Designing for Impact I: Workshop on Building the National Network for Manufacturing Innovation

SUMMARY OF RESULTS

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Acknowledgment

Many thanks to all those who participated in the workshop *Designing for Impact I: Workshop on Building the National Network for Manufacturing Innovation* held April 25, 2012, at Rensselaer Polytechnic Institute in Troy, New York. The presentations and discussions that took place at the workshop provided the foundation for this report. A complete list of participants is provided in Appendix A.

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Preface

This report documents a public workshop to collect input from the private sector on the National Network for Manufacturing Innovation (NNMI) proposal, and how an institute for manufacturing innovation along with a network could optimally be designed. Participants were predominantly from industry and academia, with state and local government representation along with economic development organizations. Representatives from the federal government participated only to explain the NNMI concept and proposed principles, and to provide answers to questions about any other related federal program.

The purpose of the *Designing for Impact I: Workshop on Building the National Network for Manufacturing Innovation* was to allow participants the opportunity to share perspectives, pose questions, and propose ideas to help shape the design of the proposed NNMI. There were four dialogues during the workshop that addressed the following topics:

- Technologies with Broad Impact
- Institute Structure and Governance
- Strategies for Sustainable Institute Operations
- Education and Workforce Development

The objective of the four dialogues was to inform workshop participants about proposed basic principles of the NNMI initiative and to solicit individual participant insights and ideas. Each participant was given the opportunity to answer a range of questions under each dialogue about the operations, goals, best practices, and other aspects for the Institutes. The scope of all dialogue discussions and the questions discussed followed that contained within the NNMI Request for Information (RFI)[1]. The individual inputs offered by stakeholders during this workshop and reviewed in this summary will assist the AMNPO in the development of the new program should the NNMI be funded.

To ensure open and unbiased public input, the workshop followed strict ground rules, including:

- Dialogs were facilitated to support open and public discussion; federal representatives did not provide input to the documented dialogs.
- All public comments were accepted and documented.
- No ranking or evaluation of any input took place, nor was any voting or consensus development permitted.
- Although the dialogs followed the topics and the questions in the RFI, participants were free to provide input on any facet of the NNMI concept.

[1] "Request for Information on Proposed New Program: National Network for Manufacturing Innovation (NNMI)," 77 Federal Register 87 (04 May 2012), pp. 26509-26511. Available at: https://www.federalregister.gov/articles/2012/05/04/2012-10809/request-for-information-on-proposed-new-program-national-network-for-manufacturing-innovation-nnmi.

1.0 Introduction

1.1 Overview

The interagency Advanced Manufacturing National Program Office (AMNPO) coordinated and held the *Designing for Impact I: Workshop on Building the National Network for Manufacturing Innovation* workshop on April 25, 2012, at Rensselaer Polytechnic Institute in Troy, New York. The AMNPO is charged with coordinating federal resources and programs to enhance technology transfer to U.S. manufacturers. Hosted by the National Institute of Standards and Technology (NIST), an agency of the U.S. Department of Commerce, participation in the AMNPO includes federal agencies involved in U.S. manufacturing and enables more effective collaboration in identifying and addressing challenges and opportunities that span technology areas and cut across agency missions. Core partner agencies in the AMNPO include the Department of Commerce, Department of Defense, Department of Energy, National Aeronautics and Space Administration, and the National Science Foundation.

1.1.1 National Network for Manufacturing Innovation (NNMI)

This public workshop was the first in a series allowing interested parties the opportunity to learn more about and provide input on a proposed new public-private partnership program, the National Network for Manufacturing Innovation (NNMI or Network). Input may also be provided by responding to a Request for Information (RFI) published on May 4, 2012[2]. The proposed Network will be composed of up to 15 Institutes for Manufacturing Innovation (IMIs or Institutes) around the country. Each Institute will serve as a hub of manufacturing excellence that will help to make United States (U.S.) manufacturing facilities and enterprises more competitive and encourage investment in the United States. This program was proposed as a $1 billion one time investment in President Obama's fiscal year (FY) 2013 budget.

