REPORT TO THE PRESIDENT

CAPTURING A DOMESTIC COMPETITIVE ADVANTAGE IN ADVANCED MANUFACTURING

Report of the Advanced Manufacturing Partnership Steering Committee

Annex 2:

Shared Infrastructure and Facilities Workstream Report

Executive Office of the President

President's Council of Advisors on Science and Technology

JULY 2012

PREFACE

In June 2011, the President established the Advanced Manufacturing Partnership (AMP), which is led by a Steering Committee that operates within the framework of the President's Council of Advisors on Science and Technology. In July 2012, the AMP Steering Committee delivered its report to PCAST, entitled *Capturing Domestic Competitive Advantage in Advanced Manufacturing*. PCAST adopted this report and submitted it to the President. The Steering Committee's report draws on preliminary reports prepared by several "workstreams." These workstream reports have been made available as on-line annexes to the Steering Committee report.

Report of the Advanced Manufacturing Partnership Steering Committee
Annex 2:

Shared Infrastructure and Facilities Workstream Report

EXECUTIVE SUMMARY

Upon extensive benchmarking and analysis of various shared infrastructures and facilities in the United States and abroad, the Advanced Manufacturing Partnership (AMP) Steering Committee's workstream on Shared Infrastructure and Facilities recommends two actions to improve the competitiveness of U.S. manufacturing: (1) establish a network of Manufacturing Innovation Institutes (MIIs) to bridge the gap between basic research performed at universities and national laboratories and the work done at U.S. production enterprises; and (2) establish a National Advanced Manufacturing Portal to provide searchable catalog of data, services, and facilities that are made available through publicly funded cooperative research centers and laboratories located within a large number of U.S. universities and national laboratories.

The MIIs, a network of public/private partnerships, would serve as regional centers for (1) promoting collaboration among industry, academia, and government on applied research and development in emerging technology areas, (2) facilitating the quick adoption of new manufacturing technologies, tools, and methodologies to make U.S. manufacturing more competitive, and (3) developing technical workforce with training and experience required by industry.

The Portal searchable on-line catalog of publicly funded research centers, services, and facilities would enhance access to these centers and facilities by small- and medium-sized manufacturers.

CHARGE TO THE WORKSTREAM

The objective of the Shared Infrastructure and Facilities Workstream is to assess opportunities to de-risk, scale up, and lower the cost of accelerating technology from research to production through unique capabilities and facilities that serve all U.S.-based manufacturers, in particular small- and medium-sized manufacturers.

PROCESS FOLLOWED

The AMP Steering Committee Shared Infrastructure and Facilities Workstream conducted an extensive benchmarking of the various shared infrastructure and facilities in the United States and abroad. We first identified a set of key attributes for the benchmarking exercise, including mission/charge, partnership model/governance, membership composition (number of large-, small-. and medium-sized companies), sectoral reach, geographical reach, funding

mechanisms, intellectual property (IP) agreement among parties, and metrics of success. We then identified a set of centers, institutes, and facilities from the United States and abroad for our benchmarking analysis. These entities included the National Institute of Standards and Technology (NIST) Center for Neutron Research, NIST Manufacturing Extension Partnership, National Science Foundation (NSF) Engineering Research Centers, Department of Energy (DOE) Innovation Hubs, California Innovation Hubs, National Nanotechnology Infrastructure Network, Semiconductor Research Corporation, Industrial Technology Research Institute of Taiwan, Advanced Manufacturing Centers in the U.K., and the Fraunhofer Institutes in Germany, among others. Key findings from the benchmarking and the desired attributes of an innovation infrastructure for advanced manufacturing are summarized in the section that follows.

