UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN · CHICAGO · SPRINGFIELD

Office of the Vice President for Research
346 Henry Administration Building
506 South Wright Street
Urbana, Illinois 61801

Lawrence B. Schook
Vice President for Research
Edward William and Jane Marr Gutgsell Professor

October 24, 2012

National Institute of Standards and Technology
Advanced Manufacturing National Program Office
VIA EMAIL to: nnmi_comments@nist.gov

RE: **University of Illinois Response to the NIST Request for Information on the National Network for Manufacturing Innovation**

Dear NIST AMNPO:

Developing new innovations in advanced manufacturing and educating a workforce with relevant technical skills are natural extensions of the University of Illinois' land-grant mission and are critical to maintaining our nation's economic competitiveness. We strongly support the proposal to create the National Network for Manufacturing Innovation (NNMI), and we are grateful for the opportunity to share our comments in response to NIST's Request for Information.

Public-private partnerships can help reignite the nation's manufacturing sector and enhance our ability to generate new products right here in the United States. The University of Illinois (U of I) is committed to making the state of Illinois and the Midwest region a destination for advanced, high-value-added manufacturing enterprises through basic and applied research and development, engagement with industry, workforce training and education pipeline development in advanced manufacturing tools, processes and systems.

Manufacturing new products emerging from advanced technologies, including advanced materials and high-precision tools, not only improves quality of life, but it also creates economic growth, generating high-quality, good-paying jobs for American workers. Further, a strong regional manufacturing ecosystem increases our competitiveness and fosters innovation. Illinois is helping to lead the charge:

- More than 30 Fortune 500 companies are based in the Chicagoland area, including manufacturing giants like Boeing, Caterpillar, John Deere, Kraft Foods and Abbott
- Illinois is one of the nation's manufacturing leaders, generating $97 billion in 2009 from value-added productivity from manufacturing
- Manufacturing represents more than a third of private sector jobs created in Illinois since January 2010
- Advanced manufacturing is one of Chicago's top strategic priorities in its February 2012 economic development plan

- The State of Illinois is one of seven states selected to participate in the National Governors Association Policy Academy on advanced manufacturing
- The U of I's National Center for Supercomputing Applications (NCSA) is a founding member of the National Digital Engineering and Manufacturing Consortium (NDEMC), extending modeling and simulation capabilities to small and medium-sized manufacturers (SMEs)

The University of Illinois is renowned for its excellence in nanomanufacturing, modeling and simulation, advanced materials, and processing technologies. Our world-class faculty attracted more $800 million of research funding in 2012. The University works closely with industry and civic stakeholders to maximize the impact of research and to set its research agenda.

It is critically important that manufacturing innovation initiatives be structured around an **industrial commons** to produce economic growth. The commons should bring together elements of an innovation ecosystem – applied research, technology commercialization, entrepreneurial talent development, workforce training, STEM education initiatives, shared infrastructure, and investment. Each of these elements is necessary but insufficient on its own. Public-private partnerships among industry, academia and government are necessary to support the virtuous cycle of innovation, improve our nation's competitiveness, originate new markets, create jobs, and generate economic growth.

Technologies with Broad Impact

The NNMI must support both (1) **foundational research**, i.e., cutting-edge research to support and enhance U.S. competitiveness in state-of-the art manufacturing technology and practice, and (2) **transformative research**, i.e., disruptive new technologies and concepts to usher in the next generation of manufacturing and product realization. Such research aims to bring novel capabilities to manufacturers and support entirely new industries.

Manufacturing Innovation Institutes (MIIs) should bridge basic and applied research, aiming to accelerate the product development cycle in order to increase the rates of innovation and growth, and to de-risk investments in new technologies. To ensure a global leadership position, the U.S. government must invest in areas of market failure, i.e., areas that industry cannot afford to invest in alone today.

