NATIONAL NETWORK FOR MANUFACTURING INNOVATION: A PRELIMINARY DESIGN

Executive Office of the President
National Science and Technology Council
Advanced Manufacturing National Program Office

JANUARY 2013

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About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is establishing clear national goals for Federal science and technology investments. The NSTC prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organized under five committees: Environment, Natural Resources and Sustainability; Homeland and National Security; Science, Technology, Engineering, and Math (STEM) Education; Science; and Technology. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology. More information is available at http://www.whitehouse.gov/ostp/nstc.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on questions in which science and technology are important elements; articulating the President's science and technology policy and programs; and fostering strong partnerships among Federal, state, and local governments, and the scientific communities in industry and academia. The Director of OSTP also serves as Assistant to the President for Science and Technology and manages the NSTC. More information is available at http://www.whitehouse.gov/ostp.

About the Advanced Manufacturing National Program Office

Hosted by the Department of Commerce, National Institute of Standards and Technology (NIST), the AMNPO is an interagency team with participation from all Federal agencies involved in U.S. manufacturing. Principal participant agencies currently include the Departments of Commerce, Defense, Education, and Energy, the National Aeronautics and Space Administration, and the National Science Foundation. The AMNPO reports to the Executive Office of the President and operates under the National Science and Technology Council.

As recommended in PCAST's advanced manufacturing report, the interagency office will enable more effective collaboration in identifying and addressing challenges and opportunities that span technology areas and cut across agency missions. In addition, the office will link Federal efforts to the growing number of private-sector partnerships between manufacturers, universities, State and local governments, and other organizations.

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EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

January 10, 2013

Dear Colleague:

For more than a century, U.S. manufacturing has been a cornerstone of American prosperity. Today, more than ever, it is essential that the Nation continues its leadership in manufacturing—to sustain the foundations of the Nation's economic prosperity and national security and to meet new challenges in the domains of energy, transportation, health care, and education. That is one reason President Obama has set scientific and technological innovation—and support for the basic research that fuels such innovation—as central priorities of his Administration.

In furtherance of these goals, this report describes the Administration's proposed National Network for Manufacturing Innovation (NNMI)—an initiative to accelerate U.S. advanced manufacturing by catalyzing the development of new technologies, educational competencies, production processes, and products via shared contributions from the public and private sectors and academia. The NNMI will consist of linked Institutes for Manufacturing Innovation (IMIs), designed to serve as regional hubs of world-leading technologies and services. IMIs will provide shared facilities to local start-ups and small manufacturers to help them scale up new technologies, accelerate technology transfer to the marketplace, and facilitate the adoption of innovative developments across supply chains. And they will act as 'teaching factories' to build workforce skills at multiple levels and to strengthen business capabilities in large and small companies.

To validate this concept, and in response to a Federal call for proposals, a public-private consortium launched a pilot IMI on Additive Manufacturing technologies in late 2012. Today that National Additive Manufacturing Innovation Institute is operating with the participation of more than 85 companies, 13 research universities, 9 community colleges, and 18 non-profit and professional associations. This report reflects lessons learned from that pilot institute as well as inputs from regional workshops and a public Request for Information.

The NNMI, which is anticipated to eventually encompass up to 15 IMIs addressing a variety of technical areas critical to U.S. global leadership, directly supports the findings of the President's Council of Advisors on Science and Technology, which has called for such a network in order to ensure a vibrant and viable American manufacturing sector for decades to come.

I look forward to working with Federal agencies, Congress, and the private and academic sectors to ensure implementation of the NNMI.

Sincerely,

John P. Holdren

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

National Network for Manufacturing Innovation: A Preliminary Design

Executive Summary

The Federal investment in the National Network for Manufacturing Innovation (NNMI) serves to create an effective manufacturing research infrastructure for U.S. industry and academia to solve industry-relevant problems. The NNMI will consist of linked Institutes for Manufacturing Innovation (IMIs) with common goals, but unique concentrations. In an IMI, industry, academia, and government partners leverage existing resources, collaborate, and co-invest to nurture manufacturing innovation and accelerate commercialization.

As sustainable manufacturing innovation hubs, IMIs will create, showcase, and deploy new capabilities, new products, and new processes that can impact commercial production. They will build workforce skills at all levels and enhance manufacturing capabilities in companies large and small. Institutes will draw together the best talents and capabilities from all the partners to build the proving grounds where innovations flourish and to help advance American domestic manufacturing.

Recognizing that a vibrant advanced manufacturing sector is vital to the American economy and national security, President Obama has proposed a $1 billion investment in a National Network for Manufacturing Innovation program. The NNMI program has the goal of advancing American domestic manufacturing. This program will seek to accomplish this by creating a robust national innovation ecosystem anchored by up to fifteen Institutes for Manufacturing Innovation. The Administration is committed to working with Congress to authorize and fully fund the President's request for the NNMI program. This report and the proposed program design included herein aims to support Congressional authorization and provide a guide for future program implementation.

The NNMI will fill a gap in the innovation infrastructure, allowing new manufacturing processes and technologies to progress more smoothly from basic research to implementation in manufacturing. The NNMI program has a scale and focus that is unique, and it is built upon concepts of a strong public-private partnership.

Because the challenges associated with manufacturing are multi-faceted, within the NNMI model, each IMI will have its own distinct manufacturing topic or technology focus, determined through a competitive proposal and review process managed by the AMNPO partners. This process will identify the highest value cross-cutting manufacturing challenges and opportunities, and proposals will bring together manufacturing stakeholders including government, industry, and academia. Stakeholders will consist of industry, academia (research universities and community colleges), relevant organizations (industry consortia, economic development organizations, labor organizations, national laboratories, etc.), and government bodies at all levels (Federal, State, and local). In their individual focus areas, institutes will act to anchor a region's innovation infrastructure, and will conduct research and demonstration projects.

IMIs will offer facilities comprising an "industrial commons" (the R&D, engineering, and manufacturing capabilities needed to turn inventions into competitive, manufacturable commercial products) to accelerate the formation and growth of small- and medium-sized enterprises (SMEs), and will integrate education and workforce training functions into their operations. IMIs will engage with many types of corporations, with particular emphasis on engaging small and medium-sized manufacturing enterprises. They will provide shared-use facilities with the goal of scaling up laboratory demonstrations and maturing technologies for manufacture. American companies and international corporations with significant holdings in the United States are envisioned as participants in these Institutes.

Institutes will be a partnership between government, industry, and academia, supported with cost-share funding from Federal and non-Federal sources. It is expected that institutes will typically receive $70-120 million in total Federal funds, depending upon the magnitude of the opportunity, maturity, and capital intensity of the technology, and scope of the focus area, over a 5-7 year timeframe. When combined with substantial non-Federal co-investment, for example 1:1, it is envisioned the total capitalization of an institute over this period will be $140 to $240 million. At greater ratios of non-Federal co-investment, an institute could achieve its goals with a lower level of Federal funding. Institutes will be expected to be sustainable within seven years of launch through income-generating activities including member fees, intellectual property licenses, contract research, and fee-for-service activities as examples. The proposed design is of a size and scale intended to provide long-term economic impact in the region and nationally.

IMIs are to be led by independent, not-for-profit institutions that strongly leverage industry consortia, regional clusters, and other resources in science, technology, and economic development. Institutes are intended to link and leverage all available resources, including institutions funded through existing Federal programs, so that they have national and global impact.

Institutes will be established through a competitive solicitation and evaluation process managed by the interagency Advanced Manufacturing National Program Office (AMNPO). Current participating agencies include the Departments of Commerce (DOC/NIST), Defense (DOD), Education (ED), and Energy (DOE); the National Aeronautics and Space Administration (NASA); and the National Science Foundation (NSF). Competitive solicitations will be sought and proposals will be peer-reviewed. Expected evaluation criteria include Institute focus and its importance for the American economy; the Institute plan to have significant production-scale manufacturing impact in its area of specialization from a research, commercialization, and workforce training standpoint; the effectiveness of the governance and management structures; the proposed Institute resources; the level of co-investment; engagement with SMEs and other community stakeholders; and the strength of the plan towards sustainability.

Leadership from the Institutes will formally collaborate through a Network Leadership Council made up of representatives from the Institutes, Federal agencies, and other entities as appropriate. The Leadership Council will oversee efforts to develop consistent and common approaches for matters such as intellectual property, contracts, research and performance metrics, and facilitating the sharing of best practices. Each Institute will also participate in the AMNPO-hosted Manufacturing Portal, a web-based resource to help manufacturers locate relevant research, research partners, and pertinent information within the Network. Each Institute's research and commercialization outcomes will be available to other IMI's as appropriate, through technology and knowledge transfer efforts.

Beginning in April 2012, a broad public engagement strategy by the Advanced Manufacturing National Program Office was used to "crowd source" the NNMI program design initiated by a Federally sponsored Request for Information (RFI) and series of regional workshops. In parallel, a pilot institute on additive manufacturing, the National Additive Manufacturing Innovation Institute (NAMII), was announced in August 2012 to move the IMI concept forward and to refine an architecture supporting the formation of the larger Institutes and Network. The RFI period has ended, and combined with the lessons learned from NAMII and rich discussions from the regional workshops, the proposed design for the NNMI is described in this report.

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1.0 Overview

Manufacturing plays a critical role in the American economy, underpins U.S. innovation, and is essential to national security. The health and performance of the U.S. manufacturing sector has become a topic of national interest and concern. In 2011, 11 of 19 major U.S. manufacturing industries produced less than they did in 2000 [1]. Over this same decade, more than 65,000 manufacturing establishments—nearly one in six—ceased operation [2], the United States share of global exports of advanced technology products fell from 21 percent to 15 percent [3], and the sector eliminated more than 5 million jobs.

The fundamental contributions of manufacturing to economic prosperity are evident from national and international perspectives. The U.S. manufacturing sector continues to be a mainstay of our economic productivity, generating $1.8 trillion in GDP in 2011 (12.2% of total U.S. GDP). Manufacturing firms lead the nation in exports: The $1.3 trillion of manufactured goods shipped abroad constituted 86% of all U.S. goods exported in 2011. Moreover, manufacturing has a larger multiplier effect than any other major economic activity—$1 spent in manufacturing generates $1.35 in additional economic activity [4].

Manufacturing's underpinning role also is corroborated in international studies. For example, according to the World Economic Forum, over 70 percent of the income variations of 128 nations are explained by differences in manufacturing product export [5].

U.S. manufacturing has begun to rebound from the recession of 2008 – 2010. The sector has recovered more than 500,000 jobs since January 2010 and the number of job openings for skilled factory workers has increased significantly. Still, the sector faces formidable challenges from a growing number of increasingly capable international competitors. Even as foreign nations and companies position themselves for advantage in markets for high-value-added products, the nature of manufacturing itself is undergoing transformative changes. The United States response to these challenges and changes will have significant impact on the Nation's future prosperity and its ability to meet future challenges in areas as diverse as defense, energy independence, transportation, and public health.

