What are the key problems and issues facing small U.S. manufacturers and their competitiveness and opportunities for growth in the near term (1-2 years), mid-term (3-5 years) and/or long-term (5+ years)?

The strategic and purposeful integration of company-appropriate Industry 4.0 technologies represents the key challenge, and most significant cost saving and revenue growth opportunity, facing small and mid-sized U.S. manufacturers across the near, moderate and long-term time horizons. According to PwC's 2016 Global Industry 4.0 Survey, manufacturers that successfully implement the Industry 4.0 technologies best-suited for their businesses no longer need to choose between focusing on a better top line or a more profitable bottom line – as they can improve both at the same time. Conversely, the Boston Consulting Group (2016) warns that "companies that take a wait-and-see approach to adoption (of Industry 4.0) do so at their peril".

For purposes of this document, Industry 4.0 includes the following nine widely-recognized technologies:

- Robotics and advanced human-machine interfaces;
- Big data and related analyses;
- Cloud computing;
- Industrial internet and the Internet of Things (IoT);
- Horizontal, vertical and customer system integration;
- Simulations;
- Augmented reality;
- Additive manufacturing; and
- Cybersecurity

To improve their performance, gain competitive edge and continue to grow and thrive in America, small and mid-sized manufacturers must adopt these new digital industrial technologies in a strategic manner and methodical pace under the guidance of objective and experienced professionals – such as those found within the national NIST MEP network.

Larger manufacturers have an optimistic outlook regarding Industry 4.0 and its potential to positively impact their performance, profitability and growth. A 2016 Boston Consulting Group study determined that 53% of their manufacturing clients (n=380) consider the adoption of Industry 4.0 a corporate priority. When asked to identify how Industry 4.0 technologies will most significantly impact their businesses, 47% identified impact through manufacturing cost reductions, 43% identified overall product quality gains and 33% identified new product innovation. Sums total to more than 100% due to company ability to select more than one (1) impact area.

It is only a matter of time before larger manufacturers push Industry 4.0 technologies further down into their supply chains, essentially making the incorporation of Industry 4.0 tools a requirement for doing business with them. The NIST MEP network has seen this occur with respect to ISO and other quality standards, Lean Manufacturing, Six Sigma and other best manufacturing practices and new technologies – and is it sure to happen again relative to Industry 4.0.

Unfortunately, however, the majority of modestly-sized manufacturers have a low level of awareness regarding how Industry 4.0 can impact or benefit their firms. In a 2015 Internet of Things Study, the MPI Group found that 43% of the more than 350 manufacturers that

participated in their analysis had a limited companywide understanding of Industry 4.0. More alarmingly, nearly one-quarter of respondents (24%) had no companywide understanding of fundamental Industry 4.0 topics. Only one-third of participants had an Industry 4.0 strategy in place, while an equal number had plans to eventually develop such a strategy and the remainder (34%) had no plans to even develop (much less fully implement) a robust approach to Industry 4.0.

Unless the nation's small and mid-sized manufacturers can match the pace of Industry 4.0 adoption of their larger counterparts and customers, domestic manufacturing growth, and the creation of well-paying manufacturing jobs, will not be maximized. This, however, presents a challenge, as smaller companies lack the technology awareness, internal capabilities, immediate access to external consultants and financial resources comparable to their larger colleagues. It is imperative, therefore, that the NIST MEP network position itself to lead small and mid-sized manufacturers in this area.

What advanced manufacturing technologies are and/or will be needed by small U.S. manufacturers for those companies to be competitive and grow in the global marketplace in the near term (1-2 years), mid-term (3-5 years) and/or long-term (5+ years)?

In order to address their Industry 4.0 needs, the NIST MEP network should consider serving the small and mid-sized manufacturing community with the following:

- Awareness Building Seminars, Workshops and Webinars;
- No-Cost or Low-Cost Assessments, Benchmarking or Evaluations at the overall Industry 4.0 level or specific component (ex: Cybersecurity, Cloud Computing, etc…) level;
- Industry 4.0 Implementation Plan Development assistance;
- Industry 4.0 Project Prioritization, ROI, Project Management and similar assistance;
- Vendor selection assistance; and
- Solution implementation assistance, directly or through partnered external consultants.

What information will be required for small U.S. manufacturers to understand a technology or related group of technologies and the risks and opportunities associated with making or not making an investment in a given technology?

Based upon the conclusions of the aforementioned MPI Group study, with respect to Industry 4.0 technologies, it is clearly a matter of manufacturers "not knowing what they don't know". Nearly one-half of all respondents had a very limited understanding of what Industry 4.0 really is and how it will impact their business.

