SECURING ADVANCED MANUFACTURING IN THE UNITED STATES

The Role of Manufacturing USA

PROCEEDINGS OF A WORKSHOP

Sujai Shivakumar and Gail Cohen, Rapporteurs

Innovation Policy Forum

Board on Science, Technology, and Economic Policy

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Preface

Manufacturing USA, originally established as the National Network for Manufacturing Innovation program, was formally established in 2014 to "bring together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure."[1] Operated by the interagency Advanced Manufacturing National Program Office; headquartered in the National Institute of Standards and Technology; and operating in partnership with the National Aeronautics and Space Administration, the National Science Foundation, and the Departments of Defense, Energy, Education, Agriculture, and Labor, Manufacturing USA is intended to create partnerships that leverage existing resources and facilitate collaboration and co-investment to nurture manufacturing innovation, accelerate commercialization, and foster a skilled manufacturing workforce. Fourteen institutes have been established to date.

On May 23, 2017, the National Academies of Sciences, Engineering, and Medicine convened a workshop to explore the role of the Manufacturing USA initiative. The specific tasks of the meeting were to "examine external reviews of the Manufacturing USA Institutes; provide an in-depth discussion of particular institutes; address the contributions of the institutes to workforce and economic development; describe how other nations are supporting advanced manufacturing; and discuss potential U.S. priorities and policies for action." (See Box 1-1, Project Statement of Task.)

The workshop was organized by a planning committee under the auspices of the National Academies' Innovation Policy Forum, which acts as a focal point for national and international dialogue on innovation policy. Operating under the guidance of the Board on Science, Technology, and

[1]Manufacturing USA website, *Program Details*. Access at https://www.manufacturingusa.com/pages/program-details.

Economic Policy (STEP), the Forum brings together representatives of government, industry, national laboratories, research institutes, and universities—foreign and domestic—to exchange views on current challenges and opportunities for U.S. innovation policy. It provides a platform for learning about the goals, instruments, funding levels, and results of national and regional programs and discussing their lessons for U.S. policy.

This particular Forum workshop built on previous work of the STEP Board, including the 2012 report *Rising to the Challenge: U.S. Innovation Policy in the Global Economy*, in which the authoring committee recommends expanded support for manufacturing,[2] and the 2013 report *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program*, in which the authoring committee recommends that "any effort to establish programs to further support manufacturing should thoroughly assess existing U.S. resources, organizations, and institutions already engaged in applied research and should take into account lessons from U.S. and international best practice."[3] In addition, the 2014 report *21st Century Manufacturing: The Flexible Electronics Opportunity* examines the potential of public–private consortia to facilitate applied research and manufacturing, as well as other measures to support the development of the flexible electronics industry in the United States.[4] Together, these reports describe current U.S. efforts as well as substantial programs initiated by leading nations to support advanced manufacturing and are relevant to understanding the wider context of U.S. initiatives to support advanced manufacturing.[5]

This proceedings has been prepared by the workshop rapporteurs as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning and convening the workshop. The views contained in the proceedings are those of individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, or the National Academies of Sciences, Engineering, and Medicine.

[2]National Research Council, *Rising to the Challenge: U.S. Innovation Policy in the Global Economy*, Washington, DC: The National Academies Press, 2012, Recommendation 5-d.
[3]National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program*, Washington, DC: The National Academies Press, 2013, Recommendation 8.
[4]National Research Council, *21st Century Manufacturing: The Flexible Electronics Opportunity*, Washington, DC: The National Academies Press, 2014.
[5]National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program,* 2013, Appendix A.

ACKNOWLEDGMENT OF REVIEWERS

This Proceedings of a workshop was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published proceedings as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We thank the following individuals for their review of this proceedings: William Bonvillian, Massachusetts Institute of Technology; Thomas Kurfess, Georgia Institute of Technology; Tom Guevara, Indiana University; Ira Moskowitz, Massachusetts Technology Collaborative; and Gregory Tassey, University of Washington.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the content of the proceedings nor did they see the final draft before its release. The review of this proceedings was overseen by Jan Youtie, Georgia Institute of Technology. She was responsible for making certain that an independent examination of this proceedings was carried out in accordance with standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the rapporteurs and the National Academies.

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Introduction

The Manufacturing USA initiative seeks to reinforce U.S.-based advanced manufacturing through partnerships among industry, academia, and government. Begun in 2012 and established with bipartisan support by the Revitalize American Manufacturing and Innovation Act of 2014 (RAMI Act), the initiative envisages a nationwide network of research centers for manufacturing innovation.[1] As of May 2017, 14 manufacturing innovation institutes had been established to facilitate the movement of early-stage research into proven capabilities ready for adoption by U.S. manufacturers.

To better understand the role and experiences of the Manufacturing USA institutes to date, a committee of the Innovation Policy Forum of the National Academies of Sciences, Engineering, and Medicine convened a workshop on May 23, 2017 drawing together institute directors and manufacturing policy experts along with leaders from industry, academia, and government. The presentations and discussions at this workshop addressed the role of the manufacturing institutes in increasing advanced manufacturing in the United States, examined selected foreign programs designed to support advanced manufacturing, and reviewed recent assessments of existing institutes. Presenters and participants also shared lessons learned and improvements and additional tasks that could be considered and adopted in the future by the institutes. (See Box 1-1, Project Statement of Task.)

The key cross-cutting themes of the workshop are highlighted in Chapter 2. This is followed in Chapter 3 by a detailed summary of the presentations. Finally, Chapter 4 outlines the key points made at the workshop. The appendixes provide the workshop agenda (Appendix A), biographies of speakers and planning committee members (Appendix B), and a list of workshop participants (Appendix C). The remainder of this introduction

[1]Section 3 of the RAMI Act calls for the establishment of Network for Manufacturing Innovation. Access at https://www.govtrack.us/congress/bills/113/s1468/text.

BOX 1-1
Project Statement of Task

To inform the work of the Innovation Policy Forum, an ad hoc planning committee under the oversight of the Board on Science, Technology, and Economic Policy (STEP) will organize a workshop to explore the role of the Manufacturing USA initiative, which is intended to create partnerships among industry, academia, and government that leverage existing resources and facilitate collaboration and co-investment to nurture manufacturing innovation, accelerate commercialization, and foster a skilled manufacturing workforce. The workshop discussion will examine external reviews of the Manufacturing USA Institutes; provide an in-depth discussion of a particular institute; address the contributions of the institutes to workforce and economic development; describe how other nations are supporting advanced manufacturing; and discuss potential U.S. priorities and policies for action. A proceedings of the presentations and discussions at the workshop will be prepared by a designated rapporteur in accordance with institutional guidelines.

presents background information on the history of the manufacturing institutes and on the federal role in this public–private partnership.

THE IMPETUS FOR MANUFACTURING USA

As Jeffrey Wilcox of Lockheed Martin noted in his keynote remarks at the workshop, the Manufacturing USA effort began with a 2011 report by the President's Council of Advisors on Science and Technology (PCAST) entitled *Ensuring American Leadership in Advanced Manufacturing*. Drawing on analyses from industry and academia, that report notes that manufacturing has declined as a share of U.S. gross domestic product and employment. Moreover, the report points out that this decline extends to advanced technologies that are invented in the United States, but increasingly manufactured elsewhere. Recognizing that technology innovation is closely tied to manufacturing knowledge, the report concludes that the United States cannot remain the world's engine of innovation absent a strong domestic advanced manufacturing sector.[2]

The PCAST report calls for an initiative that "would support innovation in advanced manufacturing through applied research programs for promising new technologies."[3] It envisions the advancement of this initiative through public–private partnerships formed around broadly applicable and precompetitive technologies. The report also calls for "the creation and

[2]President's Council of Advisors on Science and Technology, *Ensuring American Leadership in Advanced Manufacturing,* Washington, DC: The White House, 2011.
[3]Ibid.

dissemination of design methodologies for manufacturing, and shared technology infrastructure to support advances in existing manufacturing industries."[4]

To develop actionable proposals from the general findings of this report, the Advanced Manufacturing Partnership (AMP) was created. This group of leading corporate leaders and university presidents—chaired by Andrew Liveris, chairman, president, and CEO of Dow Chemical, and Susan Hockfield, then president of the Massachusetts Institute of Technology—released its first set of operational recommendations in 2012 These included calls for a system of manufacturing institutes, after a nationwide outreach and engagement process.[5] AMP was followed by AMP 2.0, a second project and report that included a major outreach and engagement effort to design policies to supplement and support the manufacturing institutes.[6] Wilcox recalled that, "all that led to executive action, which created the first of the National Network of Manufacturing Institutes (NNMI), all of which was eventually codified and made statutory through bipartisan support for the 2014 RAMI Act." The NNMI was rebranded as Manufacturing USA in 2016.

THE FEDERAL ROLE IN THE MANUFACTURING USA PARTNERSHIP

Bringing industry, academia, and government partners together within a growing network of advanced manufacturing institutes, Manufacturing USA is designed to increase U.S. manufacturing competitiveness. Each institute is an applied research center focusing on "early-phase" technology development (i.e., a "proof-of-concept" or "technology platform" development). It provides a venue where industry, academia, and government partners conduct research and development on applied manufacturing technologies of a focused nature. The benefits of this research accrue to the institute members, participants in related supply chains, and in the long run, to the nation as a whole.[7] According to the Manufacturing.gov portal, the institutes seek to

> catalyze cooperation between U.S. companies and researchers from universities and federal laboratories to rapidly develop ideas and inventions into products and processes that can be used by U.S. manufacturers. By involving small and large

[4]Ibid.
[5]President's Council of Advisors on Science and Technology, *Capturing Domestic Competitive Advantage in Advanced Manufacturing: AMP Steering Committee Report*, Washington, DC: The White House, 2012.
[6]President's Council of Advisors on Science and Technology, *National Network for Manufacturing Innovation: A Preliminary Design,* Washington, DC: The White House, 2013.
[7]National Institute of Standards and Technology, "Frequently Asked Questions, 2016 NIST NNMI Institute Competition. Access at http://www.nist.gov/sites/default/files/documents/amo/NNMI2016FAQ.pdf.