Many technologies fail to move to commercialization or reach full scale-up in the United States because the domestic private sector, particularly small and medium-sized enterprises (SMEs), find that the risks of such investments are too great for an individual entity to make. The private sector also reports challenges in accessing key skills and technical infrastructure for demonstration and prototyping purposes.

[2] "Request for Information on Proposed New Program: National Network for Manufacturing Innovation (NNMI)," 77 Federal Register 87 (04 May 2012), pp. 26509-26511. Available at: https://www.federalregister.gov/articles/2012/05/04/2012-10809/request-for-information-on-proposed-new-program-national-network-for-manufacturing-innovation-nnmi.

To meet this challenge, the United States must build on its strengths, leverage its unique research, innovation, and workforce capabilities, and create an infrastructure for manufacturing innovation to ensure that the next generation of processes and products not only will be invented in the United States, but scaled up and manufactured in the United States as well.

1.1.2 INSTITUTES FOR MANUFACTURING INNOVATION (IMIS OR INSTITUTES)

The proposed NNMI will be composed of up to 15 Institutes for Manufacturing Innovation around the country. The IMIs will bring together industry (both large companies and SMEs), universities and community colleges, federal agencies, states, and other relevant organizations to accelerate innovation through co-investment in industrially relevant manufacturing technologies with broad applications. Used in this context, "co-investment" means that non-federal entities will contribute financial and other resources to the Institutes to complement federal investments. The Institutes will take full advantage of existing infrastructure by integrating current capabilities and building new ones where needed to foster innovation that can impact the manufacturing sector on a large scale.

The objectives of the NNMI are to bridge the gap between applied research and product development, provide shared assets to help companies gain access to cutting-edge capabilities and equipment, and create an unparalleled environment to continuously educate and train students and workers in advanced manufacturing skills. The stage of the research is envisioned to be within Technology Readiness Level (TRL)[3] 4-7. It is expected that each Institute will become a self-sustaining technical center of excellence, providing and integrating innovation resources that will help to make domestic manufacturing facilities and enterprises more competitive and encourage investment in the United States.

1.1.3 WORKSHOP OBJECTIVE AND OUTCOMES

The purpose of this workshop was to allow participants the opportunity to share perspectives, pose questions, and propose ideas to help shape the design of the proposed NNMI. There were four dialogues during the workshop that addressed the following topics:

- Technologies with Broad Impact
- Institute Structure and Governance
- Strategies for Sustainable Institute Operations
- Education and Workforce Development

The objective of the four dialogues within the *Designing for Impact I: Workshop on Building the National Network for Manufacturing Innovation* was to inform workshop participants about proposed basic principles of the NNMI initiative and to solicit individual participant insights and ideas. Each participant was given the opportunity to answer a range of questions under each dialogue about the operations, goals, best practices, and other aspects for the Institutes. The scope of all dialogue discussions and the questions discussed followed that contained within the

[3] National Aeronautics and Space Administration. "Definition of Technology Readiness Levels." Available at: http://esto.nasa.gov/files/TRL_definitions.pdf.

NNMI RFI.[4] No ranking of individual ideas or consensus development took place. Although the dialogs followed the topics and the questions in the official RFI, participants were free to provide input on any facet of the NNMI concept. In total, over 1,600 individual ideas were offered by workshop attendees across the four dialogue topics. Federal government employees did not provide comments for input. The individual inputs offered by stakeholders during this workshop and reviewed in this summary will assist the AMNPO in the development of the new program should the NNMI be funded.

The workshop attracted a diverse and wide-ranging mix of over 250 participants:

- 44% from academia
- 34% from industry
- 12% from local, state and federal government
- 10% from economic development organizations

Although most participants came from the Northeast and New York state, this was truly a national conference, as attendees came from thirty-three states. A complete list of workshop participants is presented in Appendix A.

