HR practices, and marketing/communications approaches just for starters. Although these factors may not be related to the specific partnership, they form the backdrop against which it does its work.

*Response:* share information about required practices and create a standard approach for partnership work that responds to these external factors appropriately.

**Terminology misunderstanding.** Partners each have their own language, including abbreviations, acronyms, and context-specific terms. What is an ordinary work conversation with one stakeholder can be a hard to follow jargon to another.

*Response:* create a glossary of key terms, acronyms, abbreviations, and organizations that are relevant to the partnership.

**Intellectual property questions.** Questions and expectations about all aspects of legal ownership—patents, licensing, and commercialization agreements among others—will likely occur.

*Response:* create a shared framework for acknowledging these issues, and then bring the relevant parties into to discuss and resolve them. Note that members of the partnership may not be the ones with the expertise or the authority to discuss IP on behalf of their institutions.

**Organizational culture differences.** Although the power of the partnership is increased by synthesizing the different viewpoints, roles, and experiences of the stakeholders, those differences can also throw up obstacles to effective communication, collaboration, and trust building.

*Response:* the partnership and collaboration principles discussed above can help organizations align and create a partnership culture of collaboration.

**Short-termism.** When collaborations are funded for a limited purpose over a specific period, (for instance, through a government-funded initiative), this may inhibit longer-term planning, in specific development of sustainability strategies.
Response: make discussion of long-term vision and strategy part of the ongoing work of the partnership.

***Missing people at the table.*** Collaborations that bring together IHE, MEPs, and SMM may be missing key ecosystem voices that could make a difference in success.

Response: regularly assess whether there are views from outside that support the work and find ways to include these in the mix through interviews, research, participation in meetings or other means.

**Geography matters.** Distances in the regions where partnerships work can cause challenges in meeting logistics, with a fallback assumption that everything can be virtual.

Response: acknowledge the nature of these partnerships will likely require site visits, and plan accordingly in advance, rather than waiting to find out later that travel has to be arranged and paid for after all.

Challenges Particular to Higher Education Institutions

*Technology resources and expertise mismatch.* Higher education institutions may or may not have the resources and expertise to support adoption of the exact technologies that that SMMs are looking for help with.

Response: HEI's and MEPs should work together to assess what technologies are of interest to SMMs, and what's available from the HEI.

*Research-focused culture.* Higher education institutions are often focused on research and may not have a deep understanding of the day-to-day operations of SMMs or the needs of MEPs. This can create challenges in developing solutions that are truly responsive to industry problems.

Response: build a partnership in which organizations trust one another enough to share what they know and what they don’t know.

*Multiple levels of approval.* University structures often mean multiple levels of review that may not be timely, and long periods before decisions about policy are made.

Response: whenever possible, get ahead of these decisions so that actual partnership work is not held back.

*Challenges with technology transfer.* Although universities often have access to cutting-edge technology, transferring it to SMMs and MEPs can be challenging due to differences in scale, infrastructure, and technological readiness.

Response: make practical plans, and test runs, on whether and how technology can be transferred.

Challenges Particular to MEPs

*Resource constraints.* MEPs may have limited funding and resources to support collaborations, which can impact the effectiveness of the partnership.

Response: Acknowledge MEPs have many competing projects that can curtail the resources available for one specific collaboration, make realistic agreements about what the MEPs can and cannot provide.
**Lack of technical expertise.** MEPs may not have the expertise on specific technologies at the heart of the project.

*Response:* as MEPs may be the first conduit between SMMs and higher education institutions, make sure that these first meetings include appropriate subject matter experts or background for the MEPs staff.

**Challenges Particular to SMMs**

**Mix of innovative and older approaches.** SMMs may use the latest technology in some areas but not in others, and this may cause a mismatch in projects that seek to innovate broadly. Response: clarify the business need, the processes and changes that are proposed, as well as things that are not changing. Communicate this internally and to the partners.

**Limited partnership expertise.** SMMs may not have significant expertise (or even experience) in partnerships.

*Response:* the tools in this toolkit provide assistance in how to build successful partnerships.

**Metrics, Outcomes, and Impact Analysis**

The goal alignment tool prompted you to identify not only goals for each partner in the partnership, but also the metrics that you would use to track the success of the project.