> U.S.-based companies, the Manufacturing USA institutes stimulate the formation of manufacturing ecosystems, building advanced capabilities into the domestic supply chain so that new technologies developed in the U.S. are manufactured here in the U.S. rather than in other countries. Each institute works to ensure that American workers are trained for the high-paying jobs needed to manufacture these new technologies.[8]

The institutes are structured as private–public partnerships funded in part through cooperative agreements between the sponsoring federal agency and a nonfederal entity in charge of operations. The federal funding level is typically $70–$110 million, matched or exceeded by funding from private industry and other nonfederal sources, with a minimum 1:1 cost share.[9] Each institute is funded through a multiyear (minimum 5, maximum 7) cooperative agreement. As sponsoring agencies, the Department of Defense (DOD), the Department of Energy (DOE), and now the National Institute of Standards and Technology (NIST), through their separate appropriations, fund the institutes. The federal contribution decreases with time, and the institutes are expected to become self-sustaining over a period of 5 to 7 years.

As of May 2017, DOD, DOE, and NIST collectively had signed agreements to establish 14 manufacturing innovation institutes, located across the nation (see Figure 1-1). Four of these institutes were established prior to enactment of the RAMI Act. This legislation also established the Advanced Manufacturing National Program Office (AMNPO), an interagency team with core staff hosted at NIST, to coordinate federal activities in advanced manufacturing. The total federal commitment over the entire cooperative agreement period for the 14 institutes is approximately $1 billion, at present matched by more than $2 billion in nonfederal funding.[10]

[8]See https://www.manufacturing.gov.

[9]In his presentation at the workshop, Mike Molnar reported that, in terms of financial leverage, FY 2016 matching was nearly 2 to 1, surpassing the minimum requirement. Of the $333,808,455 in total institute expenditures, 66 percent of institute funding came from nonfederal matching funds and 34 percent from non-program matching expenditures. This funding supports all aspects of institute operation, including technology advancement projects, education and workforce training efforts, and capital equipment.

[10]Advanced Manufacturing National Program Office, *National Network for Manufacturing Innovation Program Annual Report*, Washington, DC: The White House, 2016.

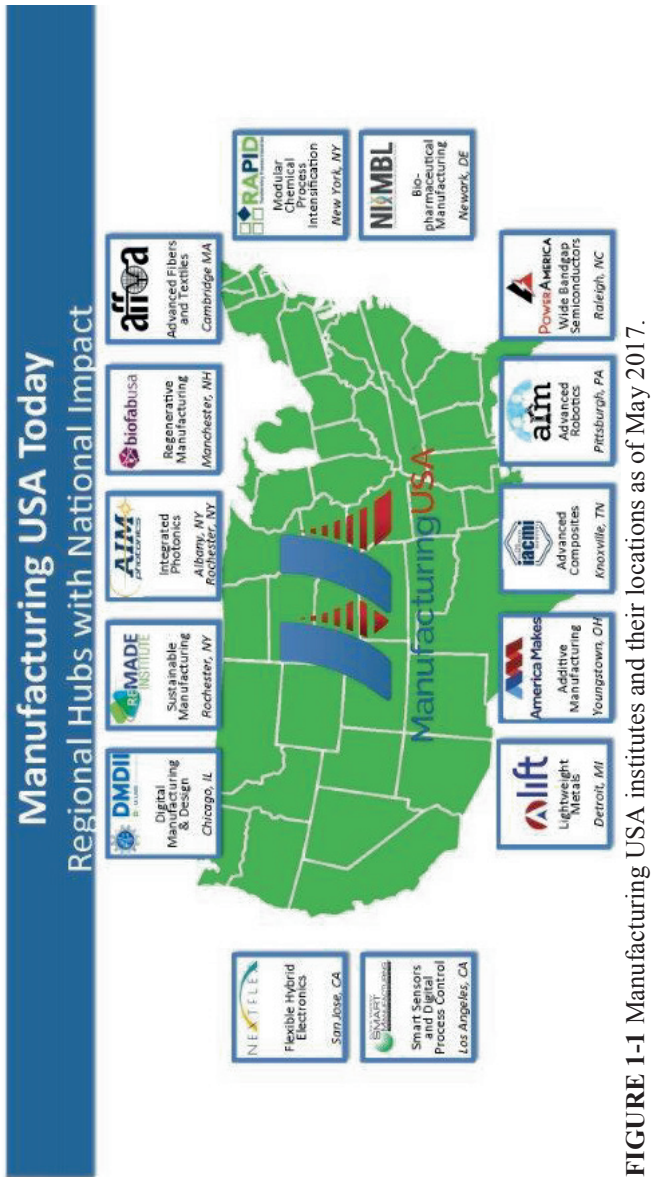

FIGURE 1-1 Manufacturing USA institutes and their locations as of May 2017.
SOURCE: Manufacturing USA.

2

Key Cross-Cutting Themes

Several cross-cutting themes emerged from the workshop presentations and discussions:

- **Importance of public–private partnerships in advanced manufacturing**—Various speakers described the relationship between a robust manufacturing sector and national security, job creation, and economic growth. They also described the results of past disinvestments in domestic manufacturing and explained how market failures may impede progress in U.S.-based advanced manufacturing.
- **Role of the Manufacturing USA institutes**—Multiple presenters emphasized the role of the manufacturing institutes in connecting university research to manufacturers, drawing new manufacturing technologies and techniques into small and large firms, fostering regional innovation ecosystems, and developing the skilled technical workforce.
- **Lessons from foreign programs**—A number of workshop participants drew comparisons and contrasts with the nature and scale of efforts in China and Germany to accelerate the development and adoption of advanced manufacturing techniques.

In addition, the workshop included an overview of recent assessments of the Manufacturing USA institutes by Deloitte, by the Government Accountability Office, and by the Advanced Manufacturing National Program Office (AMNPO) within the National Institute of Standards and Technology (NIST). Suggestions also were gathered from participants in all panels on improving the strategy and operations of the Manufacturing USA institutes. These ideas ranged from improving workforce training, to networking more effectively with state and regional organizations, to more effectively demonstrating to policy makers the return on public investments in the institutes.

Finally, participants addressed the challenge of sustaining the Manufacturing USA initiative.

IMPORTANCE OF PUBLIC–PRIVATE PARTNERSHIPS IN ADVANCED MANUFACTURING

Several participants mentioned the decline in U.S. manufacturing and the spillover effects on the entire economy as an impetus for the federal role in this public–private partnership. They made the case that a strong domestic manufacturing sector is important to sustain economic growth, create high-value employment, and carry out national missions in defense and national security.

Susan Helper, a professor at Case Western Reserve University, pointed to data showing that manufacturing matters to the United States because it provides high-wage jobs, spurs commercial innovation, improves competitiveness and reduces trade deficits, and makes a large contribution to environmental sustainability. She added that manufacturing plays a disproportionate role in innovation, accounting for 68 percent of private-sector research and development (R&D) spending.[1] Further, she argued that the existence of a wage premium in the manufacturing sector—the idea that at higher skill levels, manufacturers pay more—contributes to a higher standard of living for Americans.

Mark LaViolette, a specialist leader at Deloitte, emphasized the positive impact of advanced manufacturing across the U.S. economy. Through a multiplier effect, he said, manufacturing activity supports trillions of dollars of production in other parts of the economy through transactions covering more than 80 different industries, ranging from transportation to education.[2]

Erica Fuchs of Carnegie Mellon University made the point that jobs materialize when workers in the United States "make products no one else can." The result, she said, is the need for policies that drive innovation in production technologies and practices, as exemplified by the manufacturing institutes.

Sridhar Kota, a professor at the University of Michigan, asserted that the United States needs a strong advanced manufacturing base to carry out missions in defense and national security. Maintaining a qualitative overmatch in technology, he argued, provides a competitive advantage for the military. Arun Seraphin, a professional staff member on the staff of the Senate Armed Services Committee, agreed, adding that policy makers support the need to manufacture advanced technological products and components critical to the nation's security in trusted and reliable domestic production facilities.

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[1]Susan Helper, Timothy Krueger, and Howard Wial, *Why Does Manufacturing Matter? Which Manufacturing Matters? A Policy Framework*, Washington, DC: The Brookings Institution, 2012.
[2]See Robert E. Scott, *The Manufacturing Footprint and the Importance of U.S. Manufacturing Jobs*, Washington, DC: Economic Policy Institute, 2015. Access at http://www.epi.org/publication/the-manufacturing-footprint-and-the-importance-of-u-s-manufacturing-jobs.

In his keynote address, Jeff Wilcox, vice president for engineering and program operations at Lockheed Martin, noted that the link between manufacturing and national security was established early in the history of the republic. Alexander Hamilton, he said, "understood just how precarious the situation was that we did not have a defense industrial base in the colonies at that time. He proceeded to advocate for those policies."[3] Hamilton's arguments proved persuasive, Wilcox continued, and President George Washington declared in his first State of the Union address that the safety and interest of a free people require that they promote such manufacturers as necessary to render the new nation independent of others for essential supplies. Taking this notion forward, Hamilton established a state government–industry partnership that harnessed the waterfalls in Paterson, New Jersey, to power mills and stimulate a new industrial cluster.[4]

The Decline of U.S.-Based Manufacturing and Its Impacts

The advantages gained from domestic innovation and production, some workshop participants warned, are threatened by the atrophy of the U.S. manufacturing sector, particularly over the first decade of this century. The manufacturing institutes, they observed, were designed to regenerate production in the United States and to capture its associated benefits through introduction of much more efficient production technologies and processes, restoring a competitive edge.

