Resilient Cyber Manufacturing Mesh Networks

The recent pandemic and geopolitical tensions have highlighted the fragility of global manufacturing supply chains. While it is expected that growth in domestic manufacturing capabilities will fill the gaps created by the disruption in supply chains, long-term market trends have created significant challenges that must be overcome to build competitive, sustainable, and resilient domestic manufacturing capabilities.

Specifically, three key challenges are evident, especially in the context of small and medium sized manufacturers (SMEs) who make up over 95% of the U.S. manufacturing ecosystem[1]. First, offshore competition over the past few decades has forced many SMEs to specialize their capabilities to serve more profitable industries. This requires sizeable investments in specialized equipment, which adds to manufacturing costs. Second, considering the aging manufacturing workforce in the U.S.[2], domestic suppliers face significant challenges in recruiting, training, and retaining a skilled and knowledgeable workforce, which poses significant risks for their long-term growth and survival. Finally, the level of digitalization in SMEs is underdeveloped, with many still relying on existing business connections and word-of-mouth marketing to publicize their capabilities. These challenges make it difficult for manufacturers to identify suitable suppliers. When unforeseen interruptions occur, reliable alternatives are difficult to identify, not to mention the lack of visibility and traceability if a supplier subcontracts to others. It is therefore evident that the existing domestic manufacturing infrastructure is in dire need of a complete transformation to ensure competitive and resilient manufacturing capabilities in the United States.

To address this critical need, we envision future cyber manufacturing mesh networks that are self-organizing and self-healing, thus enabling automated, sustainable, and resilient domestic manufacturing capabilities. This vision draws its inspiration from wireless mesh communication networks that utilize the internet and wireless communication technologies to create self-organizing and self-healing networks capable of automatically rerouting interrupted communications. To realize this vision for manufacturing, however, several scientific and technical challenges, embodied in the following question, must be addressed: *how do we build cyber manufacturing mesh networks that enable (1) automated and secure identification of suppliers with the necessary manufacturing capabilities to produce the desired component(s)/product(s), (2) automated harvesting of manufacturing process capability knowledge (i.e. "manufacturing intelligence or know-how") to augment and fill gaps caused by shortage of experienced and skilled workforce, and (3) enhanced capabilities and sustainable growth of the manufacturing ecosystem?* This question can be answered by developing computational methods and tools that harness the power of data-driven methods including Artificial Intelligence and Machine Learning, the industrial internet-of-things powered by edge and cloud computing, cyber security, mixed-reality technologies that enable human-machine interaction, digitalization of machines, and lifelong workforce training programs. We further envision a community-based process knowledge lake to fill knowledge gaps in the workforce, and process knowledge sharing protocols that enable communication of manufacturing knowledge for a given product. Finally, we envision the cyber manufacturing mesh network infrastructure will empower and lower the barrier to entry for new SMEs, thereby launching a new wave of transformative growth in domestic manufacturing capabilities.

[1] https://nam.org/state-manufacturing-data/2020-united-states-manufacturing-facts/
[2] https://www.bls.gov/cps/cpsaat18b.htm