Numerous factors—private and public—shape the competitiveness and innovation performance of U.S. manufacturing, as documented in a stream of recent reports [6-17]. Common weaknesses identified in many of these studies might be labeled as "missed opportunities" or failures to reap the full economic and commercial value from public investments in research. There are many examples where materials and product technologies were innovated in the United States, but most of the significant commercial market share they enabled was lost to other countries. They include rechargeable lithium-ion batteries, oxide ceramics, semiconductor memory devices, manufacturing equipment such as wafer steppers, flat panel displays, robotics, solar cells, and advanced lighting.

As summed up by the National Science and Technology Council, "A gap exists between R&D activities and the deployment of technological innovations in domestic production of goods," contributing significantly, for example, to the growing trade deficit in high-value-added, advanced technology products [8].

Other nations and their manufacturing industries are investing and mobilizing resources to strengthen their manufacturing performance. Germany, Korea, and Japan each have more R&D-intensive manufacturing efforts than the United States [7]. These and other nations have established government-industry-academia partnerships to spur industrial innovation [8].

Similar large-scale public-private partnerships in the United States could accelerate the development of innovation infrastructure and strengthen the Nation's position in the global competition for new products, new markets, and new jobs. Although the United States has many elements of an innovation ecosystem, the assortment of joint centers, incubators, demonstration facilities, economic development partnerships, and other assets with innovation-related objectives tends to be fragmented and does not support an overarching U.S. manufacturing strategy.

Historically and even today, the United States has excelled at basic science and invention. But the commercial and economic rewards that can sprout and grow from these important early-stage accomplishments are realized in the stages following initial discovery—especially at the points of manufacturing scale-up and commercialization. This is especially true for complex, cost-efficient, high-value-added products that require development and mastery of equally complex manufacturing processes before successful commercialization can be achieved.

To strengthen U.S. innovation and manufacturing capacity and reverse the trend in which more research, production and design facilities, and supporting functions are sited overseas requires a robust innovation policy, as outlined in the Administration's *A National Strategic Plan for Advanced Manufacturing* [8]. A key component of this innovation policy is the creation of public-private partnerships to accelerate investment in and deployment of advanced manufacturing technologies, which the Steering Committee of the Advanced Manufacturing Partnership, composed of U.S. industry and university leaders, has recommended [7].

President Obama has proposed a $1 billion investment in a National Network for Manufacturing Innovation to advance American domestic manufacturing by addressing this gap [18]. This Federal investment will be managed collectively by several Federal agencies coordinated through the Advanced Manufacturing National Program Office (AMNPO).*

The NNMI program is designed to bring together industry; universities (including community colleges); and local, State and Federal governments to spur manufacturing innovation and translate it into American jobs. Up to 15 Institutes for Manufacturing Innovation will be formed.

Through long-term partnerships, the Institutes will be able to maintain a sustained focus on manufacturing technology innovation, workforce development, the transfer of promising new processes and

* AMNPO member agencies include the Department of Commerce and its National Institute of Standards and Technology (NIST), Department of Defense, Department of Education, Department of Energy's Advanced Manufacturing Office, NASA, and the National Science Foundation. NIST hosts the AMNPO.

technologies to the manufacturing sector, and the support of small- and medium-sized enterprises and aspiring start-ups for developing advanced manufacturing know-how and capabilities.

A key feature of the network and its individual IMIs is a strong focus on building clusters of advanced manufacturing capabilities that join expertise from industry, academia, and government. The NNMI will leverage existing resources with the aim of capturing the economic value of U.S. research and early-stage innovation. It will close the gap now separating American inventions, research discoveries, and ideas from the development and scale-up of domestic manufacturing capabilities necessary to make—and sell—products based on those U.S. innovations.

Emphasis will be on linking and integrating existing public and private resources into a robust national innovation ecosystem anchored by regional nodes of advanced manufacturing capabilities, where the processes to build next-generation products will be developed, demonstrated, and refined to the point where there is a clearer, lower-risk path to commercial-scale manufacturing. Institutes will facilitate and accelerate the applied and commercial development of basic research results—the outputs of work supported, for example, by the National Science Foundation or the Department of Energy's Office of Science. At IMIs, these promising "seeds" of future technologies will undergo further development and refinement into manufacturing-relevant processes and approaches for next-generation, commercially feasible products and applications that are made in the United States. IMIs are furthermore intended to produce benefits across agency boundaries that broadly support the competitiveness of U.S. manufacturers.

A benchmark for the NNMI institutes is the pilot institute on additive manufacturing, the National Additive Manufacturing Innovation Institute (NAMII). Launched in August 2012, NAMII is centered in Youngstown, Ohio. NAMII is composed of a broad coalition of more than 80 companies, nine research universities, six community colleges and 18 not-for-profit institutions. While it differs from the proposed NNMI and its Institutes (a single topic was selected *a priori*, and funding was based on existing programs from a number of agencies), NAMII demonstrates a number of IMI attributes. Significantly, industry and regional interests acted together to leverage the Federal investment of $30 million with a combined co-investment of $39 million.

The proposed NNMI has been designed using a broad public engagement strategy, and it builds on a review of best practices used to establish the pilot institute. Public engagement was pursued through a series of workshops held nationwide as well as through comments received by the AMNPO's Request for Information, published on May 4, 2012.

The focus of each Institute will be proposed by the applicants and selected through a competitive application process. As parts of a network, each IMI will: communicate best practices and coordinate efforts with other IMI's; coordinate approaches on issues such as intellectual property treatment, contract research, and performance metrics; be led by independent, not-for-profit institutions that coordinate industry partners both locally and nationwide, including SMEs; focus upon workforce development with its industry and academic partners at the university and community college levels to impact the engineering and technical workforce; and join in the governance and activities of an NNMI-wide Network Leadership Council. The President's proposal calls for a one-time $1 billion investment over a 5-7 year period, after which each IMI should be a sustainable center of excellence.

2.0 The National Network for Manufacturing Innovation Vision

Funded by a proposed one-time, $1 billion investment, the NNMI responds to a crucial competitiveness challenge with a vision of closing the gap between research and development (R&D) activities and the deployment of technological innovations in the domestic production of goods.

The proposal implements recommendations made by the President's Council of Advisors on Science and Technology (PCAST) and a wide range of other experts and organizations. It recognizes that investing in early stage research isn't enough to ensure that a new technology progresses smoothly from invention to product development to manufacturing at scale in the United States.

The IMIs will bring together industry, universities and community colleges, Federal agencies, States, and localities to accelerate manufacturing innovation and scale up by investing in industrially-relevant, cross-cutting product and process technologies. These stakeholders will co-invest with the Federal Government in each IMI, forming a strong partnership between industrial and other stakeholders to catalyze a renaissance in advanced manufacturing activity.

IMI activities may include, but are not limited to: applied research and demonstration projects that reduce the cost and risk of commercializing and manufacturing new technologies or that solve generic manufacturing problems; education and training at all levels; development of innovative methodologies and practices for enhancing the capabilities of and integrating supply chains; and engagement with small and medium-sized manufacturing enterprises (SMEs).

The President's proposed NNMI and the regional collaborations it catalyzes are designed to address barriers to rapid and efficient development and commercialization of new advanced manufacturing-process innovations, thus strengthening existing or building new innovation ecosystems in advanced manufacturing. The network and its individual IMIs will help companies to collaborate and access the capabilities of research universities and other science and technology organizations to support efforts aimed at developing and scaling up manufacturing and assembly processes. At the same time, the IMIs will help to meet the challenge of building at all levels the pool of high-skilled talent that advanced manufacturing innovation and production requires. The number of proposed IMIs, envisioned to be up to 15 institutes, will be scaled in order to provide sufficient resources for achieving regional and national impacts in advanced-manufacturing performance.

The NNMI has two fundamental components: the individual institutes and the coordinating network, as described below.

3.0 Characteristics of the Institutes for Manufacturing Innovation

The Federal investment in the National Network for Manufacturing Innovation (NNMI) serves to create an effective manufacturing research infrastructure for U.S. industry and academia to solve industry-relevant problems. The NNMI will consist of linked Institutes for Manufacturing Innovation (IMIs) with common goals, but unique concentrations. In an IMI, industry, academia, and government partners leverage existing resources, collaborate, and co-invest to nurture manufacturing innovation and accelerate commercialization.

As sustainable manufacturing innovation hubs, IMIs will create, showcase, and deploy new capabilities, new products, and new processes that can impact commercial production. They will build workforce skills at all levels and enhance manufacturing capabilities in companies large and small. Institutes will draw together the best talents and capabilities from all the partners to build the proving grounds where innovations flourish and to help advance American domestic manufacturing.

Broad public input was received regarding the desirable characteristics of IMIs and the Network as a whole through the four public "Designing for Impact" workshops held in Troy, New York; Cleveland, Ohio; Irvine, California; and Boulder, Colorado. In addition, substantial input was received through the RFI responses collected by the AMNPO. Detailed information about the participants in the workshops and respondents to the RFI may be found in Appendix A. In total, comments from nearly 900 stakeholders have contributed to the design of the Institutes and Network. AMNPO has reviewed and distilled all of this input for incorporation into this document.

IMIs will be long-term partnerships between industry and academia (including universities and community colleges) enabled by Federal, State, and local governments. In order to advance American domestic manufacturing, they will have a sustained focus on manufacturing technology innovation with a strong brand identity and reputation. They will identify critical manufacturing processes and technologies with potential transformational impact, and through their member companies, they will have the capacity to translate these technologies into market-relevant private-sector manufacturing production. IMIs will facilitate the formation of effective teams of industrial and academic experts from multiple disciplines to solve difficult problems, from pre-competitive industrially relevant research to proprietary technology development for product manufacturing. Through dual appointment of faculty and students in both research universities and Institutes, they will develop leaders familiar with research applications, new technologies, and production systems. They will engage and assist SMEs in applying and adapting new process technologies by providing technical assistance, highly trained personnel, and access to shared equipment and infrastructure. IMIs will provide education and training opportunities to build and enhance the skills of the manufacturing workforce.

3.1 Overall IMI Focus

The focus of each Institute will be on integrating capabilities through collaborations at facilities designed and equipped to further efforts addressing cross-cutting manufacturing challenges, yielding solutions that have the potential to retain or expand industrial production in the United States.

3.1.1 Defining Focus Areas

Each Institute will have a unique and well-defined focus area, such as a manufacturing process, an enabling technology, manufacturing processes for new advanced materials, or an industry sector (see Section 3.1.2). There was broad consensus among the workshop participants and RFI respondents that the emergent focus areas should be defined by the proposing teams. The proposing teams will be driven by the needs of industry, the opportunities created by new technologies, and the programmatic needs of the AMNPO partners. Many respondents cautioned against the tendency to pre-select trendy topics that don't serve this essential balance. This concept, strongly supported from public input, is to allow open solicitations with clear selection criteria rather than government-selected topics. Good ideas come from unexpected places. The government view is included as the agencies will make the selections.

The focus area for each Institute will be defined by the proposing team, and the AMNPO partners will evaluate the efficacy of the proposal in meeting a national need as part of an overall portfolio. Proposing teams will need to demonstrate that their focus area is appropriate for an Institute, including the potential to deliver regional and national improvements in advanced-manufacturing capabilities, and to meet national needs. IMIs will provide a comprehensive and detailed plan to accomplish institute objectives and impacts. Each Institute should leverage existing regional or national innovation ecosystems or catalyze the formation and sustainability of new innovation clusters. Each Institute will have a specific physical location or locations and a clear lead organization, rather than existing as a "virtual" or distributed organization. At the same time, the Institute will collaborate with organizations in any location that have relevant, complementary expertise. It is expected that Institutes will take advantage of technology clusters, and will draw talent and resources from across the nation and around the world to their site.