For MEPs, the most common metrics used are those collected through an independent third-party survey that asks clients to estimate the effects of MEP services on the following business outcomes:

- Jobs created and retained
- Sales created and retained
- Cost savings
- Investments

These metrics are likely also consistent with the aims of an SMM in engaging the MEP and the university in a project. However, there may be some more specific metrics important to the company as they engage in a project, such as production downtime, yield/scrap, or on-time orders.

For colleges and universities, common measures of impact include graduation rates, placement rates for graduates, external funds raised for research, and publications.

While these metrics are different, they are not necessarily at cross purposes. If the college or university is successful in developing a robust engaged learning program for its students, and those students participate in a project involving the SMM with good supervision and follow through, then all participants should be able to meet their goals and demonstrate positive metrics.

But understanding how each partner will view success of the project is essential to ensuring that the partnership is sustainable. Using the Goal Alignment tool to identify these metrics and the activities and inputs that will be necessary to achieve them can help.

Experts in metrics development generally recommend that Metrics be SMART: specific, measurable, achievable, relevant, and time bound. Various templates are available for defining metrics that meet these standards.
For the MEP, the surveying conducted to assess the impact of the MEP on the manufacturer’s outcomes will serve as a data source for determining those basic metrics. However, more specific metrics for the project may be desired, so the partners might need to plan for the collection of that data as the project is developed. The metrics should be defined so that it is apparent what data is needed to calculate the metric.

Funding for Partnership Sustainability

Most partnerships between MEPS and colleges or universities will need a source of sustainable funding to maintain effective programs that advance manufacturing competitiveness and the adoption of Industry 4.0 technologies by SMMs. Funding is needed to make staff available to maintain the partnership, conduct outreach, identify SMMs to work with, train students, conduct analysis, and train SMM workforce. Funds might also be needed to purchase specialized equipment.

Various grant funding sources might fit with the goals of the partnership. Funding sources might include state or federal grants. You might be able to (or required to) leverage these grants with contributions by the partners in cash or in-kind, and by fees paid by the SMM.

Aside from the NIST MEP program that funds MEP centers, other federal sources of funding for working with manufacturers include the following:

- Defense Manufacturing Community Support Program from the Department of Defense;
- Economic Development Administration’s University Center program;
- U.S. Department of Energy office of Manufacturing and Energy Supply Chains, including State Manufacturing Leadership program.
- Manufacturing USA Institutes, which lists funding for technology development and demonstration as well as workforce development that supports SMMs.

There are also many state opportunities that support technology transition and workforce development for SMMs.

Funding opportunities change constantly, and it’s a good idea to set up alerts or sign up for newsletters that will notify you when new opportunities become available.

Funding for Partnership Sustainability Tool

Determining whether a grant opportunity is appropriate to the goals of your project is another challenge. You might use the Funding for Partnership Sustainability Tool to determine whether the funding source you are coinciding with will be a good fit for the project you are considering.

Instructions are as follows:

- Fill in the name of the project you are working to fund, the funding source, and add a link to the information about the funding source. Fill in the maximum funding available.
- For Mission, consider whether the funding source mission is in line with the goals of the partnership. Under “Advantages”, talk about how the partnership can leverage that alignment. In the “How to enhance” column, consider some potential factors or elements of your proposal that could further strengthen the alignment. Under “Disadvantages, state the factors that deter alignment. Under “How to mitigate disadvantages,” consider whether there might be strategies to bring your mission more closely into alignment with the funder.
- For Quality, consider whether the funding source will offer the partnership the funding needed to provide high quality support to SMMs to support technology adoption. Under “advantages,” talk about how the partnership can use this funding source to support or enhance quality. Fill the other columns out in a similar fashion, considering how you might enhance the advantages this funder offers to support quality and deal with any disadvantages that might work against quality.

- For Accessibility, consider whether the funding source will enable the partnership to serve the SMMs that the partnership strives to serve, and consider strategies for identifying and enhancing its advantages while mitigating its disadvantages. For example, if the funding source only focuses on a subset of the target SMMs, how might the partnership combine it with other funding sources to support all of the SMMs they hope to serve?

- For Efficiency, determine whether the benefits of the funding outweigh the administrative costs, and consider strategies for identifying and enhancing its advantages while mitigating its disadvantages. For example, if the funding source requires heavy reporting, does that reporting align with other reporting requirements? Can you set up templates that will make that reporting easier?

- For Politics, assess whether pursuing or winning this funding source will help the partnership gain partners and allies? For example, will competition for funds create animosity among organizations or people you need to be effective?