[4] "Request for Information on Proposed New Program: National Network for Manufacturing Innovation (NNMI)," 77 Federal Register 87 (04 May 2012), pp. 26509-26511.Available at: https://www.federalregister.gov/articles/2012/05/04/2012-10809/request-for-information-on-proposed-new-program-national-network-for-manufacturing-innovation-nnmi.

2.0 Technologies with Broad Impact

2.1 OVERVIEW

For its particular technology focus area, each Institute should be designed to address issues related to the "industrial commons," or the collective research and development (R&D), engineering, and manufacturing capabilities that sustain innovation. This includes addressing shared problems throughout the supply and/or value chain and across multiple end-use applications. The stage of the selected technology areas is envisioned to be within TRL 4-7, whereby process economics are further clarified and scale-up issues are better defined and quantified. Further, the Institutes should have strategies for transitioning and implementing to larger-scale production beyond Institute operations.

2.1.1 WORKSHOP PARTICIPANT INPUT

Participants at the workshop were asked to provide their individual input on multiple questions for the Technologies with Broad Impact dialogue. **Table 2-1** shows the summary of the most frequent answers to the questions. Since individual workshop participants provided their own input for each question, the most frequent answers are presented, grouped by similar ideas, and are listed in decreasing frequency.

Table 2-1. Technologies with Broad Impact Questions and Responses
(Listed by similar responses in decreasing frequency)

What criteria should be used to select technology focus areas?
• Cross-cutting technology that is relevant and applicable to broad end-uses and multiple industry areas, companies, and sectors as well as the supply chain (for example, advances in metrology, particularly at the nanoscale, will enable advances in advanced materials, composites, semiconductors, etc.)
• Significant positive impact to U.S. manufacturing; whether it improves the U.S. global competitive and market position or if it is a technology area in which the U.S. could lead
• Relevance to current industry needs including technologies that address immediate and long-term company and industry problems; the needs can be identified by the industries involved in the Institutes
• Impacts on energy and environmental sustainability such as supporting carbon reduction

Table 2-1. Technologies with Broad Impact Questions and Responses
(Listed by similar responses in decreasing frequency)

- Potential to create new domestic jobs or move jobs back to the U.S. and the quality and quantity of created jobs
- TRL, especially those beyond basic R&D

What technology focus areas that meet these criteria would you be willing to co-invest in?

- Additive manufacturing including high speed and precise methods and for materials such as metals, composites, and ceramics
- Biomanufacturing (including biomimicry), biotechnology, biomaterials and products, and biomedical materials and device fabrication
- Nanotechnology and nanomaterials
- Energy, specifically involving the reduction of energy use in energy intensive processes and further development of forms of clean energy (such as photovoltaics or biofuels), and increasing energy efficiency and sustainability overall
- Sensors, sensing and instrumentation technology, and sensor integrated manufacturing
- Advanced composites manufacturing and materials
- Composite materials and manufacturing

What measures could demonstrate that Institute technology activities assist U.S. manufacturing?

- Impact on domestic employment including the number of direct and indirect jobs created and retained in manufacturing
- Number of startups including SMEs
- Number and range of industry partners and contributors engaged in the research
- Intellectual Property (IP) portfolio including the total number of IP licenses or the number of patents/patent applications related to products or processes
- Number of companies or industries using Institute developed technologies which demonstrates technology transition
- Amount invested and continued investment in the Institutes by stakeholders
- Wealth creation and revenue growth

What measures could assess the performance and impact of Institutes?