3.1.2 Illustrative Focus Areas

For the purpose of illustration only, the following are examples for each of the categories of Institute focus areas:

1. **Manufacturing Process:** Refining standards, materials, and equipment for additive manufacturing to enable low-cost, low-volume production using digital designs that can be transmitted from designers located anywhere. This focus area was selected for the pilot National Additive Manufacturing Innovation Institute, which uses existing resources and authorities. Alternate examples include advanced joining or polymer processing methods.
2. **Advanced Materials:** Developing lower-cost production methods for lightweight materials, such as low-cost carbon fiber composites, for applications that will improve fuel efficiency, performance, and corrosion resistance of the next generation of automobiles, aircraft, ships, and trains. Alternate examples include novel materials development for improved manufacturability at scale in solar power or next-generation integrated circuits.
3. **Enabling Technology:** Creating a smart-manufacturing infrastructure and approaches that integrate low-cost sensors into manufacturing processes, enabling operators to make real-time use of "big data" flows from fully instrumented plants in order to improve productivity, optimize supply chains, reduce costs, and reduce energy, water, and materials consumption.
4. **Industry Sector:** Improving medical device or biomaterials manufacturing processes to enhance safety, quality, and consistency of pharmaceuticals, chemicals, or other products by enabling rapid on-line sensing and analytical capabilities, and creating new tools for bioprocess optimization and control to enable cost-effective production methods. Other examples are development of next-generation automotive or aerospace manufacturing process technologies.

3.2 IMI Activities

According to the National Science Foundation [19], approximately 17.4 percent of total public and private R&D spending in the United States supported basic research, 22.3 percent supported applied research, and 60.3 percent supported development in 2008. Within these categories the Federal Government continues to be the nation's (and the world's) largest funder of basic, knowledge-driven R&D. Approximately 21 percent of Federal R&D supports basic research, while 22 percent supports applied research [20]. While U.S. industry accounts for almost two-thirds of all U.S. R&D funding, about 90 percent of the industry investment supports applied research and technology demonstration efforts with low levels of technical and commercial risks and short payback periods [7]. The NNMI proposal is aimed at strengthening support for R&D that lies between the 'discover/invent' beginnings of innovation and the 'manufacturing innovation/scale up' stages that precede commercialization. The Institutes, therefore, will focus on Technology Readiness Levels 4-7, defined in Table 1, which include component validation in a relevant environment, system model or prototype demonstration in a relevant environment, system prototype demonstration in an operational environment, and actual system completion and qualification through test and demonstration. The NNMI will launch a government-industry-academia partnership that galvanizes the resources of all stakeholders to achieve the critical mass of efforts needed to effectively address these stages of manufacturing innovation.

IMI activities will include, but are not limited to:

1. Applied research, development, and demonstration projects that reduce the cost and risk of developing and implementing new technologies in advanced manufacturing. An Institute's research activities will be driven by the need to mature the demonstration of component technologies in a laboratory environment toward the demonstration of a system in a representative production environment.

2. Education and training at all levels. An Institute will assess skills and certifications needed and provide educational opportunities to improve and expand the manufacturing workforce, including K-12 programs, internship opportunities, skills certification, community college engagement, university collaboration, graduate students, post-doctoral students, and retraining to meet the requirements set forth by an Institute's mission in order to impact both the technical and degreed engineering workforce.

3. Development of innovative methodologies and practices for increasing the capabilities and capacity of supply chain expansion and integration. Deployment of these will be facilitated through the Institute and its strategic partnerships and efforts to impact the larger industrial complex.

4. Engagement with SMEs. Small and medium-sized enterprises are a vital part of the manufacturing sector; SMEs in highly effective supply chains for technology-intensive manufacturing sectors have the potential to accelerate efforts to enhance U.S. competitiveness in advanced manufacturing overall. These SMEs tend to be early adopters of transformational technology, and they are well-positioned to innovate and produce jobs. This makes their involvement in Institutes essential for maximizing industry and economic impacts. However, SMEs usually invest less in R&D than larger or more established firms. Strategies to encourage the participation of SMEs in Institutes include engaging outreach partners and intermediaries that work closely with SMEs, providing valued information and services tailored to address SME needs, providing a tiered membership fee structure, allowance of all in-kind contributions for new member SMEs, the use of contract-based activities, staged licensing of IP, and similar arrangements.

5. Shared facility infrastructure. Institutes will provide shared facilities to local industry, especially SMEs and startups, with the goal of scaling up laboratory demonstrations and making technologies ready for manufacture. Each IMI will integrate capabilities and facilities required to reduce the cost and risk of commercializing new technologies and to address relevant manufacturing challenges on a production-level scale.

Table 1. Technology Readiness Levels and Manufacturing Readiness Levels, after [21]

	TRL 1:	Basic principles observed and reported	MRL 1:	Manufacturing feasibility assessed
	TRL 2:	Technology concept and/or application formulated	MRL 2:	Manufacturing concepts defined
	TRL 3:	Analytical and experimental critical function and/or characteristic proof of concept	MRL 3:	Manufacturing concepts developed
NNMI Target	TRL 4:	Component and/or breadboard validation in a laboratory environment	MRL 4:	Capability to produce the technology in a laboratory environment
NNMI Target	TRL 5:	Component or breadboard validation in a relevant environment	MRL 5:	Capability to produce prototype components in a production relevant environment
NNMI Target	TRL 6:	System/subsystem model or prototype demonstration in a relevant environment	MRL 6:	Capability to produce prototype system or subsystem in a production relevant environment
NNMI Target	TRL 7:	System prototype demonstration in an operational environment	MRL 7:	Capability to produce systems, subsystems or components in a production relevant environment
	TRL 8:	Actual system completed and qualified through test and demonstrated	MRL 8:	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production
	TRL 9:	Actual system proven through successful mission operations	MRL 9:	Low rate production demonstrated; Capability in place to begin Full Rate Production

3.3 IMI Funding, Revenue, and Sustainability

Each Institute should be of sufficient size and scope to have major national and regional economic impacts and to address the multidimensional challenges associated with the Institute's focus area. The amount of Federal funding should be appropriate to the Institute proposed. Federal funding to launch a typical Institute is expected to range from $70-$120 million over a 5-7 year timeframe. With greater than 1:1 non-Federal co-investment, an institute could achieve its goals with a lower level of Federal funding. In addition, each Institute should build into its operations model the ability to develop and leverage diverse revenue streams throughout its life. Federal funding is expected to be initially larger when an Institute is established and to diminish after the initial 2-3 years so that most of the Institute's funds are provided by private and other funding sources as time progresses.

Each Institute should have a plan to be self-sustaining, based on diverse funding sources beginning at Institute formation, and be fully independent of NNMI Federal funds 5-7 years after launch. Institutes will have the flexibility to pursue sustainable Institute revenue from a variety of sources including: member fees, fee-for-service activities, contract research or pre-production scale-up, non-NNMI grants and awards from Federal and other sources, intellectual property royalties, endowments, etc. The Board of Directors for each Institute will develop, within constraints specified by the Institute award, policies and procedures for its operation and for its revenue-generating mechanisms. Institute facilities and work products should be made available on appropriate and reasonable terms to a broad base of industrial users. The evolution of Institute facilities and work activities over time should also be informed by a broad base of industrial partners and other stakeholders.

To encourage the transition to sustainability, a portion of the Federal funds used for Institute projects will be awarded competitively among the Institutes. Competitive Project Award decisions will be made in part based on technical quality, but additionally based on prior Institute performance and the strength of industrial participation. This is described further in Section 3.7.

During the period of NNMI Federal funding, each Institute should demonstrate significant co-investment support from non-Federal sources. The non-Federal co-investment must be tangible, meaningful, and in the aggregate, substantial enough to signal strong and committed industry, regional, and local partnership. The co-investment requirement is expected to be met with both cash and in-kind contributions. In-kind and cash contributions may arise from any source, but are only counted as co-investment if they come from non-Federal sources and directly support the function of the Institute. The funds may come from the Institute (for example, using revenue from the licensing of intellectual property); the members of the Institute; State, regional, and local sources (such as economic development agencies); private donations; or other non-Federal sources. The value of in-kind contributions should be determined in accordance with OMB Circular A-110, Subpart C, Section 23.

3.4 IMI Partners and Members

The acceleration of innovation for advanced manufacturing in order to advance American domestic manufacturing requires bridging a number of gaps in the present U.S. innovation system. Each Institute will be based upon concepts of open innovation and partnerships.

Institutes should be led by an independent, U.S. not-for-profit institution with the capacity to lead an industry-wide technology, workforce development, and infrastructure agenda. Although other lead organizations (such as universities) are not prohibited, many workshop participants and RFI respondents expressed concern about the treatment of intellectual property, confidentiality, tax-exempt status, and timely responses if universities were allowed to lead Institutes. Partners in the Institute should include the full range of national, State, and local stakeholders. This includes manufacturing enterprises of all sizes including startups. In addition, a diverse set of institutions of higher education including both research universities and community colleges should be included. Other partners may include research organizations (including Federally Funded Research and Development Centers, subject to statutory or regulatory restrictions); national laboratories or government agencies (subject to funding restrictions); career and technical institutions; State, regional, and local public and private entities that support industrial clusters and associated economic development partnerships; unions; professional and industry associations; other not-for-profit organizations; and the general public. To help ensure a broad impact, Institutes should openly encourage the addition of new partners and participants wherever relevant through well-defined mechanisms.

To effectively leverage existing national capabilities and centers of excellence, Institutes are envisioned to be hubs that link the national and international resources that exist within the area of focus of the Institute. To this end, Institutes should seek to benefit and leverage the various centers and research institutions funded through existing Federal programs, such as the NSF Engineering Research Centers

(ERC) and Industry/University Cooperative Research Centers (I/UCRC) programs. These programs focus teams of faculty and students on research that provides opportunities to advance technology for their member firms through formalized partnerships with industry. The ERCs have education programs that create pathways to engineering for pre-college students. These programs also support pre-college teachers to learn engineering concepts at the centers and develop course materials to bring engineering to pre-college classrooms.

Participation in an Institute by a non-domestic organization will be allowed only when in the economic interest of the United States. This would be demonstrated by that organization's investments in the United States in research, development, and manufacturing; significant contributions to employment in the United States; and commitment that any technology arising from or assisted by the Institute be used to promote domestic manufacturing activities. Participation restrictions for non-domestic organizations may exist in some circumstances.

3.5 Engagement of IMIs with Small and Medium-sized Enterprises

A major goal of the NNMI is to support the creation, growth, and expansion of domestic SMEs, and to that end, each Institute will demonstrate meaningful outreach to and engagement with SMEs. Each Institute is expected to engage existing intermediaries, centers, and networks that work with and address the needs of SMEs, to the benefit and success of the Institute's advanced manufacturing agenda. Specific examples of organizations that, through integration with the Institute, would strengthen and expand involvement of SMEs include the NIST Hollings Manufacturing Extension Partnership (MEP) network and State and regional technology-based economic development programs. Institutes will also be encouraged, to the extent appropriate, to seek out successful SBIR awardees to support their alignment with supply chains and explore opportunities for evolutionary demonstration of SBIR technologies within the Institute's focus area.