Documenting the decline, Susan Helper noted that "we had a fairly constant size manufacturing sector—15 to 17 million people—then it fell off a cliff between 2000 and 2010. We lost a third of manufacturing jobs then, and there has been a comeback—about 900,000—since."[5] The factors behind this decline, she said, have "to do with globalization, trade agreements, strong dollar, automation, financialization, a focus on short-term corporate results, and a lack of support for sustaining the so-called industrial commons."

André Gudger, founder and CEO of Eccalon, noted that the industrial commons—a reinforcing network of research organizations and manufacturing facilities—was further degraded when U.S. businesses began to disinvest in large-scale, billion-dollar research organizations.[6] Although research

[3]Alexander Hamilton, *Report on Manufactures*, Communicated to the House of Representatives, Washington, DC, December 5, 1791.

[4]Similarly, in 1794, the War Department created government-owned armories in Springfield and Harpers Ferry for improved arms production; these facilities led to machine-made interchangeable parts and early mass-production technologies. See Merritt Roe Smith, *Harpers Ferry Armory and the New Technology*, Ithaca, NY: Cornell University Press, 1977, p. 28.

[5]Justin R. Pierce and Peter K. Schott, *The Surprisingly Swift Decline of U.S. Manufacturing Employment*, CESIFO Working Paper No. 4563, Munich, Germany: Center for Economic Studies and Ifo Institute, January 2014. Access at https://www.cesifo-group.de/ ifoHome/ publications/ working-papers/CESifoWP/CESifoWPdetails?wp_id=19104020.

[6]Gary P. Pisano and Willy C. Shih, "Restoring American competitiveness," *Harvard Business Review*, July–August 2009 Issue.

organizations such as Bell Labs generated intellectual property, he added, "such long-term research and development investments didn't look good on corporate balance sheets, so out they went. As a result, we further eroded that part of our industrial base."

Citing her research, Erica Fuchs further explained that when production of existing technologies is moved abroad to take advantage of lower wages and costs, production of the most advanced technologies developed in the United States can also become unprofitable.[7] Her research showed that in the case of advanced composites, older technologies may still be profitable abroad, but there is no incentive for domestic innovation. In the case of optoelectronics, she found that large minimum efficient scale of production and the dysfunctional effect of separating R&D from manufacturing, which had largely shifted abroad, created barriers to domestic production. In this way, she drew a direct connection between the loss in U.S. production capability and the nation's loss in ongoing innovation.

Kirk McConnell, a professional staff member on the staff of the Senate Armed Services Committee, linked the collapse of manufacturing employment to serious negative social impacts, including—in some cases—rising mortality rates and high levels of opioid addiction, particularly among working-class white Americans. He observed that the decline of the manufacturing sector also coincides with poor gains in productivity, adding that "if you don't gain in productivity, you have a moribund economy. And if you don't have a healthy economy, you don't have a strong defense."

Several speakers held out the possibility of an alternative, more positive narrative. Helper suggested that the decline of the manufacturing workforce need not be preordained. She cited Germany—where 20 percent of the workforce is engaged in the manufacturing sector, compared with 8 percent in the United States—as an example of a high-wage, developed economy that has successfully maintained a high level of manufacturing employment.

Nickolas Justice, executive director of the PowerAmerica institute, acknowledged that the offshoring of production and related research activities raises questions about the future of manufacturing in the United States. But he argued that the Manufacturing USA institutes present an important opportunity to reestablish "the lost connection with our people by designing here, by working together with people, and then trying to figure out how you are going to translate that into the economy."

Sridhar Kota agreed that "the government in partnership with the private sector has a role to nurture and mature these technologies and reduce the technical and market risk." And, he added, "we want to ensure that we anchor manufacturing of these technologies here; you cannot just mature the technology and give it to your friends and competitors overseas."

[7]Erica R. H. Fuchs, "Global manufacturing and the future of technology: Where you manufacture changes what you get," *Science* Vol. 345, Issue 6196, August 1, 2014.

The Need for Partnership Mechanisms

Advancing manufacturing through research and into production is a complex challenge. Susan Helper and others observed that misaligned incentives may inhibit the emergence of market solutions, requiring new public–private partnership mechanisms to promote cooperation.

Economic theory, Helper noted, predicts that private companies are unlikely to invest in producing new knowledge, which tends to spill over to rivals. This "market failure" means that companies will normally underinvest in R&D when other firms can benefit from their effort at little or no expense, and when there is, as a result, no relative advantage to be gained from the investment. Her point was that collaboration through partnerships reduces the risk and cost of developing innovative production technologies to individual firms, and speeds up adoption across industry.

The nature and degree of market failure varies over the R&D cycle. In this regard, Helper described three obstacles to the cooperation that can lead to a better manufacturing sector. The first is what she called the "missing middle"—the gap between investment by government and universities in emerging technologies at the earliest stages and investment by the private sector in the later stages.[8] She argued that public–private partnerships such as the Manufacturing USA institutes have a role to play in sustaining investments in manufacturing-related R&D to bridge this gap.

The second obstacle derives from weaknesses in the supply chain. Helper noted that large companies used to do a great deal of R&D in house. As firms have restructured to rely more on outside suppliers, she explained, their incentive to invest in research has diminished because the suppliers can offer the benefits of an innovation to the company's rivals as well. The innovative small startup firms that increasingly advance the technological frontiers and supply the larger aggregators also face a variety of obstacles, from securing financing to commercializing new and unknown technologies.[9] While small manufacturers represent 98 percent of manufacturing establishments, Helper observed, they perform only 33 percent of R&D. She suggested that the manufacturing institutes can help overcome these obstacles; by bringing supply chains in an industrial sector together, the institutes can enable smaller firms to obtain much better access to production innovations.

Helper identified a poorly trained workforce as the third obstacle to a more robust manufacturing sector. She noted that students and workers face a variety of challenges in linking to and persisting with appropriate training programs, as well as in keeping in pace with the changing needs of the

[8]For a description of the "missing middle" in the manufacturing ecosystem, see National Research Council, *21st Century Manufacturing: The Flexible Electronics Opportunity*, Washington, DC: The National Academies Press, 2014, pp. 13–15.

[9]For a review of challenges facing small innovative manufacturers, see National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program*, Washington, DC: The National Academies Press, 2013, Chapter 2.

manufacturing sector.[10] Here, too, manufacturing institutes could serve as a new training delivery mechanism to educate firm workforces in the new technologies they are delivering.

Helper concluded by observing that "we have a fragmented ecosystem, with a lot of potential for sharing and a lot of interdependence that is not being captured. Manufacturing USA could be a key hub to overcome that and become a key lynchpin of future policy."

ROLE OF THE MANUFACTURING USA INSTITUTES

Mike Molnar, founding director of the Office of Advanced Manufacturing (OAM), National Institute of Standards and Technology (NIST), described the mission of the Manufacturing USA program as one of "connecting people, ideas, and technology to solve industry-relevant advanced manufacturing challenges, thereby enhancing industrial competitiveness and economic growth and strengthening our national security." In line with this mission of growing and strengthening the manufacturing ecosystem in the face of a rapidly and ever changing environment, other presenters shared their views on how the institutes help to develop and commercialize new technologies, grow networks among research organizations and small and larger companies, and develop a skilled technical workforce.

Connecting University Research to Industry

The directors of several Manufacturing USA institutes described how their organizations have served as a bridge between universities and research laboratories and firms.

Lawrence Brown of Lightweight Innovations for Tomorrow (LIFT) explained that his institute's goal is to take the new technologies that emerge from universities and government laboratories, develop these ideas, and connect them to industry in a way that has impact.

Kelvin Lee of the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) stated that manufacturing paradigms and technologies in biopharma are relatively immature. He asserted that NIIMBL plays an important role in forging the cooperation needed to bring the research being conducted in this area to the next level. "In order to increase automation," he said, "in order to address some of the needs of patients going forward, we need to find a way to bring the stakeholders together."

Describing the role of the PowerAmerica institute, Nickolas Justice observed that "the process of cooperatively developing a roadmap with academic and industry partners helps to share ideas and build trust needed to

[10]For a review of workforce training and education challenges, see National Academies of Sciences, Engineering, and Medicine, *Building America's Skilled Technical Workforce*, Washington, DC: The National Academies Press, 2017.

grow the manufacturing ecosystem." Through dialogue and the sharing of ideas, he said, "you start building that supply chain because you [are] building a roadmap, but you [are] also building trust."

Yoel Fink of Advanced Functional Fabrics of America (AFFOA) suggested that although universities are often reluctant to give up intellectual property developed by their researchers, the institutes could act as their agent and facilitate their use. "By giving AFFOA this right to license or sub-license, universities could draw in investment and dedicated marketing resources to get their intellectual property to the market," he said.

Drawing Innovation into Large Firms

Jeff Wilcox explained that the Manufacturing USA institutes help large companies draw in innovation by facilitating cooperation with universities and other large and small businesses. Today's technologies are so complex that multidisciplinary teams comprised of researchers from multiple companies and universities are required to establish new "technology platforms," which then enable applied R&D in individual companies. The Manufacturing USA institutes are designed to play a leading role in creating these platforms. Later on in the technology life cycle, after commercialization and considerable production and marketing experience, "feedback loops" occur, where innovation from the factory floor of the small- and medium- sized enterprise makes its way back to the design community and the field sustainment community. The institutes can also help close these feedback loops.