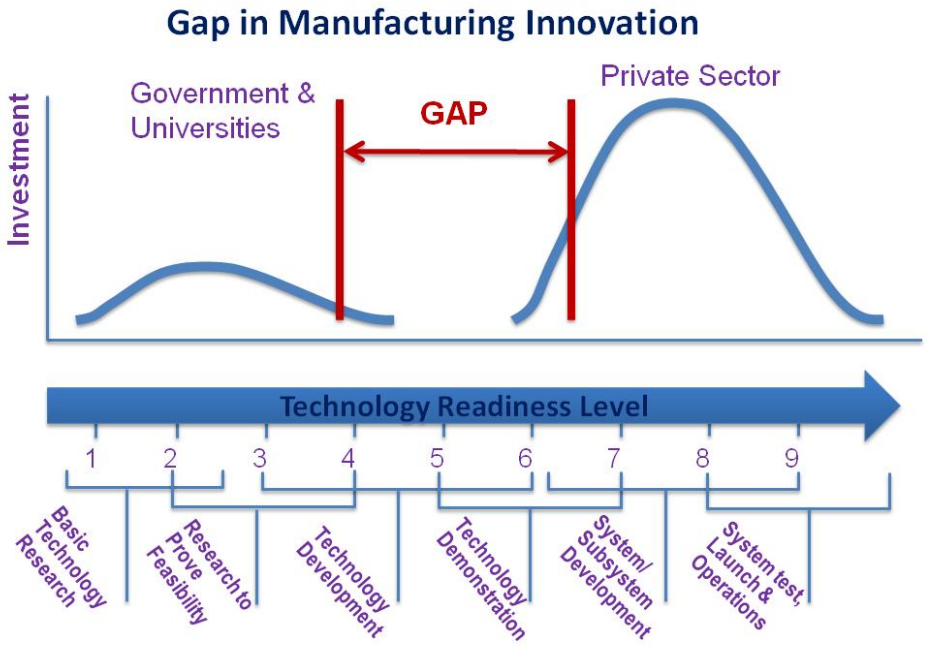
KEY FINDINGS

The United States has been a global leader in research and discovery, enabled by our first-class research universities and national laboratories. However, many of our research discoveries have not been quickly translated into products or applications in manufacturing in the United States. Many technologies fail to move to commercialization because the private sector, and particularly small- to medium-sized companies, is not able to make sufficient investment in early technologies and the cost of prototypes and scale-up are high. In fact, the stage from research to production is a perilous period in business development that is often called "the valley of death." This problem is attributable, in part, to the significant differences in the way activities in research and manufacturing are conducted. Basic research and new discoveries tend to happen in a largely disorganized endeavor, with the end goal most often being to publish the results in scientific journals. By comparison, manufacturing activities are competitive and must be focused and systematic. Channeling the results of research creativity into manufacturing requires systematic translation, supported by an "intelligent blend of public and private sector investment, targeting the most promising technologies" [1] and facilitated by shared infrastructure and facilities. Several countries have done well in this regard. In fact, the PCAST Report to the President on Ensuring American Leadership in Advanced Manufacturing provides various examples of products that are "invented here, but produced elsewhere" [2]. These examples include e-readers, flat panel televisions, semiconductor production equipment, and lithium-ion batteries. Many of these high-technology products are produced in China, Korea, and Taiwan where the governments continue to provide critical support for early technology adoption, manufacturing, and commercialization.

Our benchmarking exercise reinforced many of the observations that have been published in the various reports and reveals a significant gap in the U.S. innovation infrastructure:

- U.S. universities receive a great deal of Federal funding for basic and applied research. Though there has been an increasing emphasis by universities on technology transfer and commercialization, only a small number of discoveries and findings are translated into new products or useful methods, processes, or software to enhance economic competitiveness. Most federally funded research results in publications in scientific journals.

- The business sector performs the largest portion of U.S. research and development (R&D) work, using internal resources [3, 4]. Several large corporations, including Dow, Ford, GE, and GM, have realized the importance of long-term partnerships with academia in research and education and have developed such partnerships. But total industrial support for universities remains limited and rarely do small and medium-sized enterprises (SMEs) attempt to fund research grants and contracts with faculty members in research universities.
- The funding mechanisms for transferring the research findings and discoveries into tangible new products and manufacturing applications (e.g., NSF Small Business Technology Transfer [STTR] and Grant Opportunities for Academic Liaison with Industry [GOALI]) have been limited in their effectiveness to enhance manufacturing competitiveness due to the limited scale and duration of support.
- The United States lacks strong, branded intermediary institutes focused on applied R&D activities that bridge the gap between research and manufacturing.