Many SMEs experience common challenges that hamper their performance. They face problems with lagging productivity and business practices, missed opportunities in emerging technologies, unrealized growth potential, and leadership and succession issues. They report significant challenges in ongoing continuous improvement, identifying growth opportunities, and product innovation/development for manufacturability. As significant sources of innovation in highly sophisticated supply chains, they face increasing demands from their original equipment manufacturer (OEM) customers for improved performance, quality, consistency, and continued innovation.

An IMI may help SMEs address challenges in a myriad of ways. IMIs can provide information about technology trends and access to cutting edge technologies that assist with process innovations and development. They can provide shared facilities and access to specialized equipment that can accelerate product design, prototyping, and testing. IMIs can provide technical advice and assistance to SMEs that do not have specialized expertise on staff. An IMI should also facilitate the creation of new, start-up companies to commercialize research and development results.

SMEs interested in a broad range of services and an ongoing relationship might participate in a tiered membership structure that would minimize barriers to entry and encourage the membership of SMEs in the Institute.

3.6 IMI Governance

Each Institute should have substantial autonomy from its partner organizations and institutions and should have an independent fiduciary Board of Directors predominantly composed of industry representatives. An Institute leader such as an Executive Director should be in charge of day-to-day operations. The three key stakeholders of NNMI (industry, academia, and government) will need to have their interests preserved in a joint governance model.

Each proposal will outline the methods by which decisions will be made, including those decisions related to operations, membership, intellectual property, capital investments, project selection, funding allocation, and progress toward sustainability. Draft Institute membership and governance agreements should be included within proposals.

3.7 IMI Selection Process

The IMI selection process will be managed by the interagency AMNPO. Participating Federal agencies currently include DOC/NIST, DOD, DOE, ED, NASA, and NSF. The inter-agency AMNPO team will be responsible for managing an open, competitive selection process and for executing the award process.

Solicitations for Institute proposals may be staged, and the design and number of solicitations will depend on the availability and timing of funds. Proposals received in response to the solicitation(s) will be evaluated competitively by a review team.

The review team will include members of the AMNPO, agency partners, and other experts. The merit-based selection process may include pre-proposals, site visits, and economic and business plan analyses. Support for proposals may be offered by the AMNPO through planning and/or road mapping grants and workshops. This broad, deliberative review process can best balance the most essential U.S. industrial needs and promising opportunities and support the goals of enhancing American industrial competitiveness on regional, national and global bases.

Detailed selection criteria will be contained in the IMI solicitation(s). It is expected that criteria will include:

1. The focus on a critical national need or opportunity for U.S. manufacturing
2. Proposed activities targeting the transition of early stage manufacturing research and technology to commercial application or product
3. The proposed Institute plan to achieve significant impact in manufacturing technology development and scale up to commercialization, anticipating widespread adoption and links to job creation and broad economic impacts
4. The proposed Institute resources (personnel, facilities, and participating entities) supporting the plan
5. The level of co-investment from non-Federal entities, and the strength of the plan for sustainability beyond the initial Federal funding
6. The adequacy of the financial plan
7. The level of engagement with SMEs

8. The suitability and anticipated utilization of shared facilities
9. The level of involvement and expertise in education and workforce development
10. The adequacy of the governance and oversight model, including the degree of industry involvement and openness to relevant new participants
11. The ability of the Institute to advance American domestic manufacturing

It is likely that cooperative agreements will be the primary funding mechanism for NNMI Institute awards, although other types of grants and contracts may also be used. Continuing Federal support will be contingent on co-investment by businesses and other non-Federal entities, and on progress toward sustainable operations.

3.8 Disbursement of Federal Funds

A schedule of disbursement of funds will be negotiated for each IMI depending on the nature of the Institute and proposed projects. It is anticipated that for most Institutes, the level of Federal funding will be larger at the start, and will become progressively lower as the Institute becomes self-sufficient, as shown in Figure 1.

Figure 1 Notional Federal funding profile for an IMI

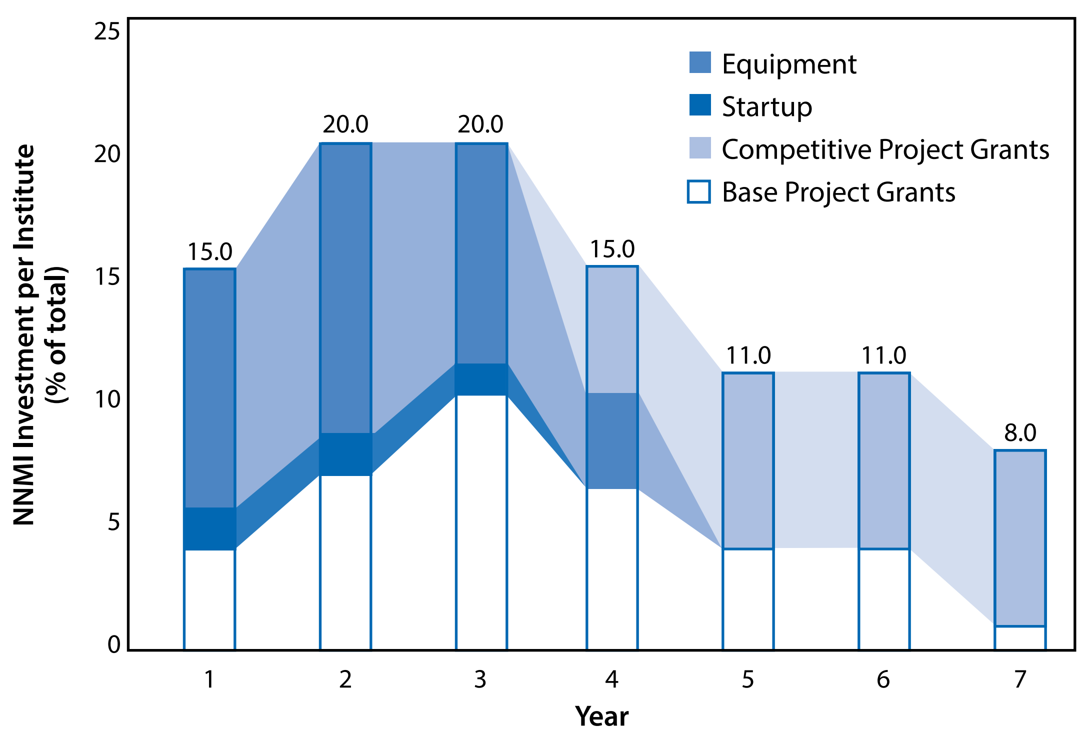


Figure 1 shows the envisioned Federal investment in an exemplar, capital equipment-intensive Institute, and is not a funding profile that will be required of all Institutes. Federal funding is shown during the first year for Equipment, Startup, and an initial slate of Base Projects. As the Institute matures, it begins to absorb more of its own operational costs. During year four, Federal funding of projects begins to depend on the Competitive Project Grants. The pool of funds available for the competitive project grants is approximately 25% of the total funding provided to the Institutes. The competitive project grants will be relatively small in number, totaling 2 or 3 per Institute beginning in year 4, and relatively large in scale, each around $2–3 million. The competitive project grants will encourage increasing partner co-investment as the Institute matures.

Continuation of Federal funding will be contingent on the completion of annual reports, and on the successful completion of a gate review process examining both quantitative and qualitative metrics of performances including: co-investment, membership, facility utilization, project portfolio, success stories, technology commercialization, or other benchmarks that assess Institute performance and impact. It is anticipated that a gate review will occur at least at year three after initial funding.

Not shown in Figure 1 is the co-investment funding provided by non-Federal sources. The non-Federal support is anticipated to be large at the time of award and primarily comprised of in-kind items such as equipment and buildings. Over time, the funding will shift to project, member fees, user fees, licensing and other sources.

4.0 National Network of Manufacturing Innovation Institutes

To ensure the IMI's fully leverage their potential to advance American domestic manufacturing, the National Network for Manufacturing Innovation will support and expand the impacts of individual Institutes, develop cross-cutting metrics and methods for evaluating impact, and promulgate best practices and standards. Each Institute will participate in the broader National Network. The purpose and functions of the Network are outlined below.

4.1 Inter-Institute Collaboration

To the extent possible, the Institutes should work collaboratively, sharing resources, best practices, and research and development results. They should transparently share funding and membership models, annual reports, and projections. The Institutes are not directly competitive, as IMIs will have diverse goals, but rather they will share the broad mission of improving U.S. manufacturing competitiveness. To support these goals, the NNMI will organize a Network Leadership Council composed of representatives of the Institutes, Federal agencies, and other appropriate entities. The Network Leadership Council will actively look for opportunities to leverage existing resources between Institutes.

4.2 Common IMI Policies

Efficient operation of the Network will be facilitated through common policies. Common policies facilitate interaction with SMEs, promote collaboration and movement within the Network, and allow IMIs to share services such human resource management. While recognizing the differing needs of various manufacturing sectors, clusters, and ecosystems, the Network will strive, as far as is practical, to maintain common policies with regard to intellectual property, contract research, operations, accountability, and marketing and branding.

4.3 Manufacturing Portal Participation

While each Institute may have its own web presence, they will also participate in and link to the AMNPO hosted "Manufacturing Portal" (www.manufacturing.gov). As the network and funded Institutes emerge, this portal will serve to direct interested parties to the resources and capabilities embodied within the overall Network. Content will include information about the focus of each Institute, structure, governance, contacts, annual reports, news, success stories, intellectual property available for licensing, member information, and more.

5.0 Rationale for the Investment

In his 2012 State of the Union address, President Obama laid out his "blueprint for an economy that's built to last—an economy built on American manufacturing, American energy, skills for American workers, and a renewal of American values."

"This blueprint," he said, "begins with American manufacturing." [22]

The President chose this starting point for good reason. Numerous recent reports have documented the critical role of U.S. manufacturing to innovation [11], jobs [23, 25], the economy [25], exports [25, 26], and national security [27]. The President has initiated a set of actions designed to make our manufacturing sector more competitive and to encourage more investment in the United States. These actions encompass sound tax policies, enforcement of trade laws, and investments in innovation, advanced technology, education, and infrastructure.

According to the non-partisan Council on Competitiveness, "U.S. manufacturing is more important than ever." [28] While not dismissing serious challenges posed by low-wage international competitors and rivals that are fast advancing in technological capabilities, the Council maintains that significant opportunities to increase production and grow exports exist for U.S. manufacturers. "The digital, biotechnology, and nanotechnology revolutions," it reports, "are unleashing vast opportunities for innovation and manufacturing." [28]

Moving to put his blueprint into action, the President has launched the NNMI program to advance American domestic manufacturing by strengthening the innovation, competitiveness, and job-creating power of U.S. manufacturing. The Network will help to address an inconsistency in U.S. economic and innovation policies. The Federal Government investment in public R&D reached more than $133 billion in FY 2009 [24], and a tax credit exists for industry-funded R&D. Yet, these measures are not matched by corresponding, strategically designed and implemented efforts and incentives to encourage domestic manufacturing of products ultimately arising from U.S. discoveries and inventions [6]. Recognizing the severity of the problem, the administration has recently taken additional action to accelerate technology transfer and commercialization of Federal research [29].