He added that the emerging suite of manufacturing institutes gives large firms and their supply chains (which are made up of smaller tier 1, 2, and 3 manufacturers) access to new technological developments across many fields. He cited specific new capabilities coming from the Digital Manufacturing and Design Innovation Institute (DMDII), LIFT, America Makes, NextFlex, and AIM Photonics that could bring important enhancements to his firm's products through their work in the areas of digital manufacturing, lightweight metals, 3D printing, flexible and hybrid electronics, and photonics, respectively. The institutes also have demonstrated their value by linking Lockheed Martin to new suppliers, he said, and by developing technological roadmaps that coordinate the company's research and innovation activities with those under way in universities and small businesses.

Christopher Murray, an assistant director with the Government Accountability Office (GAO), reported on a survey conducted by his agency in which large manufacturers credited their participation in Manufacturing USA with helping them accelerate their technology by 2 to 5 years and get their products ready for commercial release more quickly.[11]

[11]Government Accountability Office, *Advanced Manufacturing: Commerce Could Strengthen Collaboration with Other Agencies on Innovation Institutes*, GAO-17-320, Washington DC, 2017. Access at https://www.gao.gov/assets/690/683973.pdf.

Wilcox also noted that the institutes provide members access to equipment, allowing them to test new manufacturing approaches before making large investments in machinery. This access is even more critical for manufacturers who form the supply chain for companies like Lockheed Martin because they often do not have the wherewithal to do these tests on their own. The institutes play an important role as well in training skilled technical workers, he said. Overall, he concluded, Lockheed Martin has realized a very high return on its cost-sharing investments in the institutes.

Driving Innovation to Small Businesses

Speakers noted that the Manufacturing USA institutes, in conjunction with the Manufacturing Extension Partnership (MEP) program, help move advancements in technology out to small firms.

Through its national network of affiliated manufacturing extension centers and field offices, MEP provides small and medium-sized manufacturers access to technical and management expertise.[12] Jennifer Hagan-Dier, director of the Tennessee MEP program, noted that small manufacturers contribute 42 percent of the nation's production output. For these firms to be globally competitive, she asserted, "advanced manufacturing technologies need to reach them. Otherwise it simply won't be adopted pervasively in the U.S. and the potential production efficiencies won't be achieved."

In his remarks, Nickolas Justice argued that it is essential for the institutes to be engaged with small and medium-sized manufacturers "so that you can educate them on what is coming, and about what problems it can be applied to solve." Thus, he asserted, reaching out to small businesses is important to the mission of the institutes. "When you work with a MEP, you are instantly plugged into economic development in your state," he said. "This is also why PowerAmerica embeds MEP staff in its offices—to bring all of them into the organization."

Christopher Murray noted that in the GAO survey, small manufacturers cited networking opportunities as a key benefit of Manufacturing USA partnership. Membership helped them establish connections with both large and small manufacturers and suppliers and enabled them to obtain contracts they might otherwise not have been able to secure.

Networking with State and Regional Organizations

Mike Molnar emphasized that the institutes should not just conduct research. Rather, he said, "the ultimate goal of every successful institute is to really catalyze that regional manufacturing hub to have national impact."

[12]National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program*, 2013.

Mark LaViolette asserted that although the assessment by Deloitte covered only the then eight operational institutes and these were still at an early stage of their maturity, their networking effects were already in evidence.[13] Pointing to the dense network of collaboration depicted in the center of a diagram that connected the key actors, he observed that "although there are only 753 organizations that have formal memberships with these 8 institutes, there are almost 1,200 that have some sort of affiliation and want to be part of this. And then what you're looking at right there is, over 9,000 relationships amongst the organizations."

Katie Stebbins, assistant secretary for technology, innovation, and entrepreneurship for the Commonwealth of Massachusetts, noted that her state links state funding with the Manufacturing USA institutes to foster development in "places where manufacturing used to thrive, and where manufacturing in some respects still does thrive. These are the real touch points around the state," she said, "where we see the interaction between innovation and science."

Susan Helper added that states and regions traditionally implement economic development strategies that entail attracting existing industry with tax breaks, encouraging a "race to the bottom." She suggested that the Manufacturing USA institutes help states and regions evolve to a strategy of investment in shared assets, which helps create a "stickiness" so that companies will want to grow, thrive, and contribute to a locally based but globally linked productive cluster.

Developing the Skilled Technical Workforce

André Gudger observed that addressing workforce development is essential if advanced manufacturing is to take root on U.S. soil, because companies will move to where the skills and talent are located. Noting that many students do not view a career in manufacturing as adequately high-status or remunerative, he suggested that a key challenge is to educate students and workers about what manufacturing looks like today. "The next generation of shop-floors," he added, "doesn't look like they did 20 years ago."

Brennan Grignon, senior advisor and program director in the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, noted that a decline in the number of people in manufacturing is coincident with an increasing number of new types of manufacturing jobs that are remaining unfilled. Even as the institutes develop and commercialize new manufacturing technologies, she stressed, "we have to ensure that we have a skilled technical workforce that can support at all points in the life cycle." Grignon added that institutes such as America Makes, LIFT, and DMDII are

[13]Deloitte, *Manufacturing USA Program Design and Impact: A Third-Party Assessment*, January 2017. Access at https://www2.deloitte.com/us/en/pages/manufacturing/articles/manufacturing-usa-program-assessment.html.

identifying core employability and technical skills needed in many areas of advanced manufacturing.

Katie Stebbins agreed that making large investments in advanced manufacturing technologies and developing the skilled technical workforce go hand in hand. They remain big challenges, she acknowledged, even in a high-technology state like Massachusetts. Many traditional manufacturers, she observed, struggle with making long-term investments in technology and workforce training, focusing instead on satisfying their immediate hiring needs.

Jennifer Hagan-Dier emphasized the need for states to provide leadership in building a skilled technical workforce that can support locally based advanced manufacturing. Echoing a point made by André Gudger, she identified as one obstacle to this goal the fact that many students believe manufacturing work is dirty and dangerous. She argued that the institutes can play a role in improving the image of manufacturing and can work to enhance the portability and standardization of certifications and technical skills.

LESSONS FROM FOREIGN PROGRAMS

Introducing the panel on advanced manufacturing strategies around the world, Bill Bonvillian, a lecturer at the Massachusetts Institute of Technology (MIT), stressed the need to learn more about U.S. competitors' ambitions, strategies, and investments. He observed that the world's two most successful manufacturing nations, China and Germany, both are pursuing advanced manufacturing "all-out." He added that other competitor nations, including the United Kingdom, Japan, Korea, India, Singapore, and now Australia, also understand the need to support advanced manufacturing. If the United States wants to stay in the game, he argued, it has little choice but to likewise pursue advanced manufacturing.

The Role of Germany's Fraunhofer-Gesellschaft

Patrick Bressler, executive vice president of Fraunhofer USA, described Fraunhofer-Gesellschaft (the Fraunhofer Society) as a network of German institutes for applied research. Its primary mission is to perform contract research for German industry, particularly small and medium-sized enterprises, which translate basic research from universities and non-university research organizations into commercial products and industrial processes.[14] Bressler added that the Fraunhofer Academy provides advanced manufacturing training to supplement the localized apprenticeship programs supported by German manufacturing firms.

[14]For a summary description, see National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program*, 2013, Appendix A2: "Fraunhofer-Gesellschaft: The German Model of Applied Research."

Bressler also described Germany's Industrie 4.0 advanced manufacturing effort to advance digital production.[15] He suggested that this effort, which is being coordinated across several Fraunhofer institutes, may provide a model for the U.S. institutes, which could use the Manufacturing USA network capability to support a cross-institute effort to achieve a cross-cutting advanced manufacturing strategy.[16]

The annual research budget of the Fraunhofer Society totals 2.1 billion euros, 1.9 billion euros of which is generated through contract research. While the Fraunhofer and the Manufacturing USA institutes differ in particular respects, Sridhar Kota nevertheless suggested that an important lesson from the German institutes is the role and long-term commitment of the federal and state governments in providing matching funds to reinforce private investment.

China's New Manufacturing Strategy

Jonas Nahm, assistant professor at The Johns Hopkins University, explained that China's recent indigenous innovation policy focused national government support on developing early-stage research capacity.[17] This effort has not yet resulted in growing a strong early-stage research system, he said. Instead, Chinese firms—responding to incentives created by regional governments and state-owned enterprises—focused on implementing production advances, in many cases drawn from foreign firms, which had the effect of making China the largest manufacturing nation today in terms of output.

Under the new China 2025 strategy promulgated in 2015, Nahm continued, the national government's funding priority is focused directly on advanced manufacturing engineering. Charactering this as "a very top-down policy framework that comes out of the State Council in Beijing," he described it as reflecting a "shift in focus from the sort of bottom-up U.S. model of research-based innovation, as China saw it in 2006, to a much more German or Japanese model of trying to upgrade within manufacturing, rather than upgrade out of manufacturing." He added that the China 2025 strategy includes a $3 billion Advanced Manufacturing Fund, which has already made investments in firms that produce electric vehicles and robots. The Ministry of Industry and Information Technology also has pledged to open 40 Manufacturing Innovation Centers.

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[15]European Commission, *Implementation of an Industry 4.0 Strategy: The German Platform Industrie 4.0*, January 2017. Access at https://ec.europa.eu/digital-single-market/ en/ blog/ implementation-industry-40-strategy-german-plattform-industrie-40.

[16]Industrie 4.0 is similar to what is known as the "Industry Internet of Things." See Martin Wollschlaeger, Thilo Sauter, and Juergen Jasperneite, "The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0," *IEEE Industrial Electronics Magazine* Volume 11, Issue 1, pp. 17–27, 2017.