- Number of domestic jobs created and/or retained
- Amount of industry and regional funding, venture capital attracted, and other forms of public investments
- Total industry membership to ensure industry participation, partnerships, and engagement
- IP portfolio including the IP that has been generated and/or commercialized; measure can be along the lines of the number of patents
- Number of new startup companies and spin offs including SMEs

3.0 Institute Structure and Governance

3.1 Overview

Each Institute is envisioned to be a public-private partnership composed of many different types of organizations. Also, each Institute is envisioned to have a clearly defined mission, goal, and structure. Consequently, it is important for each Institute to function under a coherent framework with well-managed operating procedures that allow for flexibility. It will be important for the Institutes to demonstrate the capability to manage the complexity and diversity of the participating entities for successful Institute performance.

3.1.1 Workshop Participant Input

Participants at the workshop were asked to provide their individual input on multiple questions for the Institute Structure and Governance dialogue. **Table 3-1** shows the summary of the most frequent answers to the questions. Since individual workshop participants provided their own input for each question, the most frequent answers are presented, grouped by similar ideas, and are listed in decreasing frequency.

Table 3-1. Institute Structure and Governance Questions and Responses
(Listed by similar responses in decreasing frequency)

What business models would be effective for the Institutes to manage business decisions?
• Board of directors or advisory board that oversees major business decisions, creates by-laws, and includes participation from all members of the Institute. It may be beneficial to have the board consist of leaders or strategic thinkers in academia and industry or CEOs • Non-profit association (either 501(c)(3) or (6)) may be a good model for merging academic, non-profit, government, and private sector members and would be independent of any one individual partner • Establish a central director and/or an associate/deputy director at each Institute who reports to the board • Fee for service revenue model including contract R&D which enables industry to trust technologies and processes

Table 3-1. Institute Structure and Governance Questions and Responses
(Listed by similar responses in decreasing frequency)

- Technical review board to decide on the strategic direction of new technologies and to identify emerging manufacturing trends

What governance models would be effective for the Institutes to manage governance decisions?

- Board of directors or advisory board that oversees high level operation and includes members from participating organizations and non-participating stakeholders
- Director or associate director that reports to the board of directors or a co-directorate with one member each from industry, government, and/or academia
- Ensure SMEs are represented on the board of directors and allow them to have the same vote weight as large companies
- Ensure diverse membership with participants from industry, universities, federal and state governments, economic development partners, and others

What membership and participation structure would be effective for the Institutes, such as financial and intellectual property obligations, access, and licensing?

- Tiered membership fees that are based on the size or equity of companies or organizations that will help support the involvement of SMEs. Also, there should be lower membership costs for universities
- Use an "inventors owned" model, where IP and licensing rights are shared by the contributors to the individual projects. Other groups involved in Institute should have access licensing rights of the IP. Ownership can be divided equally or be related to the monetary contribution to project. If there is a single sponsor or the project was funded by the government, then the IP is owned by that sponsor or the Institute respectively
- Address IP and licensing expectations, cost, rights, and rules for technology and commercial access up front before an organization or company joins
- Tiered membership options for companies or organizations to determine their involvement and have different IP access and licensing fee levels. One option is to have two levels of participation - one with free access to common IP and the second as a less expensive, observer status

How should a network of Institutes optimally operate?

- Share best practices and lessons learned through a yearly conference or other type of meeting
- With a board of directors or advisory board with government, industry, and university representation from each Institute and conducts planning and policy development as well as general guidance

Table 3-1. Institute Structure and Governance Questions and Responses
(Listed by similar responses in decreasing frequency)

- Continuous communication between all network partners to transfer knowledge and share information, resources, and results. Methods include establishing a reporting function, common reporting formats, or other mechanisms to support real-time communication
- Each Institute should be mostly autonomous while sharing infrastructure and best practices and abiding by the same ground rules. When necessary, Institutes should be able to collaborate on projects and ensure there is not duplication in industries or technologies
- Conduct regular monthly or quarterly physical or virtual meetings to share problems, ideas, activities, and successes or to coordinate research

What measures could assess effectiveness of Network structure and governance?