- Large companies have developed staffs to produce the modeling and simulation software they need for competitive advantage, but the vast majority of SMEs are not capable of developing, acquiring, or using such software [5].
- The European Commission has demonstrated (through a Fraunhofer COVES Center) that SMEs can greatly improve their performance when they are provided appropriate assistance and use of modeling and simulation (M&S) capabilities [6].
- The new National Digital Engineering and Manufacturing Consortium (NDEMC) at Purdue University has provided M&S software to a few U.S. SMEs, which has allowed them to successfully compete against foreign manufacturers [7]. But only a few

universities and software companies are forming collaborative, multi-disciplinary teams that can produce the M&S software tools appropriately configured for SMEs to use.

- SMEs have a difficult time (1) finding what resources are available to them and (2) accessing those resources once they find them.
- The lack of real-world applied problem-solving experience by faculty and students in research universities has led to companies hiring college graduates that still require extensive training to function well in a company.

Our benchmarking also identified several key desirable attributes of a shared national infrastructure for supporting the translational activities for bridging fundamental research and manufacturing:

- Long-term partnership between industry and universities, enabled by government
- A sustained focus on technology innovation with a strong brand identity and reputation
- Ability to identify critical emerging technologies with transformational impact and capacity in translating these technologies into products and businesses for the market
- Ability to form effective teams of industrial and academic experts from multiple disciplines to solve difficult problems
- Dual appointments of faculty/students in both research universities and application-oriented institutions with access to fundamental research as well as opportunities for applied problem-solving to develop leaders and a workforce equipped to deal with the new technologies and production systems
- Ability to engage and assist small- to medium-sized companies that need new technologies

RECOMMENDATIONS

Manufacturing Innovation Institutes

Advanced manufacturing is defined by PCAST [2] as a "family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. This involves both new ways to manufacture existing products, and especially the manufacture of new products emerging from new advanced technologies." A national network of Manufacturing Innovation Institutes (MIIs) should be established to support advanced manufacturing. The initial areas of MII support would be in manufacturing technology areas recommended by the AMP Steering Committee Technology Development Workstream. Future areas of support could be expanded to include areas of emerging technologies that have the greatest potential for translation into products and businesses. These areas are to be identified through a regular advanced manufacturing technology roadmap process, as described by the Technology Development Workstream. (See Annex 1 for a recommended approach to develop

this permanent model and roadmap process). An open, competitive process with peer reviews ought to be used to establish the MIIs.

The goals of the MIIs are to promote collaboration among industry, academia, and government on applied R&D, to address emerging technology areas where market failures are causing U.S. innovations to be scaled up and manufactured elsewhere, to facilitate the quick adoption of new manufacturing technologies, tools, and methodologies that will make U.S. manufacturing more competitive, and to develop technical workforce with training and experience required by industry.

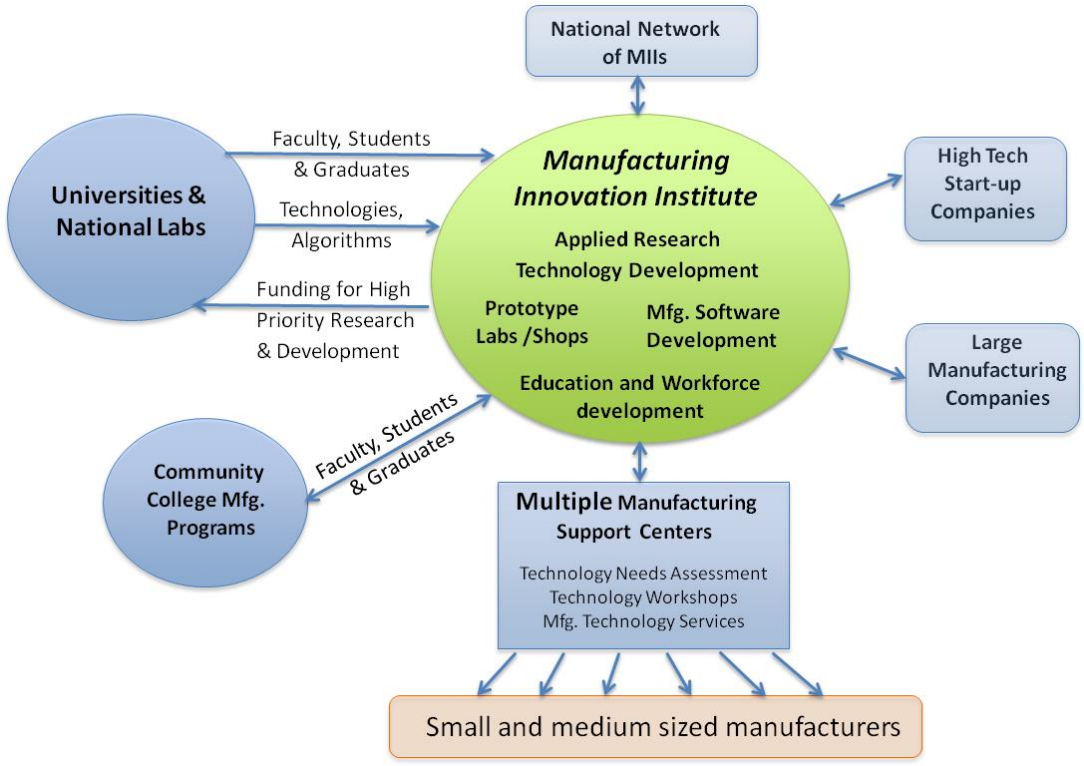
We recommend that each institute:

- Focus on an area of U.S. national economic strength or a promising emerging technology.
- Be supported by a mixed funding model with government funding being guaranteed for a minimum of 5 years with the potential of renewal for a total of 10 years, to allow for long-term project development and the ramp-up of private sector support.
- Be hosted by an industrial consortium, a university, or a national laboratory. A new or existing partnership would be eligible to apply for Federal Government funding with demonstrated commitments from industry, a state government, and a research institution. A partnership must have among its members a minimum of two large companies and shall have participation of related small- and medium-sized companies, and at least one major research university along with other regional universities and community colleges.
- Be governed by a Board of Directors composed of representatives from business, academic, and government organizations supporting the MII.
- Operate independently with contractual flexibility, but all MIIs will be members of the national network and will follow a similar governance model defined by a national governing board.
- Be staffed with full-time applied researchers who are experienced in bringing research into production, innovation enablers who support the process of technology identification and commercialization, short-term contract researchers who have specialized expertise, industrial scientists and engineers in residence, and part-time faculty, post-doctoral researchers, and student interns.
- Establish distributed manufacturing support centers throughout the region to support small- and medium-sized manufacturers that may adopt new technologies.
- Provide assistance to community colleges that seek to develop advanced manufacturing programs.
- Provide grants to other universities and businesses that are developing complementary and enabling technologies.

These MIIs would provide a shared infrastructure for technology development and serve as a "collaboratory" between research universities and businesses by providing existing and start-up businesses with greater access to research, students, internships, workforce training and development, technology transfer, and commercialization. They would also provide a variety of business services such as design, digital manufacturing, prototype and test services, and staff training.

A national manufacturing innovation infrastructure of this type would strengthen U.S. economic competitiveness in several fundamental ways:

- New technologies would not only continue to be invented in the United States, but many of them would be translated quickly into new products produced here, because the MIIs would reduce the risk of development and production through public/private partnership and shared facilities.
- Existing manufacturers would become more competitive as new manufacturing technologies, tools, and methods are transferred more effectively to production applications.
- Training of college graduates and re-education of industry workforce would be more relevant and responsive to the needs of manufacturers.
- New jobs would be created around specific technology clusters that are created and commercialized.



Funding for MIIs

Long-term government support for the MIIs would be necessary as it serves as a catalyst for long-term public/private partnerships. Private sector support, consisting of membership, contract projects, and revenues from commercialization, should be about a third of the total MII annual budget at steady state. This amount is to be matched by Federal Government funds. The remainder of the funding will be from state and university sources and other competitive grants. The Federal Government may provide a more significant portion of support during the launch and ramp-up stage of the MIIs.

Partnership: The membership fee structure for an MII shall be determined by its governing board. Membership fee and government support shall be used to support research projects of common interest. IP resulting from such projects shall be jointly owned by the members of the partnership. All members would have the option to acquire a nonexclusive, royalty-free license, in a field of use chosen by the member without the right to sublicense, to the patentable results of MII funded projects.

Contract research: An MII may engage in fee-based contract research and development with member or non-member companies. Rights to the IP from such contract research shall belong to the paying companies. Contract research and development may leverage shared infrastructure enabled by government support.