As documented by the National Science and Technology Council, "A gap exists between R&D activities and the deployment of technological innovations in domestic production of goods," [8] contributing significantly, for example, to the growing trade deficit in advanced technology products. In 2011, the United States ran a $99 billion deficit in trade of advanced technology products, accounting for 17 percent of the total U.S. trade deficit [30]. The United States has lost 687,000 high-technology manufacturing jobs since 2000 [24], when the nation posted a $5 billion trade surplus in advanced technology products.

Manufacturing plays a disproportionately large—and valuable—role with respect to the nation's innovation capacity, generating $1.35 in economic activity for every $1 of sector output [4]. Compared to all other sectors, manufacturing has the largest multiplier [31]. This figure can be contrasted to the service sectors (including financial services) that generate between $0.55 and $0.66 in additional economic activity for every $1 of sector output. Manufacturing accounts for about 12 percent of the Nation's gross domestic product, but accounts for 70 percent of domestic industry R&D spending and employs 60 percent of industry's scientists and engineers. Thus, manufacturing remains the essential core of the U.S. economy's innovation infrastructure.

Accelerating innovation and implementation of advanced manufacturing capabilities requires bridging a number of gaps in the present U.S. innovation system. Time horizons for investment payback in pre-commercial manufacturing innovation often exceed investor expectations, and technical and commercial risks are greater than they are for investments aimed at incremental improvements in existing products and services.

The commonly-held belief that knowledge spillovers reduce returns from privately-funded innovation is a related obstacle to patient, sustained private-sector investment in developing promising technologies all the way through to manufacturing and commercial market introduction. Because of the perceived so-called "free rider" problem, no single company will typically take on the risk and devote the resources needed to build the full infrastructure of underpinning manufacturing capabilities and complementary resources that would benefit an entire industry and even groups of industries. This is an area where the Federal Government can play a role to lessen that risk and help to catalyze building of an advanced-manufacturing infrastructure.

Historically and even today, the United States has excelled at basic science and invention. But the commercial and economic rewards that can sprout and grow from these important early-stage accomplishments are realized in the stages following initial discovery—especially at the points of manufacturing scale-up and commercialization. However, many technologies rooted in U.S. research fail to mature to full scale-up and commercialization in domestic factories.

5.1 NNMI in the Context of 21st Century Global Competition

Other nations also recognize the strong links between manufacturing, innovation, and prosperity. Many have established programs to strengthen the links. Currently, Germany, Korea, and Japan each have more R&D-intensive manufacturing sectors than the United States.

As technologies and products become ever-more complex and their product-development cycles shrink, successfully mastering all the stages from laboratory to marketplace requires contributions from a large network of organizations—from suppliers of equipment, parts, and services; to schools, colleges, and training programs; to utilities and other infrastructure systems. As global competition to manufacture and sell high-value-added products intensifies, the capabilities and performance of these innovation ecosystems must improve.

Many U.S. competitors also recognize the importance of these location-based linkages, and governments of these nations are investing significantly to strengthen and expand their clusters of innovation and advanced manufacturing capabilities.

In the fast-paced, highly competitive global economy, national competitiveness continues to have strong local underpinnings. Pisano and Shih define the competitiveness of a country as "the advantage workers and organizations located in one place—a local commons—enjoy in the production of specific goods or services over workers and organizations located elsewhere [32].

For the United States and other nations, national competitiveness is largely the composite result of the performance (innovation, manufacturing, and other dimensions of competitiveness) of many regions. As a result of many factors, the competeveness of a number of U.S. regions has waned over the last decade or more. One serious result with long-term economic consequences is the hollowing out of the so-called regional *industrial commons*—"the set of manufacturing and technical capabilities that support innovation across a broad range of industries" [33].

A concept closely related to industrial commons is *infrastructure*. The modern infrastructure needed to support advanced, high-tech industries has many dimensions—transportation, communication, intellectual, workforce skills, capital availability, and others. The United States has many infrastructural strengths that can be leveraged to maximize the competitive and innovation performances of U.S. industries, among them "a world-class university system, strong intellectual property protection, sophisticated managerial talent, ready access to capital, and a huge domestic market" [34].

Also included among these competitive assets is an array of private and public (Federal, State, local) programs with innovation-focused (or related) missions. Examples are consortia, university research parks, university-industry research centers, incubators, national laboratories, manufacturing extension services, skill certification programs for workers, and State and regional economic development programs. By themselves, some of these efforts have yielded commendable results.

In addition, efforts in the United States and other nations to spur innovation, build advanced manufacturing capabilities, and spawn new industries and jobs have been focused on geographic regions. Successful cluster-based approaches yield benefits that foster long-term competitiveness, including a skilled workforce, inter-firm linkages, and knowledge spillovers—all of which contribute significantly to innovation as integral components of regional industrial commons [6, 33].

While the United States has a variety of programs and activities that aim to strengthen regional innovation clusters or to catalyze the emergence and growth of new ones, the overall effort has been described as fragmented or uncoordinated [34, 35]. The lack of coordination and programmatic linkages means that the individual programs and activities (private, Federal, State, and local) may not be as effective as they could be in promoting the development, application, and commercialization of new product and process technologies, as well as new manufacturing capabilities.

To maximize chances for success, the National Research Council's report [6] advises that regional innovation clusters need to:

1. Leverage local strengths,
2. Encourage self-organization,
3. Pool resources,
4. Share risks,
5. Grow a trained workforce,
6. Connect with local universities and laboratories,
7. Provide long-term commitment,
8. Provide incentives, and
9. Monitor and measure industry needs

5.2 Overview of Existing Relevant Programs

While the Federal Government has a number of highly effective programs in its R&D portfolio for advanced manufacturing, there are no current Federal programs that cover NNMI attributes to the extent needed to significantly influence the nation's competitiveness. A balanced portfolio of targeted programs (basic research through applied scale-up) is required for a complete national response to the challenges and opportunities in advanced manufacturing. As a means of contrast, selected programs are described below and compared to the NNMI Institute vision:

5.2.1 Research Centers

Research centers typically focus on basic research, but occasionally also extend to fund applied research and technology proof-of-concept activities. Such centers are affiliated with one or more universities. Examples include:

1. NSF Industry/University Cooperative Research Centers that leverage a modest NSF investment with funding by industry members, other agencies, and other organizations to support a single- or multi-university center. The centers focus on early-stage precompetitive research.
2. NSF Engineering Research Centers are hosted at universities and promote partnerships among researchers in different disciplines and between industry and universities. ERCs are targeted at advancing transformational engineering systems, conduct research from the fundamental stage to proof-of-concept test beds, create education programs from pre-college through postdoctoral studies, and are hosted by universities. The goal is to create a culture in engineering research and education that links discovery to technological innovation through transformational fundamental and engineered systems research.
3. NSF's Materials Research Science and Engineering Centers (MRSECs) support researchers to engage in fundamental interdisciplinary research to solve complex materials problems that are intellectually challenging and important to society. Discoveries resulting from this research

are sometimes leveraged into start-up companies impacting industries across the breadth of materials science. Additionally, centers are encouraged to engage in external collaborations, which can include scientists from industry.

In addition, Federally Funded Research and Development Centers (FFRDCs)—although not focused specifically on manufacturing R&D—conduct basic and applied research and support specialized R&D resources and capabilities.

5.2.2 Research and Innovation Hubs

Hubs emphasize large and diverse teams of researchers focused on a specific high priority goal. For example, the DOE Energy Innovation Hubs are multi-disciplinary, multi-institutional, highly-collaborative teams of scientists and engineers working over a longer time frame to advance highly promising areas of energy science and technology from their early stages of research to the point where the risk level will be low enough for industry to begin to move them into development for manufacturing scale-up and the marketplace. DOE Hubs are led by top researchers with the knowledge, resources, and authority to nimbly guide efforts, seizing new opportunities or closing off unproductive lines of research.

5.2.3 Manufacturing Demonstration Facilities

MDFs help members of the manufacturing community to develop and demonstrate new manufacturing technologies. This can help manufacturers understand full-scale costs and implementation requirements, allowing them to create and justify their business case when seeking further private capital investment to bring processes and products to market. MDFs access to otherwise cost-prohibitive tools and resources, and are focused on demonstration of processes and production technologies at industrially relevant demonstration scale. DARPA and DOE are sponsors of MDFs.

5.2.4 DOD Manufacturing Technology (ManTech) Program

The DOD ManTech Program develops advanced manufacturing technologies and processes for the affordable, timely production and sustainment of defense systems. In close partnership with industry, the program impacts all phases of system development, acquisition, and sustainment by developing, maturing, and transitioning key advanced manufacturing technologies. Investments are focused on those technologies that have the greatest defense benefit and are balanced to support transition of emerging technologies, improvements to existing production enterprises, and strengthening the U.S. industrial base. ManTech has a long history of delivering critical and "game changing" advanced manufacturing technologies and processes, such as numerically controlled machines, carbon fiber composites, microelectronics fabrication, advanced radars, laser-guided munitions, lean production methods, advanced optics, and advanced soldier body armor. Many defense manufacturing technologies have spun-off into commercial markets and resulted in large economic advances for the United States. For example, the widespread commercialization of numerically controlled machine tools has been attributed to initial ManTech sponsorship and development.

5.2.5 Centers of Excellence

Centers of Excellence are another model used in a number of Federal programs. These centers are typically led by a not-for-profit or university and concentrate basic or applied research into a specific area in order to achieve a critical mass of talent and resources. DOD's Navy ManTech Program utilizes a Center of Excellence model to develop technologies and processes for the affordable production and sustainment of naval systems. Centers of Excellence have existed for Joining, Composites, Electronics, and Benchmarking Best Practices. DOE's Fuel Cell Technology Program previously sponsored four Hydrogen Storage Centers of Excellence in order to accelerate optimal materials for chemical and metal hydride hydrogen storage.

5.2.6 Deployment and Delivery Programs

Deployment and Delivery Programs provide hands-on technical assistance to companies interested in implementing lessons from classroom training or industry best practice into their business growth strategies and manufacturing operations. This includes employing new technologies to meet changing customer demands or support new product development, deploying innovative production methods, or other steps to enhance their capabilities and competitive position. For example, the DOC NIST Hollings Manufacturing Extension Partnership is a national network based on a Federal-State-local partnership providing direct services to nearly 10,000 SMEs annually through 400 centers, field offices, and partner organizations across the U.S. MEPs provide fee-based technical assistance to manufacturers to enable them to reduce costs, improve productivity, and pursue growth opportunities through innovation.