[17]Jonas Nahm, "Renewable futures and industrial legacies: Wind and solar sectors in China, Germany, and the United States," *Business and Politics*, Vol. 19, Issue 1, pp. 68–106, 2017.

Reflecting on Nahm's presentation, Bill Bonvillian commented that "if China drove to world production leadership while concentrating on an early-stage innovation model, imagine what it will achieve in an effort actually focused on manufacturing."

A Need for Metrics

Concluding his panel, Bill Bonvillian argued that "tracking the metrics on our international competitors—especially Germany and China—and what they are moving on is going to be crucial, in part to understand our own position, but in significant part to understand lessons that we are going to need to understand and learn from abroad." He drew attention to Jonas Nahm's $3 billion estimate for the new China 2025 strategy's Advanced Manufacturing Fund and Patrick Bressler's estimate of 2 billion euros annually to support the Fraunhofer Society's mission to link research to German industry. By comparison, he observed, the 14 Manufacturing USA institutes are funded thus far through cooperative agreements with the Department of Defense (DOD), the Department of Energy (DOE), and NIST totaling about $1 billion in federal commitments, matched by $2 billion in private funding, spread over a 5- to 7-year period.

In his policy roundtable comments, Sridhar Kota emphasized that other leading countries have robust and well-funded national strategies to support advanced manufacturing. In the United States, by contrast, the Manufacturing USA institutes and the MEP system are the only real policy tools currently available to build the nation's industrial base. While these programs can be improved, Kota argued, "we should absolutely double down on them. How could we not afford to have funding for these new entities?"

RECENT ASSESSMENTS OF THE INSTITUTES

Even though the Manufacturing USA institutes are still young, they have undergone three major assessments to date: an external independent review by Deloitte that looked at the institutes' role and accomplishments writ large, a review by GAO that examined more narrowly how the institutes are meeting their statutory obligations, and a review by AMNPO within NIST to define metrics for success and gauge how well the institutes are performing against these metrics.

In his presentation, Mark LaViolette, a co-author of Deloitte's third-party review, outlined the major findings of that review.[18] Overall, the review found that the institutes enabled companies to overcome fragmentation in the U.S. manufacturing sector that had blocked their ability to collaborate in furthering advanced manufacturing. The review also found that the institutes are addressing the skills gap. The report cites the case of the LIFT institute for

[18]Deloitte, *Manufacturing USA Program Design and Impact*, 2017.

lightweight metals, which, finding that about 200,000 production jobs were unfilled in its multistate region, expanded its workforce education role to help fill this gap. In general, LaViolette said, the review found that the institutes, and the network, appropriately embraced a "shared services" approach.

GAO's Christopher Murray said his team examined the status of the Manufacturing USA network and the extent to which manufacturers and other entities have used the institutes.[19] They also looked at the extent to which performance measures are in place to help the Department of Commerce assess progress toward achieving the program's statutory purposes. A final objective of the GAO review, Murray said, was to gauge the extent to which the Department of Commerce has taken steps to coordinate the efforts of agencies that contribute to the Manufacturing USA program. Overall, he concluded, "We are consistently impressed by not only the complexity of the program but also how deliberately it has been developed over the course of the last few years, starting from the PCAST [President's Council of Advisors on Science and Technology] reports in 2011 up to the present day, and there are a lot of moving parts."

Mike Molnar reported that as of 2016, the Manufacturing USA program included 830 members, two-thirds of which were manufacturers, and that two-thirds of these were small manufacturers. Other participants included 177 universities, community colleges, and other academic institutions. There were also 105 other entities participating, including federal, state, and local government agencies; federal laboratories; and not-for-profit organizations.

In terms of financial leverage, Molnar reported that fiscal year (FY) 2016 matching was nearly 2:1—double that called for in the Revitalize American Manufacturing and Innovation (RAMI) Act of 2014. Of $333,808,455 in total institute expenditures, 66 percent of the funding came from nonfederal matching funds and 34 percent from non-program matching expenditures. These expenditures, Molnar said, fund all aspects of institute operation, including technology advancement projects, education and workforce training, and capital equipment. He added that, in terms of technology advancement, there were 191 active R&D projects at the institutes in FY 2016.

Finally, with respect to developing an advanced manufacturing workforce, Molnar noted that institute-led workforce programs reached nearly 28,000 students and workers, including 23,560 students in institute R&D projects, internships, or training. A further 3,386 workers completed institute-led certificate, apprenticeship, or training programs. In addition, 1,023 teachers and trainers participated in institute-led training for instructors.

SUGGESTIONS FOR IMPROVING MANUFACTURING USA

In addition to the observations of the above three formal assessments of the Manufacturing USA institutes, several workshop participants suggested areas for improvement. Some called for developing strategies to improve buy-in

[19]Government Accountability Office, *Advanced Manufacturing*, 2017.

and collaboration from federal agencies, state and regional authorities, and participating firms. Others called for stronger efforts to train the skilled technical workforce. Examples include:

- **Study networking challenges.** Susan Helper noted that beyond advancing new technologies, the institutes face challenges in facilitating the transition of these technologies to the marketplace. In some cases, rules and norms governing particular markets create silos, she observed, inhibiting fuller participation by small innovative firms, while in other cases, incentives created by extant company procedures may not be consistent with the companies' stated goals of drawing in innovation. More work is needed, she argued, on designing the organization of firms and markets, including through the Manufacturing USA network, so they facilitate the growth of supply chains and linkages binding local and regional clusters. She called for a better framework to make the institutes effective prototypes of innovation clusters, which could then provide the economic infrastructure for regional technology-based growth.
- **Get more industry buy-in.** Jeff Wilcox called for speeding up and standardizing membership agreements, asserting that "it is disappointing how long it has taken us to get membership agreements concluded and to get projects going." He proposed further that the manufacturing institutes be more industry-focused, observing that some institutes "tend to have an academic flavor and bent in terms of their initial members." Third, he suggested that more institutes adopt industry roadmaps as a way of coordinating research teams and industry partners. "The existence of technology roadmaps is something that is not everywhere in all the institutes," he said.
- **Collaborate with the state and regional networks.** Jennifer Hagan-Dier suggested that both the Manufacturing USA institutes and the state MEP centers could benefit from closer collaboration. By partnering more closely with MEP, she elaborated, the Manufacturing USA institutes could increase their visibility to manufacturers, researchers, and educators. She argued that greater collaboration also could help ensure the involvement of small and medium-sized enterprises (SMEs) in the processes and activities associated with informing and developing the research agendas of the institutes, increase SMEs' participation in the research, and ensure the transition of Manufacturing USA research results to manufacturers for implementation.
- **Demonstrate return on investment to the states.** Katie Stebbins suggested that the institutes and the network more broadly pursue closer engagement with state policy makers and officials with respect to the institutes' contributions to the regional economy. She emphasized the importance of articulating to state policy makers that

there is a clear return on investment for the state cost share. This objective, she acknowledged, can create a tension between the real need to organize a complex national system around a series of emerging manufacturing technologies very quickly and the need to integrate these efforts with state economies and demonstrate tangible benefits to local constituents. Mike Molnar stressed the need for metrics that can be used to measure gains and rewards as one way to communicate the return on states' investments in the institutes, especially as regards "cluster" gains and supply chain gains.

- **Connect other R&D agencies to the advanced manufacturing agenda.** Erica Fuchs suggested that that the institutes reach out more broadly to federal agencies that support R&D. While the institutes can fund platform technologies, she emphasized that the foundational work behind those technologies is also critical. This means, she suggested, that ways should be found to engage other R&D entities, through the development of research agendas and technology roadmaps with the institutes, which will be important to the success of an advanced manufacturing strategy in the United States.[20]
- **Engage veterans in manufacturing.** Brennan Grignon observed that LIFT's new pilot program targets servicemen and -women 6 months prior to their separation from the military. "Instead of waiting until post-separation for these men and women to figure out what they are going to do and what additional training they might need," she suggested, "we provide them the training prior to separation. And then when they separate, they are employable."
- **Leverage government workforce training providers.** Several participants proposed that institute programs to train the skilled technical workforce link with existing federal and state programs, including those supported by the National Science Foundation; the Departments of Education and Labor; and outside groups such as the Midwest German Chamber of Commerce, which is spearheading efforts to develop apprenticeship programs.
- **Learn from each other.** Mike Molnar observed that, while the institutes have a common framework, they are characterized by a diversity of approaches that adapt to the needs of their particular industries and technologies. Even so, he said, there is significant scope for them to learn from each other, and he expects that going forward, learning across the institutes will occur more rapidly. To this end, he noted that the program has established the Institute Directors' Council

[20]Relatedly, Bonvillian notes that "if ongoing federal mission agency R&D can focus more on enabling manufacturing technologies, that could be an important complement to the manufacturing institutes, helping create new manufacturing paradigms." See William B. Bonvillian, "Advanced Manufacturing: A New Policy Challenge," *Annals of Science and Technology Policy* Vol. 1, No. 1, p. 89, 2017.

to provide a forum for the directors to talk with each other on a monthly basis. He added that he looks forward to being able to gauge project impacts as they begin in time to bear fruit.

THE SUSTAINABILITY CHALLENGE

Susan Helper expressed the hope that as the outcomes of the institutes become apparent, it will be possible to demonstrate the broad social and economic benefits of the overall program. There are now a "lot of cool institutes," she said, and "they are working together." But "they are small and their funding is not assured. So can we scale up these institutes and give them some kind of long-term lease on life?" Currently, institutes face a five- to seven-year term for federal support, which many feel may prove inadequate to sustaining their long-term impact.