Performance Review for MIIs

The MIIs shall follow a regular schedule of independent reviews based on a set of criteria established by the MII network, which may include inventions and other IP, technology licenses, startups, companies (in particular, SMEs) supported, and company satisfaction. In addition to the annual review, a major review shall be carried out every 3 years. After a 3-year major review, an MII may be recommended for funding for another 5 years upon successful review (a second 3-year review will be carried out during year 6 or be recommended for closing within 2 years upon a negative review. An MII may re-compete for government support every 10 years if the MII adopts new technology focus areas.

Manufacturing Innovation Institutes Compared to Existing Research Entities

The MIIs represent a coordinated national network for supporting translational activities to bridge the gap between research and manufacturing. Translational research will be the hallmark of the new innovation infrastructure, with the primary measure of success being the number of new high-value products being manufactured by U.S. companies in the United States and new advanced manufacturing processes and technologies being adopted. The MIIs may be compared to the following existing research entities:

> *NSF Engineering Research Centers (ERCs)*: The ERCs are charged with conducting science-based research in creating the next generation of engineering systems and educating students at all levels about the science and technology of such systems. Activity within an ERC lies at the interface between the discovery-driven culture of science and the innovation-driven culture of engineering. Industry collaboration is required, but membership fee structure is not mandated by NSF, and industry serves in an advisory role (Industry Advisory Board).

NSF Industry and University Cooperative Research Centers (I/UCRCs): NSF began the I/UCRC program in 1973 and approximately 50 I/UCRCs have been supported by NSF. These are membership-based centers with NSF providing a small amount of support, ranging between $35 thousand and $70 thousand annually. To qualify for NSF support and I/UCRC designation, the membership must consist of six companies, with a total annual membership fee of $300 thousand. Industrial members serve on the Advisory Board. The types of research projects carried out in I/UCRCs vary greatly from center to center.

DOE Innovation Hubs: The concept of the Innovation Hubs was based on the Discovery and Innovation Institutes developed by James Duderstadt through the Brookings Institute. While the hub model is of value to the MIIs, the key difference lies in that the hubs are focused on advancing promising areas of energy science and engineering from the earliest stages of research to the point of commercialization and are funded entirely by the Federal Government. The Hubs also do not have a mandate to improve the technological capabilities of SMEs.

Example Technology Areas to Establish Manufacturing Innovation Institutes

The technology areas that we recommend be supported by the MIIs have been identified by the AMP Steering Committee Technology Development Workstream, and new ones would be identified through the regular Technology Roadmap exercise, as recommended by the Technology Development Workstream. Several technology areas that have received enthusiastic support from our regional meetings and industry surveys are:

Lightweight Structures: Composites, titanium, and other materials have wide applications in aerospace, automotive, and the defense industries. Cost-effective manufacturing of such materials into lightweight structures can lead to enhanced product performance and reduced energy consumption. An MII focused on developing innovative, cost-effective processes for these materials and the joining and assembly of them into structures would have a significant impact on performance and energy efficiency of commercial and defense products.

Manufacturing Scale-up for Flexible Electronics: Electronic circuits mounted and assembled on flexible substrates allow them to be reshaped and bent during use. Flexible electronics have many applications, including 360 degree cameras, sensors, health monitors, electrical connections between subassemblies and the like. An MII focused on the development of scalable production technologies for flexible electronics would lead to broad applications of flexible electronics, leading to new products and businesses.

Digital Manufacturing: Advanced simulation and modeling technologies enable manufacturers to predict product and manufacturing system performance with such great fidelity that they no longer have to build and test costly physical mock-ups of proposed new products, manufacturing processes, and facilities, which, in the past, resulted in added costs and long delays in bringing new products to markets. Unfortunately, small- and medium-sized companies, who comprise the supply chains to

large manufacturers, do not possess such modeling and simulation capabilities. At the same time, new modeling and simulation algorithms are constantly being developed in universities, but they are not directly usable in manufacturing. A Digital Manufacturing Innovation Institute could be set up as one of the first MIIs, with its missions being: (1) selecting, evaluating, and certifying existing manufacturing-related engineering modeling and simulation software; (2) providing grants to commercial software developers to provide "pay-as-you-use," cloud-based high-performance computing (HPC) software needed by SMEs that want to use simulations of existing and future manufacturing processes, materials, and operations; (3) providing funding to other universities and laboratories for the computational modeling of current research results related to new materials, manufacturing processes, and operations; and (4) supporting SMEs in digital manufacturing. Such an MII would help improve U.S. manufacturing competitiveness by shortening the time to market and improving quality and productivity of manufacturing.