5.2.7 Federal Support for Advanced Manufacturing Workforce Development

There are several Federal programs and activities in support of developing and nurturing a workforce skilled in advanced manufacturing. For example:

1. DARPA's Manufacturing Experimentation and Outreach (MENTOR) effort engages high school students in collaborative, distributed manufacturing and design.
2. State directors of career and technical education, along with the Department of Education, are promoting the National Career Clusters Framework, which supports quality career and technical education programs through learning and comprehensive programs of study. Manufacturing is one of 16 Career Clusters, guiding development of programs of study in manufacturing that bridge secondary and postsecondary curricula.
3. The Department of Labor's Employment and Training Administration (ETA) supports the development of a skilled manufacturing workforce through the Registered Apprenticeship program, the Workforce Investment Act programs, and the manufacturing competency model. This employer-validated model outlines the skills necessary to pursue a successful career in the manufacturing industry. ETA's competitively awarded grants also support efforts to accelerate education and training programs for high-skilled occupations in the advanced manufacturing field. The Trade Adjustment Assistance Community College and Career Training Grant Program, for example, catalyzes partnerships between community colleges, the public workforce system and employers to develop innovative educational training models in advanced manufacturing, among other critical industry sectors. By raising technical skill levels, American workers can obtain the industry-recognized credentials required to enter and advance along career pathways in the manufacturing sector.

5.3 Differences between Existing Programs and the NNMI Vision

The notable distinctions between NNMI Institutes and existing Federal programs include:

1. **Federal investment level:** The I/UCRC and ERC funding levels are an order of magnitude lower per center than is planned for Institutes. Such centers have a structure typically aligned with university policies and requirements, and do not have the Institute's industry focus. Workforce development is addressed in ERCs, but community colleges are not an integral part of an ERC. Leadership originates with research universities, while with Institutes, leadership is provided by industry, as well as government, academic, public and private laboratories, and any other affected parties that are stakeholders within that IMI. Research projects for both of the NSF center programs described above target the early stage fundamental research to proof-of-concept.
2. **Focus on prototyping and scale-up:** The focuses of many of the existing Federal programs and the proposed Institutes are fundamentally different. With existing Federal programs, the investment is primarily in basic and applied early stage research without a specific focus on manufacturability and manufacturing processes and technologies. Existing industry investment is predominantly in late stage research and demonstration and incremental process development. The region between these two investment areas is recognized as an underfunded and critical area. One of the fundamental concepts central to the NNMI is that a government-industry-academia *partnership* will leverage the resources of everyone to address gaps in innovation in the manufacturing space, which includes both developing manufacturing technologies and designing/modifying products to enable their manufacture.
3. **MEP centers** were intended to pull applied research, technologies, and innovations from universities, Federal labs, and other sources to support client SME growth initiatives. Historically, MEP centers have focused on SME process improvements and quality issues. In recent years, the program has sought to build on that expertise and SME client relationships to accelerate the rate of adoption of new technologies by clients. MEP connects technology opportunities and SMEs to move new product opportunities into production and into the market faster and with greater returns on investment. This relatively nascent MEP initiative would complement NNMI directions.
4. **Industry-driven:** In the Institutes, industry will have a strong role in the identification of the technology area and research agenda through their co-investment. NAMII's technology focus on additive manufacturing, in contrast, grew largely out of Federal agency needs (although the topic is widely supported by industry as a critical focus area). In addition, the industry-wide cross-cutting focus of NNMI Institutes will often span the research interests of many industry partners, academic partners, and multiple Federal agencies.
5. **Significant industry co-investment:** With NNMI, the Federal funding will be heavily leveraged by Institute partners' direct co-investment at a sufficiently large scale to affect regional economies or entire industry sectors. This will increase the impact of Federal funding. It will force the Institute to have a pragmatic focus on industrially relevant technologies, and also will empower the partners as true stakeholders in the Institute's success.

6. **Network attributes:** The NNMI program includes a vision for the Institutes to interact through a National Network.

6.0 National Additive Manufacturing Innovation Institute—the Pilot Institute

In March 2012, when President Obama unveiled his proposal to build the NNMI, he also initiated steps to jumpstart the NNMI with a Pilot Institute. The Pilot Institute would serve as a proof-of-concept for the NNMI Institutes. A collaborative interagency team was convened and determined that the topic of Additive Manufacturing would garner the most benefit for the defense, energy, space, and commercial sectors of the nation, and should be the focus of the Pilot Institute. Additive Manufacturing, also commonly known as 3D printing, is an emerging and evolving collection of manufacturing processes that build metal, plastic, or ceramic parts using layer-by-layer build-up techniques, precisely placing material as directed, based on a software representation of the three-dimensional part geometry.

The competition for the Pilot Institute was launched through a DOD Broad Agency Announcement (BAA) in May 2012. Proposals for the Pilot Institute were due on June 16, and the award to the National Additive Manufacturing Innovation Institute (NAMII) was announced on August 16, 2012 [36]. NAMII is headquartered in Youngstown, Ohio, and it is comprised of a broad coalition of more than 80 companies, 9 research universities, 6 community colleges, and 18 not-for-profit institutions.

While NAMII is the Pilot Institute, it differs from the proposed IMIs in several important ways. The focus area was pre-defined based on agency needs, funding was obtained from multiple agencies, and the partner agencies set the capitalization at a significantly lower level than is envisioned for an IMI.

Proposal evaluations were conducted by an interagency advisory council of technical experts from the DOC, DOD, DOE, NASA, and NSF. Based on the evaluation process stated within the BAA, the advisory council selected the National Center for Defense Manufacturing and Machining (NCDMM) to manage the Pilot Institute. This public-private partnership between NCDMM and the Government was awarded as a cooperative agreement using $30 million of Federal funding and an additional $39 million provided as cost share, mostly from industry and the states of Ohio, Pennsylvania, and West Virginia.

This long-term, public-private partnership between State and local governments, industry, and academia (including research universities and community colleges) is enabled by the Federal Government and, as such, DOD and other partnering agencies used cooperative agreements (rather than grants or contracts) to fund the government portion. A governance board along with an executive committee and technical advisory board comprised of industry, academia, and government representatives oversee the Institute's activities. Using a cooperative agreement also allows for substantial involvement by the Federal Government, and is consistent with the broad interest in additive manufacturing across the multiple agencies that collaborated to launch the pilot initiative.

In summary, NAMII was formed in parallel with the ongoing effort to architect the broader NNMI and hence is technically not part of a yet-to-be-formed network. However, it represents a critically important seeding of the concept and its construction and early activities are helping to inform the design and development of the full NNMI enterprise.

7.0 Crowd Sourcing the Design of the NNMI

To develop a knowledge base regarding the President's proposed NNMI, and to assist in the NNMI design, the AMNPO embarked on a nationwide strategy to solicit input from stakeholders from industry, academia, State and regional governments, economic development authorities, industry associations and consortia, private citizens, and other interested parties.

7.1 NNMI Request for Information

On May 4, 2012, the AMNPO, through NIST, published a Request for Information (RFI) in the Federal Register inviting interested parties to provide public comment on the new proposed public-private NNMI program [37]. Comments in response to the RFI were accepted through October 25, 2012. The RFI sought open input on the NNMI and specific input on 21 questions in four categories related to the structure and operations of the individual Institutes and the NNMI. The topics and questions were:

Technologies with Broad Impact

1. What criteria should be used to select technology focus areas?
2. What technology focus areas that meet these criteria would you be willing to co-invest in?
3. What measures could demonstrate that Institute technology activities assist U.S. manufacturing?
4. What measures could assess the performance and impact of Institutes?

Institute Structure and Governance

1. What business models would be effective for the Institutes to manage business decisions?
2. What governance models would be effective for the Institutes to manage governance decisions?
3. What membership and participation structure would be effective for the Institutes, such as financial and intellectual property obligations, access and licensing?
4. How should a network of Institutes optimally operate?
5. What measures could assess effectiveness of Network structure and governance?

Strategies for Sustainable Institute Operations

1. How should initial funding co-investments of the Federal Government and others be organized by types and proportions?
2. What arrangements for co-investment proportions and types could help an Institute become self-sustaining?
3. What measures could assess progress of an Institute towards being self-sustaining?
4. What actions or conditions could improve how Institute operations support domestic manufacturing facilities while maintaining consistency with our international obligations?

5. How should Institutes engage other manufacturing related programs and networks?
6. How should Institutes interact with State and local economic development authorities?
7. What measures could assess Institute contributions to long-term national security and competitiveness?

Education and Workforce Development

1. How could Institutes support advanced manufacturing workforce development at all educational levels?
2. How could Institutes ensure that advanced manufacturing workforce development activities address industry needs?
3. How could Institutes and the NNMI leverage and complement other education and workforce development programs?
4. What measures could assess Institute performance and impact on education and workforce development?
5. How might Institutes integrate research and development activities and education to best prepare the current and future workforce?

In total, the AMNPO received seventy-eight (78) separate RFI responses from industry, academia, economic development, State and regional authorities, national laboratories, and private citizens, representing the viewpoints of nearly more than 100 separate entities [38].

7.2 NNMI Regional Workshops

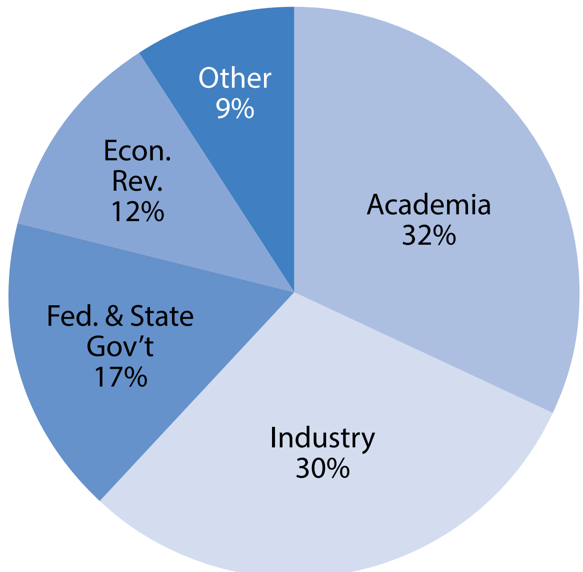
In addition to the RFI as a crowd sourcing tool, the AMNPO held four regional workshops as part of its strategy for soliciting input. The four *Designing for Impact* regional workshops attracted approximately 875 attendees from across the country. Participants included leaders and representatives from industry; academia; economic development organizations; State, local and Federal Government; and other organizations (see Figure 2). The four workshops were:

1. **Designing for Impact I:** April 25, 2012, at Rensselaer Polytechnic Institute in Troy, New York
2. **Designing for Impact II:** July 9, 2012 at Cuyahoga Community College outside Cleveland, Ohio
3. **Designing for Impact III:** September 27, 2012 at the Arnold and Mabel Beckman Center of the National Academies of Sciences and Engineering in Irvine, California
4. **Designing for Impact IV:** October 18, 2012 at the Millennium Harvest House in Boulder, Colorado.

Reports [39] from all four workshops summarizing the individual recommendations and comments of workshop attendees have been used to assist in the design of the NNMI.

Through these outreach efforts, the Federal agency partners explored a wide-ranging set of issues central to the design of the NNMI, including technology focus areas, institutional design and governance issues, and management of the network as a whole to amplify the impact of individual Institutes.