Arun Seraphin asserted that for the Manufacturing USA initiative to survive, it must make its case as to why it is valuable to Congress, to decision makers in the Pentagon, to universities, and to incumbent firms. To this end, he said, the institutes need a communications strategy that pairs data needed for a structured study of economic impact with anecdotal information on the mission value and employment gains resulting from new technologies. He added that there is a "tension between wanting to do good science and technology and manufacturing research at a place like an institute, and then doing nothing to ensure that it actually creates American jobs in America." While the institutes find support on Capitol Hill for their role in strengthening U.S. competitiveness and in ensuring access to trusted technologies, he warned that there will be "frustration if we start to see the intellectual property generated out of the institutes appearing in overseas production lines."

3

Summary of Presentations

This chapter provides a more detailed synopsis of each of the workshop presentations and accompanying discussion.

WELCOME

David Hart, cochair of the Innovation Policy Forum of the National Academies of Sciences, Engineering, and Medicine, welcomed the participants and audience to the workshop. He introduced the Forum as a focal point for national and international dialogue on innovation policy. Previewing the workshop, he said it would "introduce you to the Manufacturing USA institutes and update you on what they are up to and how they are doing it." The day, he said, would feature the perspectives of some institute directors as they seek to establish their institutes and address their new missions. The presentations would encompass recent external reviews of the institutes, as well as perspectives of what other leading economies are doing to promote advanced manufacturing. Hart invited the participants to "think through the contributions of the institutes to key elements of manufacturing, such as workforce, economic development, and international competitiveness." He then invited Jeff Wilcox, vice president for engineering and program operations at Lockheed Martin, to deliver his keynote address.

KEYNOTE ADDRESS

Jeff Wilcox said he was honored to be the day's "lead-off hitter." He said he would provide an industry view on "why the Manufacturing USA institutes are important, what we are doing, what we are getting out of it, and why we are advocating for it."

Alexander Hamilton's Focus on Manufacturing

Wilcox began by recalling the debate stimulated by Alexander Hamilton's 1791 *Report on Manufactures,* which outlined the value of establishing a manufacturing sector in the United States for the defense and economic growth of the young republic.[1] Wilcox noted that Hamilton "understood just how precarious the situation was that we did not have a defense industrial base in the colonies at that time. He proceeded to advocate for those policies." Hamilton's arguments proved persuasive, and President George Washington declared in his first State of the Union address that the "safety and interest [of a free people] require that they should promote such manufactories as tend to render them independent of others for essential, particularly military, supplies."[2]

Hamilton also spoke of the role of the public sphere in nurturing and promoting manufacturing. Wilcox explained that Hamilton did not believe free market forces alone would create a new manufacturing industry. He described Hamilton's role in establishing a government–industry partnership that harnessed the waterfalls in Paterson, New Jersey, to power mills and stimulate industrial activity. "Samuel Colt started his firearms business there; the first steam engines were manufactured there," Wilcox noted, adding that this "partnership that Hamilton started as Secretary of the Treasury nurtured an incredible innovation ecosystem." According to Wilcox, the Manufacturing USA network of institutes follows this American tradition of public–private partnerships that foster ecosystems for innovation and create new products and jobs that grow the economy and advance the nation's security.

The Impetus for Manufacturing USA

Wilcox traced the origins of Manufacturing USA to a 2011 report by the President's Council of Advisors on Science and Technology (PCAST) entitled *Ensuring American Leadership in Advanced Manufacturing*.[3] Taking the findings of this report forward, the Advanced Manufacturing Partnership (AMP) made a series of specific manufacturing policy recommendations in 2012.[4] This group of leading corporate leaders and university presidents was led initially by Andrew Liveris, chairman, president, and CEO of Dow Chemical, and Susan Hockfield, president of the Massachusetts Institute of Technology.

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[1]Alexander Hamilton, *Report on Manufactures*, Communication to the House of Representatives, Washington, DC, December 5, 1791.
[2]George Washington, First Annual Address to Congress, January 8, 1790.
[3]President's Council of Advisors on Science and Technology, *Ensuring American Leadership in Advanced Manufacturing,* Washington, DC: The White House, 2011.
[4]President's Council of Advisors on Science and Technology, *Capturing Domestic Competitive Advantage in Advanced Manufacturing: AMP Steering Committee Report*, Washington, DC: The White House, 2012; President's Council of Advisors on Science and Technology, *National Network for Manufacturing Innovation: A Preliminary Design,* Washington, DC: The White House, 2013.

AMP was followed in 2014 by AMP 2.0, a second project and report that included calls for a major outreach and engagement effort to design policies to supplement and support the manufacturing institutes.[5]

"All that led to executive action," Wilcox said, "which created the first of the National Network of Manufacturing Institutes (NNMI), all of which was eventually codified and made statutory through bipartisan support for the Revitalize American Manufacturing Innovation (RAMI) Act of 2014." The NNMI was rebranded as Manufacturing USA in 2016.

The Value Proposition for Lockheed Martin

Wilcox described Lockheed Martin as an American global aerospace, defense, security and advanced technologies company that has long seen the value in investing in U.S.-based advanced manufacturing. He noted that the company's Skunk Works "has probably been one of the nation's foremost laboratories for advanced manufacturing and still is because it matters so much to our mission."

Wilcox explained that his company became involved in the Manufacturing USA initiative from the start. "It made a decision early to go all in," joining the initiative's first seven institutes. He characterized this involvement as a significant commitment because each institute is different, and calls for different types of interactions and relationships. Despite the added management effort this commitment demands, he said he views it as worthwhile, explaining that "the innovation part is an obvious part of the why." Describing Lockheed Martin as a steward of the innovation chain of suppliers and partners of various sizes, he noted that the Manufacturing USA institutes draw innovative businesses into this ecosystem. "A large part of the value proposition is the chance to work side by side with small and medium-sized manufacturers," he said, "and of course academia, and learn from each other and bring them into the fold as a part of our supply chain."

This ability to draw in innovation in advanced manufacturing is particularly important for Lockheed Martin, Wilcox added, because innovation increasingly takes place on the factory floor and then makes its way back to the design community and the field sustainment community. In this respect, he observed, innovation today is different from the traditional model—pioneered by Henry Ford and others—whereby "most of the value creation is in the design phase and then you make blueprints and you ship them off and somebody else stamps them out for you." Already, he noted, Manufacturing USA is informing the design community. "Similarly," he said, "the sustainment community has

[5]President's Council of Advisors on Science and Technology, *Accelerating U.S. Advanced Manufacturing*, Washington, DC: The White House, 2014. This AMP 2.0 committee presented this report to the members of the National Academies Innovation Policy Forum on October 27, 2014. Access the agenda at http://sites.nationalacademies.org/PGA/step/PGA_152473.

> "You have all of a sudden got this wealth of information coming off the factory floor and other places because of this work in the Digital Manufacturing and Design Innovation Institute (DMDII)–University of Illinois Labs. There is so much data coming off these machines. We also now have the ability, as we make things, to have in situ sensors and build sensors into our structures. There is data coming off those when you interrogate them."
>
> —Jeff Wilcox, Lockheed Martin

started to realize they have new tools at their disposal—like scanning techniques and 3D printing of parts in the field."

Integration of Capabilities

Wilcox then described the variety of additional ways in which the Manufacturing USA institutes advance Lockheed Martin's engagement in a range of emerging technologies (Figure 3-1):

- *Cognitive assistants*—As a world of information that was previously stovepiped or inaccessible is brought to the desktop, developments in

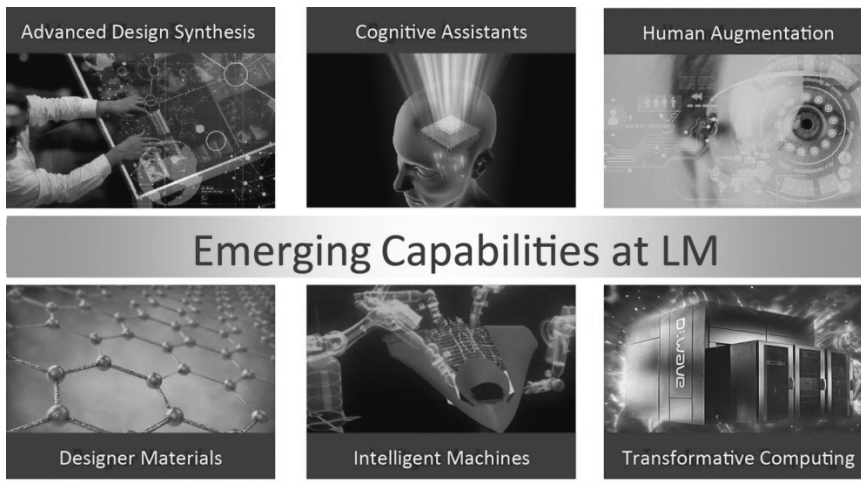

FIGURE 3-1 Emerging capabilities at Lockheed Martin.
SOURCE: Presentation of Jeff Wilcox, Lockheed Martin, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA.

artificial intelligence and cognitive assistance aid in understanding the art of the possible by bringing things together without the effort involved in human structuring.

- *Human augmentation*—These advances create cognitive and physical improvements as an integral part of the human body, enhancing human capabilities and efficiency.
- *Designer materials*—Advances in lightweight metals and composites are expected to have significant applications in metal printers and in aerospace. "The Manufacturing USA institutes have been really helpful to us in terms of being able to pool resources and get new materials certified and to create allowance sheets," Wilcox noted.
- *Intelligent machines*—According to Wilcox, "We are coming to a world where robots work side by side with people. That is going to unlock a really tremendous partnership between people and machines."
- *Transformative computing*—New advances in quantum computing and biomorphic computing are needed to provide the tools necessary for the next generation of manufacturing.