- Number of new and retained domestic manufacturing jobs
- IP including licensing and patents
- Amount of outside funding from industry, venture capital, and other sources
- Membership growth and total number of industry, government, and academic members
- Number of products created, marketed, and/or commercialized and amount of technology transfer to industry
- Number of companies created and their success

4.0 Strategies for Sustainable Institute Operations

4.1 Overview

Each Institute would be catalyzed through an initial investment from the Federal Government. Each Institute should have a plan and strategy for private sector co-investment and should maintain robust performance beyond the initial federal investment. Institute members will need to demonstrate the necessary financial and strategic commitment to ensure successful operation.

4.1.1 Workshop Participant Input

Participants at the workshop were asked to provide their individual input on multiple questions for the Strategies for Sustainable Institute Operations dialogue. **Table 4-1** shows the summary of the most frequent answers to the questions. Since individual workshop participants provided their own input for each question, the most frequent answers are presented, grouped by similar ideas, and are listed in decreasing frequency.

Table 4-1. Strategies for Sustainable Institute Operations Questions and Responses
(Listed by similar responses in decreasing frequency)

How should initial funding co-investments of the Federal Government and others be organized by types and proportions?
• Invest in capital expenditures, especially allowing a portion for equipment • Invest in staffing the Institutes, specifically to hire people who will go into the field to gauge the needs of industry and build interest • Leverage existing resources including infrastructure, equipment, and buildings • Industry and government should have equal cost shares for funding (50/50 funding) • Institutes should be initially federally funded then transition to private funding • Fund projects that can demonstrate early successes which can lead to further collaboration and increases in private funding • Federal funding should be used to set up Institute organization and infrastructure, including personnel, facilities, equipment, and leadership staff

Table 4-1. Strategies for Sustainable Institute Operations Questions and Responses
(Listed by similar responses in decreasing frequency)

What arrangements for co-investment proportions and types could help an Institute become self-sustainable?

- Gradually decrease federal funding and increase non-federal funding over time, possibly through a five year plan. This allows SMEs to join activities with an incentive to contribute later
- Fee for services such as prototyping or contract R&D and where industries can purchase capability for specific applications or licenses
- Conduct projects and research that add value for stakeholders and customers by being relevant to market and industry needs, resolving immediate to mid-term problems, and applicable to multiple manufacturing sectors. This will help attract alternative funding as companies will see the value in the Institute
- Collect membership fees
- Fees from licensing IP in the form of new technologies, products, and processes
- Provide training and/or certification in emerging processes for private sector

What measures could assess progress of an Institute towards being self-sustainable?

- Number of members including the types of members as well as those that are new or sustaining
- Growth in non-federal funds from outside sources including the private sector, project fees, membership dues, and corporate investment, and how the funding proportions change over time
- Meeting milestones that are established through a comprehensive business plan. The business plan will outline goals and outcomes for the program and include tracking of traditional milestone, budget, and schedule metrics
- Willingness of industry to self-fund the Institute through a transition over time from government funding to fee for services and industry dues and investment
- Number or total amount of private/public investments and contributions attracted and whether there is continued investment from companies
- IP portfolio including the total number of patents and other development and licensing of IP
- Increase in domestic manufacturing jobs and payroll as well as workforce development numbers and job placement

What actions or conditions could improve how Institute operations support for domestic manufacturing facilities while maintaining consistency with our international obligations?

- Support the supply chain including SMEs and parts manufacturers
- Protect IP rights through strong IP and licensing agreements or by limiting Institute-generated IP to U.S. companies

Table 4-1. Strategies for Sustainable Institute Operations Questions and Responses
(Listed by similar responses in decreasing frequency)

- Focus on domestic manufacturing by allowing international participation but with IP restrictions or encouraging international collaborators to locate domestically with tax credits for U.S. based capital equipment and facilities
- Invest in manufacturing education to strengthen technical workforce and improve the quality of U.S. manpower and encourage the participation of domestic students
- Be cost effective to compete with lower cost labor markets and remain globally competitive

How should Institutes engage other manufacturing related programs and networks?