Figure 2 *Designing for Impact I-IV* Workshop Participation by Sector



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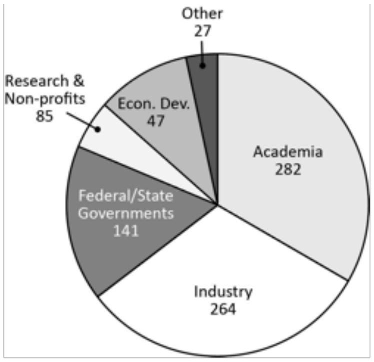
Appendix A: NNMI Public Workshop and RFI Participants



Rensselaer Polytechnic Institute
April 25, Troy New York

Cuyahoga Community College
July 9, Cleveland Ohio

Nat'l Academies Beckman Center
September 27, Irvine California

Univ. of Colorado
October 18, Boulder Colorado

Academia (282)

Alfred University

Arizona State University

Association of Public and Land-grant Universities

Case Western Reserve University

City University of New York

Columbia University

Iowa State University

Kansas State University

Kent State University

Lorain County Community College

Macomb Community College & Auto Communities Consortium

National Institute for Pharmaceutical Technology and Education

Pennsylvania State University - Electro-Optics Center

Purdue University

The University of Akron

University at Albany – CNSE

University at Buffalo

University of California Davis – College of Engineering

University of California, Berkeley - College of Engineering

University of Illinois

University of North Carolina at Charlotte

University of Rochester – Center for Emerging and Innovative Sciences

University of Southern California – Information Sciences Institute

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BAE Systems Land & Armaments

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Eastman Kodak

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Lumetrics

M7-Technologies

Modria Inc.

Mongan Intech Corporation

Optimax

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Dinsmore, Jason, Dinsmore & Associates, Inc.

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Dolan, Benjamin, RapidTech

Dotson, Dennis, Dotson Iron Company

Drumm, Gregory, Nation Grinding Inc./Nation Coating Systems

Ducoin, David, Lockheed Martin Electronic Systems

Duggan, Jim, Edison Tech Center

Dykstra, William, Temper

Easterbrooks, Don, Canton Drop Forge

Edwards, Doyle, Brewer Science

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Gonzalez, Ray, TGD

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Graham, Lawrence, PCCAirfoils

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Greenspon, Judy, NPI Services, Inc.

Grimes, Thomas, LNE Group LLC

Grischuk, Walt, Ora Technology

Guerra, Nick, Perfekta Aerospace

Gurumurthy, Prasanna, LuK USA

Gustafson, Daniel, NextEngine

Guymon, Lance, Wolf Robotics

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Hagerty, Brian, Reactor Institute

Hainsey, Robert, Electro Scientific Industries

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Harney, Paul, Perkins+Will

Harricharran, Kunwar, Battelle Production and Field Support

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Hatch, Mark, TechShop

Hatkevich, Steve, American Trim, LLC

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Philippi, Therese, Alion Science and Technology

Phillippy, Bob, Newport Corporation

Philpotts, Alvin, Emerging Technology Applications Center (ETAC)

Poliks, Mark, Endicott Interconnect Technologies, Inc.

Polizzi, Anthony, Rocket Science Tutors

Powell, Katie, Munro Companies, Inc.

Rahman, Derrick, SunVeil Solar Inc.

Ralston, Dennis, KLA-Tencor Corporation

Ramsey, Dougals, Alcoa Inc.

Razum, Joe, GE

Rehkopf, Jackie, Plasan Carbon Composites

Rhoda, Doug, Wolf Robotics

Rini, John, LNE Group LLC

Rivard, Adam, Pratt & Whitney

Roberts, Anthony, Jacobs Technology

Robinson, Ron, IT Data Storage / 3DCAD Printer Corproation

Robinson, Jim, TechShop, Inc.

Rockstroh, Todd, GE Aviation

Rothrock, Ginger, RTI International

Rowlen, Kathy, InDevr

Rustic, Joseph, CTL Engineering

Salihagic, Selma, Ball Aerospace & Technologies

Sanne, Anil, Avittor International Corporation

Sariri, Kouros, FMI

Saunders, Glenn, Upstate New York LRIG, Inc.

Schilling, Patricia, Tugboat Software Inc.

Schorzman, Derek, Liquidia Technologies, Inc.

Schramko, Ken, Lam Research

Schroeder, William, Kitware, Inc.

Shattuck, Jay, Underground Systems, Inc.

Sheet, Lubab, Lam Research Corp

Shiveley, Tom, Innovative Industries

Shrader, Eric, Palo Alto Research Center

Silvashy, Ryan, Falcon Foundry

Singh, Prabhjot, GE Global Research

Smith, Robert, Analytical Mechanics Associates

Smith, Gary, D'Addario & Company, Rico International Division

Snell, Michael, Silfex Corporation

Speir, Ryan, Allineate

Srinivas, Girish, TDA Research, Inc.

Stangle-Castor, Nannette, Fuentek, LLC

Stark, Paul, Manaex

Stellon, Gene, Covidien

Stephen, Jennings, Raydiance

Stimson, Tom, The Timken Company

Strong, Amy, Fuentek, LLC

Sullivan, Rose Ann, TechVision21

Sutton, Craig, Deere & Co

Tackett, Edward, RapidTech, Nat'l Center for Rapid Technologies

Thompson, Dave, AlloSource

Tredway, William, United Technologies Research Center

Tymkiw, Andy, Edwards Lifesciences

Ulintz, Peter, Anchor Manufacturing Group

VanDyne, Ed, VanDyne SuperTurbo, Inc.

Vargas, John, Futek Advanced Sensor Technology, Inc.

Venkataraman, Bala, Magni-Power Company

Veres, Janos, Palo Alto Research Center

Viens, Daniel, United Technologies Research Center

Voss, Bob, Panduit Corporation

Vu, Truc, Microsemi Corporation

Wahlig, Bill, Long Island for Technology

Walker, Rae, Axiom Medical Inc.

Welch, Ken, MSC Software

Wenner, Chauncey, United Launch Alliance

Weyer, Greg, LuK USA LLC

White, Christian, iComputer

Willnecker, Gerald, Powdermet Inc.

Winslow, Kyle, McAllister & Quinn

Wolf, Christopher, ITN Energy Systems, Inc.

Wong, Brian, Enevate Corporation

Wosczyna-birch, Karen, Center for Next Generation Manufacturing

Wu, Yutong, APIC

Yamakage, Masahiro, Toyota Motor Engineering & Manufacturing North America, Inc.

Yoss, Mark, Lockheed Martin

Zimmer, Stephen, USCAR

Zimmerman, Burr, Urban Venture Group, Ltd.

Economic Development Organizations (47)

Agenda 2020 Technology Alliance of the Forest Products Industry

Colorado Workforce Development Council

Manufacturing Advocacy and Growth Network

Mid-Columbia Economic Development District

NorTech

Bagley, Rebecca, NorTech

Baunach, Dorothy, Greater Cleveland Partnership

Berger, Scott, AIChE

Black, Sharon, Blacksmith Multimedia, Inc.

Boulier, Paul, Team Northeast Ohio

Brancato, Jeffrey, NorTech

Britton, Patrick, NOCHE – Northeast Ohio Council on Higher Education

Chase, Joan, Greater Cleveland Partnership

Coats, Jack, Center of Innovation for Nanobiotechnology (COIN)

Esoda, Eric Joseph, Northeastern Pennsylvania Industrial Resource Center, Inc.

Fowler, Linda, Regionerate LLC

Franchell, Michael, Community Based Business Incubator Centerm, Inc.

Gattozzi, Nick, Greater Cleveland Partnership

Giles, Merle, NCSA

Goodpasture, Tim, City of Wichita

Gundersen, Daniel C, Baltimore County Department of Economic Development

Hoag, Michael, WIRE-Net

Holsheimer, Alex, County of San Bernardino EDA

Houldin, Joseph, Delaware Valley Industrial Resource Center

Hutchison, Hutch, High Technology Rochester

Johnson, Kyle, Next Generation Economy Center

Kedar, Shilpa, The Cleveland Foundation

Klonsinski, Mike, Wisconsin Economic Development Corporation

Knepell, Angie, Colorado Association of Commerce and Industry

Lawrence, Jeffrey, Center for Economic Growth

Lecz, Alan, Workforce Intelligence Network

Lee, George, Glimmerglass Ltd.

Lund, Ken, Colorado Office of Economic Development and International Trade

Martell, Terrence, Akron Global Business Accelerator

Martin, Nancy, Monterey Bay Economic Partnership

Milbergs, Egils, Washington Economic Development Commission

Nafziger, Wendi, Longmont Area Economic Council

Nance, Christopher, Greater Cleveland Partnership

Paytas, Jerry, Fourth Economy

Pfunder, Jack, Manufacturers Resource Center

Pritchard, Peter, Center for Economic Growth

Reinhardt, William, Edison Tech Center

Robey, Claudette, Next Generation Economy Center

Severson, Peggy, Denver Office of Economic Development

Shakour, Elias, Michigan Economic Development Corporation

Steinmetz, Joe, APS-Development

Stumo, Michael, Coalition for a Prosperous America

Federal/State Government (141)

Colorado Office of Economic Development and International Trade

Naval Surface Warfare Center – Corona Division

North Carolina Department of Commerce

Oak Ridge National Laboratory – Measurement Science & Systems Engineering Division

