This submission is a collaborative response on behalf of: Arizona State University, Michigan State University and, The Pennsylvania State University. Provided in this document is a brief description of our programs and a description of the significant resources within the supply chain management programs at these three universities.

Arizona State University (ASU) is represented by the W. P. Carey Department of Supply Chain Management, a consistently ranked Top 5 nationally for undergraduate and graduate programs by U.S. News & World Report. Our research advances knowledge in global supply chain management while focusing on issues of practical importance, and our faculty is globally recognized for expertise in procurement, supply management, operations management, logistics and supply chain performance optimization. With more than 1,400 Supply chain management students, Arizona State University is one of the largest supply-chain programs in the United States. Also, several leading edge centers reside within the supply chain management department including the Network for Value Chain Excellence, the Internet edge Supply Chain Lab, and the jointly operated CAPS Research.

Michigan State University (MSU) is represented by the Department of Supply Chain Management (SCM) in the Eli Broad College of Business. SCM includes both the Midland Research Institute for Value Chain Creation and the Demmer Center for Business Transformation. MSU SCM has undergraduate, graduate, and executive programs that are ranked in the Top 5 nationally. The program is recognized for its end-to-end supply chain perspective including the disciplines of sourcing, manufacturing, logistics, new product development, and international business. The nationally recognized MSU SCM faculty complete basic and applied research in supply chain strategy, operations, and technology based on collaborations with industry executives. The MSU Supply Chain Council includes 40 national firms who focus on supply chain research and talent development.

The Pennsylvania State University (PSU) is represented by the Smeal College of Business, its department of Supply Chain and Management Information Systems and our Center for Supply Chain Research. As one of the largest departments in the college, both by faculty and student enrollment, our program is consistently ranked in the Top 5 in the country by a variety or agencies and represents the quality of both our research and education capabilities as recognized by industry. In addition we have a strong, industry focused, Center for Supply Chain Research (CSCR) sponsored by over 60 companies (many fortune 500) with powerful connections to the needs and best practices of industry. Our research, both academic and practitioner, covers a broad array of mainly applied topics in supply chain management.

Questions

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

Some of the key issues that US small manufacturers face can be described as:

1. *Near-term:*
   - *Higher tax burden, capital and labor costs compared to competing small manufacturers in low-cost, low-regulation nations.*
   - *Availability of reliable and skilled supplier firms.*
   - *"Amazon" effect on supply chains, particularly the constant pressure to reduce lead-times while simultaneously improving service levels and maintaining balance in inventory levels.*
   - *Differences between customer and supplier in their abilities to share accurate, real time, cost effective information. This is problematic for small manufacturers dealing with large customers.*
   - *Ability to integrate technologies required by upstream suppliers and downstream customers.*
   - *Complex supply and distribution channels.*
   - *Availability of capital to develop, manufacture and distribute product. Utilizing the supply chain to support capital needs may be a potential solution.*
   - *Coping with dramatic technological change that can make current processes obsolete quickly.*
   - *Managing compliance regulations and risk, and the* ability to cost effectively comply with regulations.
   - *Availability of skilled and semi-skilled labor to respond to growth.*

2. *Mid-term:*
   - *Building competency to manage their supply chain operation (as distinct from supply chain design). This includes many of the individual issues below.*
   - *Moving from a physical of information/data to virtual data platforms. This includes the need to move toward data-based decision making and corresponding analytics.*
   - *Data sharing through cloud environments and across diverse platforms.*
   - *Managing complexity such as growth in mass customization and changes in technology.*
   - *Developing rapid learning and implementation capabilities to enable manufacturers to adjust to their rapidly changing supply chain environment.*
   - *Monitoring supply chain execution: visibility, metrics and responses.*
   - *Understanding cyber security risks and cost effectively mitigating these risks.*
   - *Mitigating cost pressures effectively. For example; reducing waste, improving product quality, etc.*

- *Identifying opportunities to work with key customers to provide solution opportunities.*

3. *Long-term:*
   - *Changing labor force demographics and the impending retirements of "baby-boomer" generation of skilled labor.*
   - *Sustainability, and tracking/improving related metrics. Sharing metrics upstream and downstream.*
   - *Change in workforce dynamics that has resulted in desire by young professionals to have more job and career flexibility.*
   - *Lack of desire of those entering the work force to establish a career in manufacturing.*
   - *Lack of available training opportunities for establishing a skilled and semi-skilled workforce in a changing manufacturing landscape (more automated, less physical).*
   - *Lack of ability to market capabilities to downstream OEMs and other Business-to-Business customers.*
   - *Recapturing domestic business. When business is lost to overseas suppliers, it is difficult to re-shore.*
   - *Ability to transform current business models in order to support new technologies, new capabilities and new value propositions for customers.*

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

Types of manufacturing technologies required of small manufacturers fall into several categories:

- *Software:*
  - *Supply chain planning and optimization.*
  - *Interconnectivity (with customers and suppliers).*
  - *Data security.*
  - *Track and trace (inventory as well as movement of product and workflow status) combined with a physical technology (RFID, Bar-Code, Internet of Things, etc.).*
  - *Risk analysis.*
  - *Data analysis.*
  - *Data analytics.*
  - *Cognitive computing and Machine learning.*
  - *Supply chain and network design.*

- *Additive manufacturing technologies:*
  - *Physical equipment for production and,*

- *Data management tools and,*
- *Design tools, and*
- *3D printing.*

- *Line automation technologies.*

(a) What would be the appropriate Manufacturing Readiness Level or Technology Readiness Level for those technologies in order for small U.S. manufacturers to consider adoption?