- Through regular interactions including workshops, conferences, monthly meetings, yearly summits, or technical symposiums to exchange ideas and best practices
- Continually engage through a virtual environment such as a website, virtual collaboration platform (e.g., TelePresence), Wiki or blog with periodic reports to provide activities and progress
- Add representation from other manufacturing programs to the board of NNMI and encourage cross participation of board members
- Collaborate based on needs and mutual benefits and include other programs with a related vision and mission
- Exchange technical staff and other personnel including researchers
- Leverage the success and existing capabilities, resources, and infrastructure of these other programs

How should Institutes interact with state and local economic development authorities?

- Engage economic development authorities as a partner of the Institute or network to encourage cooperation and work towards business development. Collaboration can include sharing facilities, guidance, or resources
- Be able to attract funding from state and local economic development authorities
- Include state and local economic development authorities in Institute governance through board memberships or create an economic development advisory group to amplify and leverage federal funding

What measures could assess Institutes contributions to long term national security and competitiveness?

- Metrics on domestic manufacturing jobs created and saved
- Number of products and processes derived from the Institute that have been commercialized and purchased by manufacturers
- Ability to continuously innovate to maintain security and competitiveness and lead in keystone technologies

Table 4-1. Strategies for Sustainable Institute Operations Questions and Responses
(Listed by similar responses in decreasing frequency)

- Increase in the manufacturing section of the U.S. balance of trade
- IP developed including the number of patent applications and patents granted

5.0 Education and Workforce Development

5.1 Overview

The availability of qualified workers is essential to the scale-up of new manufacturing technologies. Manufacturing competitiveness in an era of rapid technological and market change requires workers to have advanced skills and the foundational knowledge to quickly obtain new skills. Developing and enhancing the skill set of current, displaced, and new employees will be critical for Institute success.

5.1.1 Workshop Participant Input

Participants at the workshop were asked to provide their individual input on multiple questions for the Education and Workforce Development dialogue. **Table 5-1** shows the summary of the most frequent answers to the questions. Since individual workshop participants provided their own input for each question, the most frequent answers are presented grouped, by similar ideas, and are listed in decreasing frequency.

Table 5-1. Education and Workforce Development Questions and Responses
(Listed by similar responses in decreasing frequency)

How could Institutes support advanced manufacturing workforce development at all educational levels?
• Work with industry, schools, universities, and community colleges to develop programs that encourage involvement in manufacturing including internships, work study, summer work, apprenticeships, fellowships, and co-ops
• Especially engage K-12 students with a focus on Science, Technology, Engineering, and Mathematics (STEM) education support and programs while nurturing interest and introducing materials for manufacturing
• Curriculum development: Incorporate manufacturing into curriculum, develop the curriculum materials for high schools and community colleges, and include science (physics and chemistry), technology, and mathematics. Courses and degree programs should be designed based on an understanding of industry needs

Table 5-1. Education and Workforce Development Questions and Responses
(Listed by similar responses in decreasing frequency)

- Train the current industry workforce, displaced workers, or those returning to the workforce through continuing education. They have more experience and have good work ethic but may not want to return to college. Possibilities include contracts with the government to train existing/incumbent workforce or with companies to train their existing workforce in new technologies
- Engage and partner with all levels of education including K-12, community colleges, technical schools, colleges, and universities, at all degree levels (Associate's, Bachelor's, Master's, Doctoral) Change the perception of manufacturing with youth, students, and parents. It is no longer a "second class job" and parents may value manufacturing but not want their children to work in the field. The modern vision of manufacturing is not your father's manufacturing – it should be made exciting again and become the new popular degree
- Fund scholarship programs at the associate, undergraduate, and graduate levels. These could focus on specific areas with post-graduation employment commitment

How could Institutes ensure that advanced manufacturing workforce development activities address industry needs?