Aitcheson, Leslie, Army NVESD

Adams, Richard, National Renewable Energy Laboratory

Alexander, Ronald, NASA Glenn Research Center

Anderson, John, CMTC

Anselmi, Robert, Department of Veterans Affairs

Balder-Froid, Kristin, Lawrence Berkeley National Laboratory

Barkman, William, Y-12 National Security Complex

Bartolotta, Paul, NASA Glenn Research Center

Barton, Russell, National Science Foundation

Baumann, Eric, NASA Glenn Research Center

Blue, Craig, Oak Ridge National Laboratory

Boeman, Ray, Oak Ridge National Laboratory

Brennan, Ann, National Renewable Energy Laboratory

Brinkley, David, Office of the Secretary of Defense

Brown, Sherrod, Senate

Bugnitz, Tom, CAMT

Cantwell, Elizabeth, Lawrence Livermore National Laboratory

Carrillo, Larry, Sandia National Laboratories

Christensen, Dana, National Renewable Energy Laboratory

Christensen, Michael, OSD ManTech

Christensen, John, Office of Secretary of Defense

Christodoulou, Leo, Advanced Manufacturing Office Department of Energy

Cooper, Kenneth, NASA Marshall Space Flight Center

Cox, Ashley, NYSERDA

Cupples, Chris, Office of Congressman Tim Ryan

Dalzell, Jack, NASA Glenn Research Center

Daniels, Edward, Argonne National Laboratory

Daniels, Lynn, Department of Energy

Dempsey, Patrick, Lawrence Livermore National Laboratory

Duggan, Maureen, Congresswoman Louise Slaughter

Duly, Diane, NASA Glenn Research Center

Eberle, Cliff, Oak Ridge National Laboratory

Elledge, Raymond, CMTC

Evans, Jamey, Department of Energy

Evans, Heather, NIST

Fielding, Jennifer, Air Force Research Laboratory

Gallagher, Patrick, NIST

Gannon, Jesse, Senator Sherrod Brown's Office

Garver, Lori, NASA Headquarters

Giovannetti, Dean, NASA Ames Research Center

Gomez, Fabio, CMTC

Gove, Jeffrey, Ohio Board of Regents

Green, Virginia, CMTC

Greer, Frank, NASA Jet Propulsion Laboratory

Gupte, Prasad, NIST

Hanigan, William, Medina County Workforce Development

Hardin, John, Office of Science and Technology

Hardy, David, Department of Energy

Harris, Stewart, NASA Langley Research Center

Hart, Jack, Office of Advocacy/ Small Business Administration

Heinrichs, Patricia, Air Force

Henschel, Gregory, Department of Education

Herling, Darrell, Pacific Northwest National Laboratory

Hines, John, NASA Ames Research Center

Hogan, Kathleen, Department of Energy

Holesinger, Terry, Los Alamos National Laboratory

Horseman, Ken, Agency of Commerce & Community Development

Hoyt, Diana, NASA

Ivester, Robert, Department of Energy

Kadtke, James, National Nanotechnology Coordinating Office

Kaplar, Robert, Sandia National Laboratories

Kathe, Eric, U.S. Army

Kelley, Michael, NIST

Kilbane, Grace, Department of Labor Employment and Training Administration

Koppel, Jacques, CEMC

Korsmeyer, David, NASA Ames Research Center

Kramer, Bruce, National Science Foundation

Kumar, Abhai, DPAC

Lee, Jonathan, CMTC

Liang, Ranty, NASA Jet Propulsion Laboratory

Liby, Alan, Oak Ridge National Laboratory

Lugo, Ray, NASA Glenn Research Center

Maher, Angela, HUD – Strong Cities, Strong Communities

May, Deborah, Lawrence Livermore National Laboratory

McIlwain, Michael, Idaho National Laboratory

Meador, Michael, NASA Glenn Research Center

Miller, Jason, White House National Economic Council

Miller, Dennis, Y-12 National Security Complex

Min, Sangkee, Lawrence Berkeley National Laboratory

Molnar, Mike, NIST

Narotski, Bill, Ohio EPA – OCAPP

Ott, Ron, Oak Ridge National Laboratory

Peck, Mason, NASA

Peterson, Eric, Idaho National Laboratory

Prusha, Stephen, NASA Jet Propulsion Laboratory

Prymak, Bill, Department of Energy

Pugliano, Victor, US Army ARDEC

Pye, Miriam, New York State Energy Research and Development Authority

Ratcliff, Adele, OSD (MIBP)

Reinfurt, Edward, Empire State Development Corporation

Reyes, Matthew, NASA Ames Research Center

Richards, Joni, NASA

Rinker, Mike, Pacific Northwest National Laboratory

Roberts, Jim, NYSTAR

Robinson, Kem, Lawrence Berkeley National Laboratory

Russell, John, Air Force Research Laboratory

Sastri, Bhima, Department of Energy

Schen, Michael, NIST

Schmid, Steven, NIST

Scotti, Stephen, NASA Langley Research Center

Shaw, Robert, NASA Glenn Research Center

Sherman, Aleta, CAMT

Shipers, Larry, Sandia National Laboratories

Shkel, Andrei, DARPA

Silcox, Brett, NASA Headquarters

Simmons, Jerry, Sandia National Laboratories

Singerman, Phillip, NIST

Slobodian, Cheryl, CMTC

Smith, Marilyn, US House of Representatives

Sofos, Marina, Advanced Manufacturing Office, Department of Energy

Sorensen-Bain, Sumer, CAMT

Sosa-Mallory, Michelle, National Renewable Energy Laboratory

Steitz, David, NASA

Streiffer, Stephen, Argonne National Laboratory

Supola, Neil, US Army NVESD

Tartz, Karla, State of Colorado

Tate, LaNetra, NASA

Teter, David, Los Alamos National Laboratory

Thompson, Gary, NIST MEP

Tibrea, Steven, Savannah River National Laboratory

Tolbert, Carol, NASA Glenn Research Center

Trease, Brian, NASA Jet Propulsion Laboratory

Turner, Clayton, NASA LARC

Ulsh, Michael, National Renewable Energy Laboratory

Utz, Robin, US Department of Education

Vaia, Richard, Air Force Research Laboratory, Materials and Manufacturing Directorate

Veris, Kim, NASA Glenn Research Center

Vickers, John, NASA

Visconti, Kelly, Advanced Manufacturing Office, Department of Energy

Wach, Steve, Savannah River National Laboratory

Ward, Brynne, DRC (OSD ManTech)

Watson, Jim, CMTC

Werkheiser, Mary, NASA Ames Research Center

Werkheiser, Niki, NASA

Wolfenbarger, Debora, NASA Jet Propulsion Laboratory

Wunsch, Thomas, Sandia National Laboratories

Zucca, Gregory, Cuyahoga County Department of Development

Research & Non-Profits (85)

Center of Innovation for Nanobiotechnology (COIN)

Conexus Indiana

Optoelectronics Industry Development Association

SEMATECH

Semiconductor Equipment and Materials International (SEMI)

Smart Manufacturing Leadership Coalition

Society of Manufacturing Engineers

The Maritime Alliance

The Ohio Aerospace Institute

The Security Network

The Solar Energy Consortium

Adams, James, Metal Powder Industries Federation

Aller, Mike, Space Coast Energy Consortium

Anderson, Steve, SPIE

Balachandra, Anita, SEMATECH/TechVision21

Berry, Daniel, MAGNET

Boccanfuso, Anthony, The National Academies

Brown, G. Ronald, Agenda 2020 Technology Alliance

Carnes, Kelly, TechVision21

Ciesinski, Michael, FlexTech Alliance

Colbert, Beth, Ohio MEP

Conrardy, Chris, EWI

Crocker, Judith, MAGNET

Crumrine, Susan, Southwest Research Institute

Cupoli, Edward, SEMATECH

Dale, James, Metal Powder Industries Federation

Davis, Jonathan, SEMI

Dumitriu, Monica, Ohio Aerospace Institute

Evans, Paul, Southwest Research Institute

Flannigan, Clay, Southwest Research Institute

Fleegle, Gary, National Center for Defense Manufacturing and Machining

Fralix, Michael, [TC]2

Fry, Michele, Young Innovators' Society

Gibson, Kimberly, EWI

Gilmore, Randy, National Center for Manufacturing Sciences

Girard, Jamie, SEMI

Goodstein, Mark, Cleantech Los Angeles

Hardy, Roy, Forging Industry Association

Heaton, Tim, Colorado Advanced Manufacturing Alliance

Hock, Carolyn, InSoCal CONNECT

Holladay, Dan, SEMATECH – PVMC

Horton, Nancy, Energy Industries of Ohio

Hunt, Warren, The Minerals, Metals & Materials Society

Hurt, Pam, Society of Manufacturing Engineers

Kelbassa, Ingomar, Fraunhofer ILT

Krizman, Greg, MAGNET

Lanke, Eric, National Fluid Power Association

Looman, Kathleen, Society of Manufacturing Engineers

Majcher, Donald, Ohio Aerospace Institute

Maloney, Thomas, Connecticut Center for Advanced Technology

Martin, Michael, Edison Materials Technology Center (EMTEC)

McAulay, Jeff, Fraunhofer CSE

McDougle, Jack, Council on Competitiveness

McIntyre, Cynthia, Compete. Council on Competitiveness

McKinnis, Leonard, Center for Labor and Community Research

Meyer, Carl, The Solar Energy Consortium

Mudry, Rosemary, Energy Industries of Ohio

Nolan, Edward, MAGNET

O'Donnell, Michael, MAGNET

Otterman, Nadine, Young Innovators' Society

Pacelli, Mary Ann, MAGNET

Porter, Kweli, Rainforest Recycling Company

Rael, Denise, FlexTech Alliance

Rafferty, Bill, Southwest Research Institute

Rankin, Tyra, Texas Clean Energy Council

Resnick, Ralph, National Center for Manufacturing Sciences

Rochester Regional Photonics Cluster

Ruen Blanchard, Sarah, ASERTTI

Salay, David, Ohio Aerospace Institute

Sattler, Dwayne, Ohio Technology Consortium (OH-TECH)

Schmidt, Bob, MAGNET

Schober, John, MAGNET

Sloan, Susan,The National Academies - GUIRR

Smith, Larry, SEMATECH

Snow, Dave, Purdue Manufacturing Extension Partnership Center

Srivastava, Anil, TechSolve, Inc.

Taylor, Rebecca, National Center for Manufacturing Sciences

Thompson, Dennis, SCRA

Tieckelmann, Robert, SEMATECH

Vairamohan, Baskar, Electric Power Research Institute (EPRI)

Vaze, Suhas, EWI

Warndorf, Paul, AMT – The Association For Manufacturing Technology

Wellington, Jane, Society of Manufacturing Engineers

Weil, Richard, Cleantech Los Angeles

Whitefoot, Katie, National Academy of Engineering

Wong, Perry, Milken Institute

Other (27)

Chris Cassidy Consulting

JumpStart

The Information Technology & Innovation Foundation

The Motorsports Education Foundation

Berkowitz, Kevin

Buthe, Chris, Lean Enterprise Development

Denning, Mary Kaye, Capital of Know-How

Gartenlaub, Marshall, Technical Employment Training

Gary, Steve, Avery Dennison

Grover, Kristie, BIOCOM Institute

Hanmin, Chen

Hooper, Nicholas, UK Science and Innovation Network

Huggan, Phillip

Jory, Rick

Kakiris, Barbara, Barbara Kakiris Consulting, LLC

Kerzicnik, Ernest, Enginuity, LLC

Loveman, Stanford, Out of the Blox

Marcal, Pedro, MPACT

Mouakkad, Sally, British Consulate-General Los Angeles

Overmoyer, Richard, Fourth Economy Consulting

Payne, David, Ohio Republican Party

Petersen, Kevin, Food Chain Safety

Reyes, Matthew, Exploration Solutions, Inc.

Rojhani, Ethan, PwC

Talnack, Marie, Talnack & Associates

Trerotola, Ron, Trerotola Associates

Tseng, Shirley

Appendix B: Glossary of Abbreviations

AMNPO	Advanced Manufacturing National Program Office
AIR	Accelerating Innovation Research
BAA	Broad Agency Announcement
CRS	Congressional Research Service
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
ED	Department of Education
ERC	Engineering Research Centers
ETA	Employment and Training Administration
GDP	Gross Domestic Product
GOALI	Grant Opportunities for Academic Liaison with Industry
IMI	Institute for Manufacturing Innovation
I/UCRC	Industry/University Cooperative Research Centers
MDF	Manufacturing Demonstration Facilities
MENTOR	Manufacturing Experimentation and Outreach
MEP	Manufacturing Extension Partnership
MRL	Manufacturing Readiness Level
MRSEC	Materials Research Science and Engineering Centers
NACK	National Nanotechnology Applications and Career Knowledge
NAMII	National Additive Manufacturing Innovation Institute
NASA	National Aeronautics and Space Administration
NCDMM	National Center for Defense Manufacturing and Machining
NIST	National Institute of Standards and Technology
NNMI	National Network for Manufacturing Innovation
NSF	National Science Foundation
PFI	Partnerships for Innovation
R&D	Research and Development
RFI	Request for Information
SBIR	Small Business Innovation Research
SME	Small and Medium Enterprises
STTR	Small Business Technology Transfer
TRL	Technology Readiness Level

Executive Office of the President
National Science and Technology Council
Advanced Manufacturing National Program Office