National Advanced Manufacturing Portal

The goal of the National Advanced Manufacturing Portal is to provide a searchable catalog of data, services and facilities that are made available through publicly funded cooperative research centers and laboratories located within a large number of U.S. universities and national laboratories, in order to enhance access to such resources by small and medium-sized manufacturing firms in the U.S.

The proposal for a National Advanced Manufacturing Portal was developed in the spirit of addressing government coordination and data access issues recently highlighted by President Obama. Firms as well as industry and technology experts reported that conventional web searches (like Google) did not produce useful results. This problem is in part due to the vast variation and complexity of the research and innovation conducted throughout the U.S. network of cooperative research centers. Simply put, finding a practical answer to the simple questions that pervade advanced manufacturing such as, "Where can I find out if there is a better adhesive that works just as well as the one I use now?" or "Is there an alternative to this film coating?" is nearly impossible for small firms with limited time and limited R&D staff.

The National Advanced Manufacturing Portal would address this problem by creating a single web portal where SMEs (as well as others) can search for the cooperative research centers that best meet their needs. With this information, firms can make both short and long-term R&D plans. The Portal would make progress towards the goal of "pushing innovation down the supply-chain" by providing SMEs with the ability to plan their process innovations as well as improve the design and development of new products. It would connect firms to the existing network of publicly funded R&D resources that are meant (by legislative intent and design) as access points for SMEs to gain technical assistance and information about advanced manufacturing processes.

The National Advanced Manufacturing Portal would provide a current catalog of information about 1) what can be accessed (the portfolios of the cooperative research centers) and 2) what technical assistance and resources SMEs want to access (their inquiries). It would

also allow state and local science and technology policymakers to quickly find what federally funded resources are available. It would also allow researchers to determine the relative coverage of S&T resources in a given area or in a targeted technology. This could lead to vastly more efficient S&T policy investment and coordination.

Second, this "open web portal" would be designed to provide an even playing field for firms and allow them to cross technology, industry, and sector boundaries. This open format would not require targeting (and the constant reevaluation of targets) of technology/sector investments. The real-time innovation on the R&D side (the institutions) would determine how they write/update their searchable catalog portfolios and the real-time production (and pre-production) needs of firms define their search queries. No intermediary would be required to guess the scope and definitions of firm needs or technological capacities. No central authority would be required to keep up with the innovations at cooperative research centers.

Almost all private sector or pilot "web-portal" projects are member-based (meaning log-ins or memberships are required) and/or sectoral in coverage. These also typically try to connect up a supply-chain. Also, private sector web portals and databases are largely intended to sell something. These resources either connect suppliers to contractors or sell R&D services, intellectual property, or technical assistance to production firms. This web portal would serve solely as an information intermediary rather than a market intermediary.

The up-front resource requirements to launch and maintain the Portal are comparatively small; cooperative research centers would provide and update the information on their own facilities through a web reporting interface using a standardized format. This reporting would produce the content portion of the National Advanced Manufacturing Portal. The web portal itself would need to be hosted and maintained by an appropriate federal agency.

Design of the Portal

The portal will be in the form of a searchable catalog of publicly funded cooperative research centers. Initial implementation is limited to peer-reviewed facilities (i.e. grant-recipients of public funding) in order to ensure quality of facilities listed. The intended user group is SMEs, but its use is not restricted.

Searchable Fields in the Catalog (drop-down menus):

- Where is the facility? (city, state)
- What is the facility? (name, network, partners)
- Technology specializations (organic photonics, thin film coatings)
- Industry specializations (OPVs, medical devices, printed electronics)
- Sector specializations (energy, health, aerospace, space, defense, consumer electronics)
- Keyword (nuclear, oak ridge, Atlanta)
- What equipment is available to firms? (particle accelerator)
- Is technical assistance available? (Y/N)
- Is training available? (Y/N)
- Is there a fee for access? Different fee structures? (Y/N)
- Are scale-up facilities on site? (Y/N)

- Is there a proposal review process required? (Y/N)
- Are certification services available (environmental, ISO, CCC's)? (Y/N)
- Can small production runs be conducted? (Y/N)

Cooperative Research Center Portfolios in the National Advanced Manufacturing Portal (a brief description written by each CRC elaborating on the following):

- What are the costs/fees for access to equipment?
- What technical assistance is available to firms?
- What are the IP arrangements including non-disclosure agreements?
- What kind of incumbent worker training is available?
- What are the requirements for access?
- What is the training process?
- What is the time line for access?
- What certifications are available?
- Whom do I contact?