For small manufacturers, Manufacturing Readiness Levels need to be at 8 (demonstrated capability) or greater. The reasoning is that these firms do not have the investment capability or, resources needed to move technologies form earlier phases through adoption. The risk/reward for earlier phase technologies is better researched and developed outside small manufacturing firms.

It is possible, if appropriate, that new technology/tool development organizations might partner with small manufacturers in development phases, prototyping training materials and tools. This is assuming there is a significant strategic fit with the small manufacturer's objectives and capabilities; and, that the time and dollar investments on behalf of the manufacturing firm are relatively small or made at low risk.

(b) 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 any given technology?

Small manufacturers need to understand developmental technologies at a fundamental level. Since their core expertise is not typically the development or implementation of new technologies, it is not necessarily important that they have deep expertise in this area. What they will need to understand is:

- *How can new technologies make a positive difference in our business?*
- *What are the investment and risks associated with adopting this new technology?*
- *What alternative technologies are there that should be considered?*
- *What is the timeline for implementing this technology and its expected longevity?*
- *What is the level of skills and expertise required to apply this technology?*
- *What alternative business models may be necessary to support the new technology?*

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

Information about new and advanced technologies can be delivered to small manufacturers and second and third tier suppliers through multiple pathways. The primary Federal pathway is through the 51 Manufacturing Extension Partnership (MEP) offices via their staff and contractors. Other partners will be important for broad deployment:

- *University activities such as symposiums, fairs, train the (MEP) trainer and direct executive programs deployment.*
- *Community college training programs for new employees.*
- *Online offerings co-developed by MEPs, universities and community colleges.*
- *Webinars and short videos*

(3) What technologies and/or business models are important to small U.S. manufacturers as they choose and participate in any particular supply chain?

This would be best determined by research done involving; university supply chain centers, MEP's and OEM's. We have identified in question 2 above, some areas that will be important in the near and mid-terms.

Supply chain network design and simulation tools like those seen by university supply chain students.

(4) 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?

This would be best determined by research done involving; university supply chain centers, MEP's and OEM's.

We have identified in question 1 above, some areas that are important to address. If core competencies can be externally developed and leveraged (shared resource) then risk is lowered and returns are improved. In addition, as we can see in an example like the 3rd Party Logistics industry (3PL's), these complementary service industries can maintain high levels of technology and faster improvements over time than being adopted internally.

Currently, many firms are interested in developing and implementing sustainability programs. Much like quality programs three decades earlier, sustainability is becoming a prerequisite for working with larger firms.

Discussions regarding 2nd and 3rd tier suppliers can design and offer value added solutions to their key customers.

(5) Are there any other critical issues that NIST MEP should consider in its strategic planning for future investments that are not covered by the first four questions?

Other critical or, strategic issues areas that might be considered by NIST and the MEP's in their planning are:

- *How can manufacturers leverage research and development assets at universities?*
- *What are the areas of focus such as supply chain management that manufacturers need to improve?*
- *How can manufacturers obtain and comprehend industry feedback on areas of interest and investment?*
- *What technologies have been developed and are they applicable and affordable?*
- *What can manufacturers do to attract, develop and maintain talent?*
- *How can understanding regarding how value propositions can be designed and delivered to their customers be disseminated?*
- *How cam manufacturers develop managerial and operational leaders for 2nd and 3rd tier supply chains?*

In developing and deploying solutions it will be important to engage ALL stakeholders (small manufacturers, OEMs, mid-tier suppliers, MEPs, state economic development agencies, universities, community colleges, etc.). One critical issue is what new partnerships should be explored for the development and delivery of supply chain management competency and tools. MEPs have not been terribly successful in partnering with universities to develop and deliver services. An important vehicle to consider is the practice-oriented industry-funded supply chain centers at universities with highly ranked supply chain programs. Examples include Penn State's Center for Supply Chain Research and Institute for the Study of Business Markets, Michigan State's Supply Chain Council, Midland Research institute for Value Chain Creation and Demmer Center for Business Transformation, and Arizona State's Network for Value Chain Excellence, Internet Edge Supply Chain Lab, Sustainability Consortium and the jointly operated (with ISM) CAPS. These universities and their centers provide strong linkage to OEMs whose needs will drive the capabilities that second and third tier suppliers need to acquire.

There is also value in partnering with DoD since their product supply chains depend on a strong network of second and third tier suppliers. These schools also have strong connections with DoD facilities.