Several technology areas satisfy these criteria:

- Digital manufacturing. Digital technologies have the potential to truly transform how manufacturing will be done in the future. These technologies rely on significant computational resources, such as supercomputing power and ultra-high speed connectivity, as well as domain and functional (i.e., programming) expertise. The U.S. can accelerate innovation by developing new digital supply chains and an industrial Internet that lowers barriers to entry and democratizes access to game-changing digital tools for both original equipment manufacturers (OEMs) and SMEs. Further, researchers and industry alike must be armed with the professional programming talent that can create advanced software tools, which are suitable for modern parallel hardware and necessary for advanced digital experimentation. These advancements would ultimately reduce modeling and simulation costs, enable efficient modeling of complex supply chains and systems, enhance design optimization, reduce design and production costs, and quantify challenges in production, in supply chain, and in energy efficiency to innovate more frequently and efficiently.

  U of I is home to the Blue Waters Project, which will become the world's most powerful petascale computing system by year-end 2012. Not only will the Cray supercomputer system be favorable to the types of modeling and simulation that manufacturers care about, but the storage systems

will be the world's largest and fastest. Significant fractions of Blue Waters are available for industrial use, including NNMI institutes.

- Nanomanufacturing technologies. The U.S. is currently leading the field, and these technologies will impact many important future applications, such as flexible electronics, novel solar energy harvesting devices, and biomedical devices. For instance, advanced biomedical devices, such as bio-sensors, point-of-use biochips and diagnostic devices, 'smart' bandages, and implants, require expertise in bio-photonics, imaging, nano-biotechnology, microfabrication and nanomanufacturing. Strong expertise in microscale and nanoscale fabrication processes is required to address the challenges that accrue from the growing requirements of molecular-scale precision in manufacturing.

- Materials design, processing, and prediction. Materials science is a major strength of U.S. research universities national labs, and industry. The U.S. must build upon this strength and integrate materials research fully into advanced manufacturing. These efforts are not limited to the making of products, but also include analyzing and predicting short- and long-term properties of manufactured components, such as materials damage and fatigue effects. Advanced application of complex modeling and simulation would accelerate innovation in novel materials. Today, manufactured goods are more than just an assemblage of fabricated metal structures and, as such, the processes used to realize them transcend the traditional metalworking processes.

- Automation/mechatronics and cyberphysical manufacturing. Modern manufacturing machines must be more than just automated tools. Instead, they must support programming, communications, monitoring and sensing, data processing and storage, and, in general, function as an autonomous unit in a heterogeneous cyberphysical environment. Machine-tool manufacturers need new tools to develop state-of-the-art, intelligent machine tools for advanced manufacturing in various sectors like transportation, electronics, food and agriculture, and health care. New approaches are needed for (a) rapid engineering of customized, energy-efficient machine tools, (b) energy efficient, computer controlled tools for micro and nanomanufacturing processes, and (c) tools for calibrating and monitoring machines to reduce scrap and increase yield and energy efficiency in manufacturing.

Institute Structure, Governance & Sustainability

Key structural considerations include the following:

- MIIs must promote collaboration between industry, academia, and government to work together on applied manufacturing research and development in an industrial commons. The institutes should be either university-led or company-led, but involving both parties in the larger consortium, with the expectation of eventually becoming a stand-alone, self-sustaining non-profit research organization.

  For example, NDEMC is an exemplary public-private partnership, involving the Department of Commerce EDA, Department of Energy, NIST, NSF, Office of Science and Technology Policy, the U of I's NCSA, Lockheed Martin, General Electric, Procter & Gamble, Deere & Company, the state of Ohio, Ohio Supercomputer Center, Purdue University, National Center for Manufacturing Sciences, and the U.S. Council on Competitiveness.

- Federal funding should be matched initially by private and/or state funding, and federal investments must demonstrate commitment to the project through self-sustainability (i.e., 5-7 years). Federal funding will incentivize early involvement of private industry, which will want to ensure the MII's sustainability during the term of engagement.

- MII program areas and projects should be driven by industry needs. Accordingly, governance structures should allow the MII to be nimble and responsive to evolving challenges faced by industry.

- MIIs should include significant involvement of SMEs, which may be coordinated through a cyberphysical infrastructure – i.e., an open and accessible advanced manufacturing enterprise, in which consumers and producers are brought together in a digital cloud, thereby integrating every step in the design/make process. Social networks akin to "Alibaba" could further provide a platform for SMEs, suppliers, and large companies to communicate and exchange services; U of I faculty are developing a similar platform – www.B2Busa.com.