- Ensure that there is representation from industry as well as other key stakeholders in the governance of the Institute, either on a steering group or advisory board
- Engage and ask companies about their needs. The Institute can partner with industries, listen to their needs, and ensure their contribution. Conducting surveys or another method of facilitating continual dialogue can help ensure frequent feedback and input on industry needs and skill and knowledge requirements for the workforce
- Encourage internships at industry partners for both graduates and undergraduates
- Ensure industry is involved in and can provide feedback on the constant assessment of curricula development. A possibility is to have curriculum development committees with academic and industry co-chairs
- Promote industrial networking and received feedback through periodic meetings, workshops, or open houses
- Encourage fellowships, co-ops, work/school/hired programs, executive/professional exchange programs, or students working in research teams at all levels (high school, undergraduate, and graduate) in company funded projects

How could Institutes and the NNMI leverage and complement other education and workforce development programs?

- Offer or sponsor mentoring programs, apprenticeships, fellowships, internships, co-ops, or sponsored research. Internships can be with the Institute or with industry partners

Table 5-1. Education and Workforce Development Questions and Responses
(Listed by similar responses in decreasing frequency)

- Identify existing programs (including federally funded programs such as NSF's Advanced Technology Education program and NIST's Manufacturing Extension Partnerships; research universities doing education, outreach, and workforce development through NSF funding; or others funded by NSF or Department of Labor) and either make them a part of the NNMI or build on their success by using the existing infrastructure and capabilities of these programs
- The Institutes will have more experts and equipment and will be able to provide technical expertise and access to facilities and technologies. Providing facilities can incentivize interest in manufacturing activities
- Offer certification and accreditation programs including certificates for specialties or emerging technologies, to be offered at community colleges or colleges even for people who already have degrees

What measures could assess Institute performance and impact on education and workforce development?

- Employment and hiring rates of the graduates that were connected to the Institute, including the placement of graduates at industry partners, regional Institutes or companies, and within the supply chain. This could be quantified as a percentage or by the number of doctorates, interns, co-ops, or apprentices that obtained jobs after graduation
- Graduation statistics and rates for graduates that are entering the industry workforce and the number of students (including K-12, community college, graduate, and undergraduate levels) that are pursuing a manufacturing career
- A measure of people involved in Institute training including course enrollment numbers, the number credentials or certificates awarded, and the number of courses completed
- Industry feedback through surveys to determine the effectiveness of the Institute's education and workforce development to ensure that the industry is satisfied with their employees and able to find sufficiently skilled workers and to determine current and future workforce needs
- Number of domestic jobs created
- Number of students (including K-12) engaged and involved in Institute programs and exposed to advanced manufacturing concepts

How might Institutes integrate research and development activities and education to best prepare the current and future workforce?

- Involve students from all levels (K-12, STEM, community college students, undergraduates, and graduates) in industrially driven R&D programs that include teamwork. Also include R&D as part of certificate and degree programs by having participants do laboratory or project work using state-of-the-art equipment

Table 5-1. Education and Workforce Development Questions and Responses
(Listed by similar responses in decreasing frequency)

- Foster involvement mainly through internships (that can possibly be government funded) as well as thesis research, work study programs, co-op education programs, mentorships, and apprentice programs in applied R&D
- Include industry to help set R&D priorities and needs to ensure that students are solving real, relevant issues and thus provide well defined projects
- Provide hands-on activities in scaled and relevant manufacturing demonstrations, pilots, and research for students and participants in workforce development programs to provide experience and foster excitement

Appendix A. Participants

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Appendix B. Acronyms/ Abbreviations

AMNPO	Advanced Manufacturing National Program Office
IMI	Institute for Manufacturing Innovation
IP	Intellectual Property
NIST	National Institute of Standards and Technology
NNMI	National Network for Manufacturing Innovation
NSF	National Science Foundation
R&D	Research and Development
RFI	Request for Information
SMEs	Small and Medium Sized Enterprises
STEM	Science, Technology, Engineering, and Mathematics
TRL	Technology Readiness Level