Content Generation and Maintenance

Publicly funded agencies would submit and regularly update content on their facilities and resources (as a reporting requirement of public funding). The resulting track-able inquires (counts of inquires on particular technologies, resources, types of centers, equipment) can feed back into a better understanding of the needs of firms, creating the possibility of improved targeting of specific actors and the services most needed (for example: SMEs and assistance with process innovations).

Suggestions for Implementation/Launch:

- Use mailing lists of existing programs to broadcast availability (for example, the MEPs have over 30,000 client firms)
- NIST/MEP might serve as administrative host agency
- Link to manufacturing.data.gov and/or other non-profit and public web portal networking initiatives (such as Autoharvest.com)
- Coordinate with portal initiatives in other Federal agencies that are focused on other aspects of the pre-production process
- The developer of the Portal should be well versed in the variation in cooperative research center structures (university-based, public sector, and public/private partnerships)

CONCLUSIONS

To enable the United States to successfully translate discoveries into products or applications in manufacturing, the AMP Steering Committee Shared Infrastructure and Facilities Workstream recommends the establishment of a national network of Manufacturing

Innovation Institutes (MIIs) to bridge the gap between basic research performed at universities and national laboratories and the work done at U.S. production enterprises. These institutes would serve as an anchor for technology development, education, and workforce training.

MIIs should support prioritized manufacturing technology areas, focusing initially on those recommended by the Advanced Manufacturing Partnership Steering Committee, and subsequently on high priority new technologies as they arise. Future areas of support would be expanded to include emerging technologies that have the greatest potential for commercialization. These areas should be identified using a permanent model and roadmap process for prioritizing investment in advanced manufacturing technology. An open, competitive process with peer reviews should be used to establish the MIIs. (See Annex 1 for a recommended approach to develop this permanent model and roadmap process).

We recommend that at least 5 such Institutes be established in 2012, increasing by 5 per year with the goal of establishing a total of 30 over a 6-year period.

We also recommend the establishment of a National Advanced Manufacturing Portal that would support rapid technology development and commercialization among the SME community by providing a roadmap to existing shared facilities and resources to support their work.

REFERENCES

1. E. Mills and J. Livingston, "Traversing the Valley of Death," *Forbes.Com*, November 17, 2005.
2. President's Council of Advisors on Science and Technology, "Report to the President on Ensuring American Leadership in Advanced Manufacturing," June 2011.
3. National Science Board, "Chapter 4, R&D: National Trends and International Comparisons," in *Science and Engineering Indicators 2010.*
4. Battelle and *R&D Magazine*, "2012 Global R&D Funding Forecast," December 2011, http://www.battelle.org/aboutus/rd/2012.pdf.
5. B. Feiereisen, "High Performance Computing for Manufacturing—Why is it Not Used Everywhere?" in *Digital Manufacturing Reports*, October 11, 2011, http://www.digitalmanufacturingreport.com/dmr/2011-10-11/high_performance_computing_for_manufacturing_%E2%80%93_why_is_it_not_used_everywhere_.html.
6. A. S. Kazi, T. Ristimaki, O. Balkan, M. Kürümlüoglu, J. Finger, and T. Sustar, " Model-Based Collaborative Virtual Engineering in the Textile Machinery Industry: Living Lab Case Study," ICE 2009, 15th International Conference on Concurrent Enterprising, http://85.236.55.73/Projects/444/ICE%202009%20Conference%20Paper/3_ICE2009_CoVES_Living%20Lab%20Case_Balkan.pdf.
7. Council on Competitiveness, "U.S. Manufacturing—Global Leadership through Modeling and Simulation," 4 March 2009, http://www.compete.org/images/uploads/File/PDF%20Files/HPC%20Global%20Leadership%20030509.pdf.