The NIST MEP network has a rich and successful history of building manufacturer awareness of emerging business trends and moving those same manufacturers to the appropriate level of action. Examples include:

- In 1999, NIST MEP developed several helpful "Y2K Bug" tools that enabled clients, many of which were unaware of how the advent of the year 2000 could impact their computing systems, to evaluate and mitigate their risk.
- In the mid-late 2000's, NIST MEP centers skilled-up and encouraged clients to become more innovative, using approaches such as JumpStart, IDEO, Innovation Engineering and other methodologies – as a result, clients now utilize NIST MEP centers for both cost-control AND top-line focused engagements.

- NIST MEP developed ExportTech services that successfully introduced manufacturers to the benefits of exporting and simplified what, in their mind, was a very complex undertaking.
- NIST MEP rolled out several Disaster Preparedness & Recovery tools with great success, even though being prepared for a natural disaster, fire or act of violence is not front-of-mind among the typical NIST MEP center client.

As mentioned above, in order for NIST MEP to experience equivalent success in the Industry 4.0 arena, centers must provide manufacturers, first and foremost, with awareness-building seminars, workshops, webinars and other venues to help them become more aware of what "they don't know". Once that awareness is cultivated, NIST MEP centers need to provide their clients with a methodology for identifying and evaluating the ROI on selected Industry 4.0 tools and tool implementation engagements under consideration. This methodology needs to capture the quantitative and qualitative benefits of tool implementation – such as how Cloud Computing will not only reduce file storage, updating, maintenance, hardware and security costs, but will also speed up customer inquiry times, allow team members to access files remotely or perhaps enhance the overall worker or customer experience.

Again, NIST MEP has success in utilizing these types of analyses. For example, many centers currently utilize the Reshoring Initiative's Total Cost of Ownership (or TCO) tool – which calculates both the quantitative (purchase, shipping, storage, fees, taxes, etc…) costs of supply chain inputs and the qualitative (political risk, supplier disruption risk, natural disaster risk, etc..) factors that should be considered when making sourcing and supply chain decisions.

How is the information about advanced manufacturing technologies best delivered to small U.S. manufacturers and/or MEP Centers that support those manufacturers?

As previously referenced, information about advanced manufacturing technologies is best delivered to small and mid-sized U.S. manufacturers throughout informational seminars, workshops and webinars. Information is also efficiently and effectively conveyed through plant tours and site visits that allow manufacturers to physically see and experience how another manufacturer is utilizing the technology. For certain Industry 4.0 technologies, such as Additive Manufacturing or Augmented/Virtual Reality, having manufacturers tour regional resource centers, as may be resident in local universities or federal labs, may prove beneficial.

What complementary business services, including information services, are and/or will be needed by small U.S. manufacturers and/or MEP Centers to take full advantage of advanced manufacturing technologies at the company or supply chain level?

As mentioned above, NIST MEP centers should consider the provision of informational sessions or other activities designed, primarily, to bolster small and mid-sized manufacturer awareness of the ways in which Industry 4.0 technologies threaten or, in many cases, represent an opportunity to, their businesses. Ideally, those efforts will be sufficient to move many manufacturers to take action.

Once that decision is made, however, NIST MEP centers must have the complementary services needed to keep that manufacturer engaged, motivated and moving forward. More specifically, manufacturers are likely to need the following services:

- The performance of a no-cost or low-cost assessment, either at the higher Industry 4.0 level (all tools) or specific component/tool level – such as Cybersecurity or Additive Manufacturing – sufficient to allow clients to gauge their current level of awareness and implementation, business risks/benefits and readiness to implement.
- Industry 4.0 Implementation Plan development assistance – so that manufacturers can balance immediate actions with a long-term focus.
- Industry 4.0 Project Prioritization, ROI and Project Management services – so that clients can efficiently implement the right Industry 4.0 tool at the right time for maximum ROI and sustainability.
- Vendor selection assistance – so that smaller manufacturers utilize only the best regional consultants, equipment/software vendors and systems integrators and do not get taken advantage of because of their lack of in-depth knowledge of the technologies.
- Solution implementation assistance – directly or through partnered external consultants – so that clients can benefit from NIST MEP network shared resources, knowledge, expertise and cost structure efficiencies.

As the Boston Consulting Group summarized in their Sprinting to Value in Industry 4.0 publication (2016), the implementation of Industry 4.0 is a matter of “running sprints, but managing a marathon”. The NIST MEP national network of centers is uniquely qualified to assist small and mid-sized manufacturers with the implementation of specific point solutions relative to advanced manufacturing technologies while also encouraging and enabling their clients to keep a long-term, enterprise transformation perspective. This should be the focus of any resultant Federal Funding Opportunity (or FFO) issued in the months ahead.