Manufacturing institutes are now working to develop technologies and processes in most of these areas.

Wilcox also drew attention to what can be possible through the integration of these capabilities, and how this potential can be realized through the networking of the institutes. "Manufacturing USA is a national network because these are not one-off things," he observed. "These are not metals over there and composites over there, and robots over there. It is really a whole new way of doing things. That is what advanced manufacturing means to me and to us. That is why this community is so important."

The Benefits of Working with the Manufacturing USA Institutes

Pointing to a map locating the advanced manufacturing institutes, Wilcox next highlighted many of their features and benefits:

- *Developing new manufacturing techniques*—Lightweight Innovations for Tomorrow (LIFT), the center that is working to speed the development of new lightweight metal manufacturing processes, has, Wilcox said, "done a super job of looking for new welding techniques and in developing the technology for thin wall castings."
- *Training the workforce*—LIFT is also training the workers who will use these new processes in factories. Wilcox noted that this focus on workforce development "by really all the institutes" is a top concern—along with taxes and regulations—for small and medium-sized manufacturers. He added that LIFT and other institutes "have done a

great job at helping folks become lifelong learners and putting educational products out there."

- *Lowering manufacturing costs*—Wilcox explained that, "being in aerospace, composites are a big deal, because they are light and strong, but tend to be expensive." He observed that the Institute for Advanced Composites Manufacturing Innovation (IACMI) has set a goal of lowering cost by 25 percent, and "this is really going to be great for the whole industrial supply chain."
- *Scaling up*—"Getting from invention to scale is something we have not done well, historically," Wilcox asserted. "The institutes are really designed to do that."
- *Sharing equipment*—Wilcox stated that LIFT and IACMI "have done a super job of getting together and collaborating. There is equipment up in Detroit where they do metals as well as composites because both are important for aerospace. This ability to get equipment for member use has been good for us, and I know for many of our partners."
- *Developing standards*—"It is one thing to have a new process and a new material," said Wilcox, "but to get it certified is expensive and time-consuming. But if you are a member of America Makes (the 3D printing institute), they certify these and develop allowance sheets for these new components, and then you have access to it as a part of your IP [intellectual property] rights. That saves a lot of companies—big and small—a lot of money."
- *Ensuring cybersecurity for manufacturing*—Wilcox observed that "a lot of factory floor equipment is still running on really old operating systems that are networked and not protected like they need to be. Manufacturing USA has taken it on here, in particular at DMDII [Digital Manufacturing and Design Innovation Institute]."
- *Providing access to expertise*—"The access to knowledge and intellectual property that we get [through the institutes] for our investment is huge," Wilcox said.
- *Ensuring industry leadership*—In Wilcox's opinion, "For these [institutes] to be successful there has to be a strong industry value proposition. These cannot be sandboxes for research. For the most part, projects are selected and the technology roadmaps are driven by industry and industry need."
- *Convening expertise*—"At the end of the day," Wilcox said, "the power to convene, especially across market segments, has been huge. There is so much that we could learn from other industries, but there is just no time. These centers serve as a place where we get to meet other market segments and learn from each other."

Suggestions for Improvement

Finally, Wilcox offered some suggestions for areas in which the institutes can do better. He called for speeding up and standardizing membership agreements, noting that "it is disappointing how long it has taken us to get membership agreements concluded and to get projects going." Next, he suggested that the manufacturing institutes be more industry-focused, observing that some institutes "tend to have an academic flavor and bent in terms of their initial members." Third, he suggested that more institutes adopt industry roadmaps as a way of coordinating research teams and industry partners, saying, "The existence of technology roadmaps is something that is not everywhere in all the institutes." Finally, he proposed that the institutes leverage the Manufacturing Extension Partnership (MEP) system, which provides a wide range of services to small and medium-sized manufacturers, to foster greater collaboration and outreach across the nation's manufacturing networks.

Wilcox concluded his remarks by reminding the audience that the task of building a successful network and advancing innovation in manufacturing must ultimately focus on the people who work to make it happen and the people who benefit from this effort. Recalling the advice of Winston Churchill, he observed that "this is about people. It is about all the people that we can help reach their full potential."

PANEL I: INSTITUTE ROUNDTABLE

David Hart thanked Jeff Wilcox and introduced Ravi Shanker, vice president for lightweighting at the Dow Chemical Company, who moderated the roundtable of institute directors.

Shanker began his remarks by noting that Dow's chairman, Andrew Liveries, shares his passion for "taking raw materials and converting them downstream into value-added products through the power of science and technology." In keeping with the spirit of championing manufacturing, he continued, "we are obviously big supporters of manufacturing initiatives and manufacturing technologies as they span across from the latest and the cutting edge all the way to existing industries and how we believe some of them can be revived using technology."

Shanker emphasized that Manufacturing USA is very much a public–private partnership. The advantage of its being public, he said, is that it can "be strategic and be able to take the big bets that companies individually cannot make but are needed for the future and the good of the country." The advantage of the private side of the equation, he asserted, is that the institutes are "very focused on deliverables, on the results, on the economic, social, and jobs benefits."

Shanker then turned to introducing the panel. "As you can see in the chart [Figure 3-2]," he pointed out, "14 institutes have been launched. On the

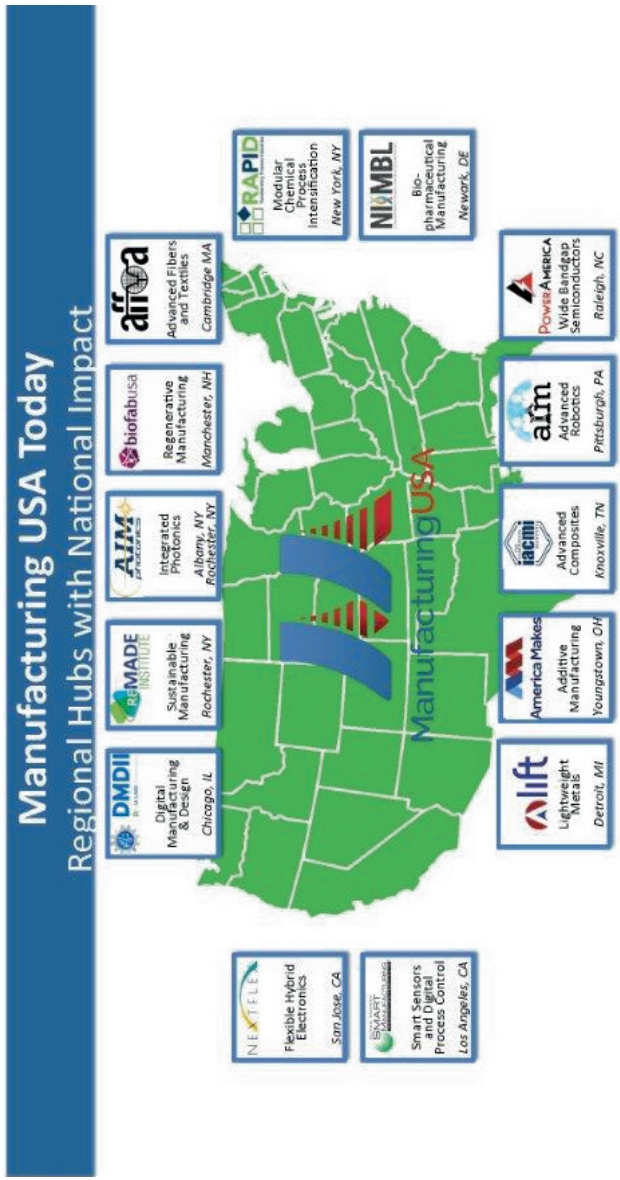

FIGURE 3-2 Manufacturing USA today.
SOURCE: Manufacturing USA.

panel we have two directors from institutes that were launched in 2013 (LIFT and PowerAmerica) and two directors from relatively nascent institutes (AFFOA [Advanced Functional Fabrics of America] and NIIMBL [National Institute for Innovation in Manufacturing Biopharmaceuticals]), and we will talk about those and the learnings that each of them can have." Moreover, he noted, "we have a diversity of institutes in terms of their scope, their characteristics, their experiences, and their backgrounds."

Shanker asked the panel members to describe the basic rationale for their institutes and how they see their organizations evolving, taking into account their value chains and industrial and public partners. He invited the panel members to comment on how the locations of their institutes were chosen. Over the course of the discussion, he asked them about how the institutes are working with the state MEP offices to develop regional innovation ecosystems. He also asked them about their approaches to IP generated through the collaborative work at their institutes. Finally, he requested that they "give a little flavor" of how they balance the interests of their university, industry, and federal stakeholders, and explore how their institutes plan to remain self-sustaining in the future.

Role of the Institutes

Introducing his institute, Lawrence Brown, executive director of LIFT, explained that "we are all about metals and how they enable lightweight solutions at the end of the day. We look at how we can better employ the use of metals to enable enhanced performance in our various vehicles, platforms, and components." The institute's goal, he said, is to take the new technologies that come out of the nation's universities and government laboratories, develop these ideas, and connect them to industry in a way that has impact. "It is great to have new technology," he said, "but, from my perspective, if you cannot find a home for it and you cannot have the right individuals to be able to embrace it and to make sure that it gets applied in the workforce, then we have missed our mark."