  NDEMC provides a framework to harness the power of high performance computing (HPC) to provide accessible modeling and simulation expertise to SMEs, thus supporting a more nimble, digitally-capable supply chain. For its pilot, four OEMs, including Lockheed Martin, GE, Procter & Gamble, and Deere, contributed funding to support the involvement of eight SMEs in their supply chain.

- The value of co-location of university and industry is also an important consideration – particularly one in a large metropolitan center like Chicago. An environment where technology-based businesses can work with faculty and students would enable opportunities for collaborative research and commercial endeavors, e.g., sponsored research, curriculum and teaching contributions, faculty consulting, and partnerships on federal grants.

  Manufacturers in the U of I Research Park include ADM, Abbott, Caterpillar, Deere, Littelfuse, and Sony. At any given time, approximately 350 student interns from the Urbana campus are working in these companies, gaining valuable work experience while making real contributions to internal corporate R&D and product development programs. Deere opened an innovation center in the Research Park to "accelerate [their] innovation strategy and leverage the capabilities of the external environment." They reported that the relationship "has made significant contributions at John Deere in terms of new relationships that expand [their] technology vision, innovations that solve complex problems in [their] business, and filling [their] global talent pipeline with students that build new capabilities for [their] business." A center in Chicago would be positioned to attract many more companies due to its centralized location.

- For the NNMI to become sustainable, industrial stakeholders and beneficiaries must be full partners, including contributions of cash, in kind support, and expertise. A membership fee or fee-for-service model could apply to both OEMs and SMEs, with contributions scaled appropriately to the size of the partner and its match with NNMI objectives. We envision that SME could receive subsidies through cost-sharing programs with OEMs and/or federal, state or local grant programs.

  NCSA's Private Sector Program (PSP) is a self-sustaining business unit within NCSA with its own staff and computational resources. Partners pay fees depending upon company size and computational usage. PSP partners include Boeing, Caterpillar, Dell, Deere, GE, Nokia-Siemens Networks, Procter & Gamble, and Rolls-Royce.

- NNMI must provide strong support for proof of concept programs or funding streams aimed to bridge valley of death. MIIs must develop a strategy for developing and retaining spin-out companies. Licensing revenues from such companies may further impact long-term sustainability.

The U of I's Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS), one of only three nano-manufacturing centers in the U.S., works closely with the office of Technology Management, award-winning EnterpriseWorks startup incubator, and seed-stage venture fund IllinoisVentures to foster technology commercialization and company formation. Since its inception, R&D efforts have resulted in 54 patent disclosures, of which 36 were filed. Nano-CEMMS has also spun out 13 companies, many of which reside in the U of I Research Park in Urbana-Champaign. Overall, the U of I Research Park has incubated more than 145 startup companies since 2001, helping to turn U of I research into commercial businesses.

- MIIs should be structured to foster interdisciplinary pursuits, bringing together industry domain experts, project consultants, software programmers, and researchers. For instance, researchers in both academia and industry should be paired with the programming expertise necessary to scale digital experimentation to large, complex systems, e.g., those that require petascale systems like Blue Waters. By bringing together the necessary skills and infrastructure in an industrial commons, interdisciplinary teams from industry and academia can more readily interact and thereby more rapidly innovate.

Education and Workforce Development

In addition to conducting cutting-edge research and development, the NNMI must foster education and workforce development to develop the next generation of skilled workers in an advanced manufacturing economy. Training for scientists, engineers and technicians should focus on the broad range of skills and expertise needed for the advanced manufacturing workforce. These skills include the ability to work in multidisciplinary teams alongside industry, develop entrepreneurial thinking oriented around solving real work problems, and make game changing advances in advanced manufacturing.

- Training programs supported through NNMI should encourage university partners to foster entrepreneurial skills, which is typically best done with direct hands-on experience. To best prepare students to work outside of academia, programs should give them opportunities to experience life outside of academia. By fostering interactions within the industrial commons, shared experiences may produce increased opportunities for innovation.

- MIIs should connect to fellowship and internship programs that allow students to spend part of their student careers working in industry, creating networks between academia and industry, fostering real-world learning, and providing students with greater understanding of workforce opportunities.

  Caterpillar hires cost-effective U of I student interns to work on simulation and analysis projects for internal clients at its Simulation Center in the U of I Research Park. Students work on project teams monitored by a full-time staff member. This workforce also serves as a talent pipeline since over 50% of interns have accepted full-time positions with Caterpillar upon graduation.

- MIIs should fully utilize information technologies, including massive open online courses (MOOCs), for workforce training and education.

  The U of I is a lead university on the new education platform, Coursera, which offers online course modules to hundreds of thousands of students. For instance, computer science professors are working with NCSA's accessible HPC resources to consider how to offer a course in GPGPU (general-purpose computing on graphics processing units) programming to 10,000 students on a web-based education platform.

- MIIs should integrate the pipeline for future manufacturing workforce from grade and high school students, to junior and community colleges (technical skills), to universities and graduate schools (basic and applied research). Such integrated training will significantly enhance the quality of the U.S. manufacturing workforce. Preparation of students for STEM-related jobs is critical for competitive economic growth and filling our pipeline with workers to address the growth expected in high-wage, knowledge-based occupations.

  The U of I's Nano-CEMMS includes a Human Resource Development Program that supports pre-college, undergraduate, and graduate students, as well as teaching professionals. During the past year, 535 K-12 teachers and 4364 students attended Center programs and used learning modules developed by the Center.

  The U of I became a Project Lead the Way (PLTW) National Affiliate University in 2005, offering workshop sessions on its Chicago and Urbana-Champaign campuses, coordinating statewide Illinois PLTW program implementation, and supporting efforts in cooperation with the Illinois State Board of Education. The university's Chicago campus offers three summer workshops to over 40 high school teachers per workshop over a three week period.

  The university's I-STEM initiative aims to foster accessible, effective STEM teaching and learning at local, state and national levels, thereby preparing a highly able citizenry and STEM workforce. By joining with units across the university and external partners that include industry, government, professional associations and local school districts, the university's I-STEM initiative provides STEM experiences for students as early as preschool, STEM teacher development programs, and undergraduate and graduate STEM research experiences.

- MIIs should offer access to customized training services and technical assistance, as well as public workshops and certificate programs. Project consultants and workforce programs are integral to an industrial commons.

  UI-BIS (Business Innovation Services, supported by the U of I Extension Program) has served over 6500 companies (>65% manufacturers) during its 28 year history, aiming to assist SMEs to grow and create jobs, become more globally competitive, help employers improve efficiency in processes, build export capability, develop new innovative products, business models and markets, and lower energy costs for sustainability and profitability.

Together with the city of Chicago, the state of Illinois, our fellow research institutions, and industry and community partners, the U of I leverages our research strengths and educational resources to make Illinois and the Midwest a destination for advanced, high-value-added manufacturing enterprises. Our innovative research leads to the development and commercialization of next-generation products, processes, and systems. And, as one of the world's leading educational institutions, we understand the importance of entrepreneurship education and workforce development to nurture the next generation of skilled workers in advanced manufacturing economy. The U of I supports the educational needs of SMEs by equipping engineers and technical workers with the new tools and skills they need to innovate, thereby enabling the broad application of advances in manufacturing design, production, and quality assurance. Further, we support the recreation of the American industrial commons – bringing together research talent, a skilled workforce and industry expertise under shared infrastructure – to foster collaborative endeavors that will accelerate innovation in advanced manufacturing.

Thank you for this opportunity to share our feedback regarding the National Network for Manufacturing Innovation. We appreciate your leadership in seeking to establish the infrastructure necessary for ensuring our nation's competitiveness and security. We look forward to sharing how the University of Illinois can help shape the Midwest as the cradle of the federal government's advanced manufacturing agenda.

Best regards,

Lawrence B. Schook
Edward William and Jane Marr Gutgsell Professor
Vice President for Research