Nickolas Justice, executive director of PowerAmerica, highlighted the

> "From where I sit, Alexander Hamilton had it right. Manufacturing enables our economy on a global scale. If we fail to manufacture, we can watch our economy diminish. Along with that, I truly believe that manufacturing is an enablement to innovation. It helps to spur innovation. It helps to drive innovation. Manufacturing is that vehicle. That is why I took this position. I want it to be able to have impact, not just in the technology base, but to be able to impact our economy and human lives at the end of the day. That is my drive."
>
> —Lawrence Brown, LIFT

role of the institutes in developing industry roadmaps. Not only do roadmaps help ensure that "you are staying focused on your mission, your charter," he observed, but the process of cooperatively developing a roadmap with academic and industry partners facilitates the sharing of ideas and building of trust needed to grow the manufacturing ecosystem. "It is the transfer of knowledge that happens when I build that roadmap," he said. Through dialogue and the sharing of ideas, he asserted, "you start building that supply chain because you were building a roadmap, but you were also building trust."

Yoel Fink, chief executive officer of AFFOA, described his institute's mission as transforming notions of "traditional fibers, yarns, and textiles into concepts of highly sophisticated integrated and networked devices and systems."[6] He explained that AFFOA addresses the spectrum of manufacturing challenges associated with volume manufacturing of revolutionary fibers and textiles, from design to end products. The institute, he said, is "introducing Moore's Law for fibers, realizing that in the years ahead, the basic functions of fibers are going to accelerate and grow in a way that is reminiscent of the rapid innovation for semiconductors." He also noted that AFFOA is introducing the concept of fabrics as a service rather than merely as a good, as they are traditionally viewed, "which will allow us to monetize fabrics through the services that they provide." He stated that the textile products of the future will "see, hear, sense, communicate, store, and convert energy; regulate temperature; monitor health; and change color" while delivering the conventional qualities of textiles to benefit the commercial consumer and warfighter.[7]

Kelvin Lee, director of NIIMBL, explained that his organization is seeking to advance the research and commercialization of biologics—complex proteins used to treat a variety of illnesses, which cannot as yet be made by following a chemical recipe. He noted that the entire industry is about 30 years old, and "as such, the manufacturing paradigms and technologies are frankly quite immature. In order to go to the next level, in order to increase automation, in order to address some of the needs of patients going forward, we need to find a way to bring the stakeholders together. That was really the impetus that helped form NIIMBL." He added that the institute's teams have common objectives but varying interests: industry wants to advance the technology and provide value to shareholders; public health authorities want to ensure an efficacious, safe, and reliable supply of medicine; and academia wants to advance knowledge and train students. The institute seeks to advance all these objectives.

Choice of Location

Brown noted that a great deal of thought was given to the location of LIFT in Detroit. The location was based on resources found in the five-state

[6]Stephen K. Luckowski, Deborah Kahan, and Abhai Kumar, "A fabric revolution: AFFOA is weaving the next fiber and textile revolution," *Defense AT&L* September–October 2016.
[7]Access at http://go.affoa.org.

region "down the I-75 corridor," where 50 percent of all the metalwork in the country is done, where significant innovation in metalworking technologies is already occurring, where there is a workforce that understands metalworking technologies, and where the automobile industry is in close proximity. He said that "we chose to have our headquarters in downtown Detroit because we wanted to be a part of the renaissance there."

Justice said that his institute is located in Raleigh, North Carolina, to take advantage of power electronics research being conducted by the North Carolina State University. "We are doing that because it complements the land grant colleges and the engineering schools so well in a broad sense," he observed. While noting that PowerAmerica is regionally focused "because our funding agency for the university is the state and the people of the state," he explained that power electronics is so ubiquitous across every area of manufacturing that the institute is networked with seven of the other institutes.

Fink noted that the business of AFFOA includes traditional knitting, so it includes the established textile firms, but that the majority of its members are startups from across the country. "What we are trying to do," he said, "is to create a situation where we lower the barrier to innovation and actually enable startups to link into emerging production and distribution systems." AFFOA's focus on enabling startups to scale new fiber technologies in collaboration with other institute members provides an interesting model for other institutes.

With respect to the choice of location for NIIMBL, the only National Institute of Standards and Technology (NIST)–led institute, Lee explained that the Mid-Atlantic region (Delaware, Maryland, and Pennsylvania) offered a tremendous amount of relevant activity, as did regions in California, North Carolina, and Massachusetts. "We made an early decision that we really are not going to be particularly regionally focused," he observed, "not that we are not going to leverage state resources and regional impact. I would argue that while we are headquartered in Delaware, really our location, I would just say is the United States of America."

Partnering with the Manufacturing Extension Partnership

According to Brown, LIFT views the MEP as a key partner, helping to connect the institute with small and medium-sized manufacturers in the region that are involved in the institute's technology area. "Early on," he added, "we actually put money on the table for MEP to come in and help to facilitate some of the relationships—so that we could better understand what their needs are, and what we need to make them successful." Though this process, he found that small manufacturers were interested in becoming more aware of technological advances being developed by LIFT, as well as ensuring that original equipment manufacturers were more aware of their capabilities.

Justice argued that it is essential for the institutes to be engaged with industry "so that you can educate them on what is coming, and about what problems it can be applied to solve." Reaching out to small businesses is

therefore important to the mission of the institutes. This is where the MEPs come in, he said: "My local MEPs have been around for many years; they have those connections out there. When you work with a MEP, you are instantly plugged into economic development in your state." He added that this is also why PowerAmerica embeds MEP staff in its offices, "to bring all of them into the organization."

Managing Intellectual Property

Brown explained that LIFT's IP policies are embedded in its membership agreement: "Membership has its privileges based upon the level that you come in. Our gold and silver members have nonexclusive royalty-free rights because they are paying into the program at a higher level, meaning that they do not have to participate in the actual project where the IP was generated, but any project that we do, they have access to that."

Fink noted that IP plays a formative role in AFFOA's Made in USA policy: "The first step is that we went out and negotiated with universities to basically get the right to sublicense their IP in the area of fibers and fabrics with one stipulation, which is that our licenses require the licensee to manufacture in the U.S. all of the IP-related fiber and fabric products." His point was that although institutes face difficult intellectual property challenges, the mechanism of acting as an agent for university participants to license their IP allows the institutes to enable institute participants to have collaborative access to IP needed for new manufacturing technologies. He added that the federal investment in AFFOA is vital to convincing universities that, by giving AFFOA this right to license or sublicense, they can bridge the valley of death in terms of investment, and also draw in dedicated marketing resources to get their IP to the market.

Lee noted that his institute is new and is still developing is policies on IP, and that he is learning from what the other institutes have done in this respect. One approach is to establish some basic operating principles in a membership agreement and by-laws. "But at the end of the day," Lee said, "the IP that is generated for ground IP and relevant background IP is going to be project specific. You have to address it at that level for those partners on that particular project." In his relatively nascent industry, he added, there is a great diversity of opinion among the major manufacturers about the allocation of IP rights in these contexts. "That is because there are so many opportunities and so much growth potential in the industry," he suggested.

Justice observed that there is no formula for IP that can be applied across the institutes. "The answer," he said, "is what works with your industry and what works with your partners, and what you can deal with in the legal constraints you are in."

Sustainability

Brown noted that the issue of sustainability will vary from institute to institute. LIFT, he said, has no deep pockets, and no university or other organization support. "I look to continue to be a nonprofit in the future," he said, "but I also look to sustain myself through several elements—primarily looking at being an engineering services provider that creates organic capabilities inside my headquarters to do development, to do workforce education and training, and to create a learning lab for workforce development." He added that LIFT would seek to form new public and private partnerships that provide value as a way of sustaining itself.

In his remarks, NIIMBL's Lee noted that "as a new institute, we have not hit our steady state yet. It is to be seen whether our governance model is going to be the right one for our community. We have to be flexible in that." He explained that his institute has consulted with its stakeholders, as well as with other institutes, on what works and tried to integrate that into what can work for the institute's particular community. To craft a sustainable structure, he said, he wants to understand "why any single organization would want to join" and to ensure that "they have some value back in the context of governance. With our tiered membership structure, the tier one organizations, those companies, they have a relatively large cash contribution. They would expect to get something back in terms of their ability to make decisions for the institute." With smaller businesses, he added, "it is a much more modest buy-in, but it is important to ensure and require their engagement on projects and other activities."

Justice observed that he started out very optimistic about his institute's being sustainable and being a big player, but that it had been a challenge to get the institute up and running. He noted that the offshoring of manufacturing and related research activities resulting from globalization raised questions about the future of advanced manufacturing in the United States. He asserted that the institutes are important to reestablish "the lost connection with our people by designing here, by working together with people, and then trying to figure out how you are going to translate that into the economy." He suggested that the sustainability of the institutes would depend on how seriously policy makers take up the issue of globalization and offshoring.

Concluding this roundtable, Shanker lauded the directors for their efforts to develop their institutes and thanked them for their service to the nation.

PANEL II: MANUFACTURING USA AND REGIONAL ECONOMIC DEVELOPMENT

Introducing the second panel, on regional economic development, David Hart said that speakers would provide a variety of regional and institutional perspectives.

Workforce Development and the Institutes

Brennan Grignon, senior advisor and program director in the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, explained that she works with the Departments of Commerce and Energy to help coordinate all of the education workforce development efforts around the institute network, writ large. Together, they seek "to integrate from an education workforce development perspective the core competencies that shape all of the technology areas that are represented by the 14 institutes."

Grignon identified as the overall challenge that a decline in the number of people in manufacturing is occurring even as there are an increasing number of new types of manufacturing jobs that are going unfilled. Even as the institutes develop and commercialize new manufacturing technologies, "we have to ensure that we have a skilled technical workforce that can support at all points in the life cycle." She emphasized that new technologies are not making manufacturing work obsolete; rather, they are creating new types of labor requiring new competencies. She added that these occupations also call for highly qualified and skilled workers who are well paid.

The Competency Model

Grignon observed that institutes such as America Makes, LIFT, and DMDII are identifying core employability and technical skills needed for many areas of advanced manufacturing. The standard competency model, she noted, looks at the common employability skills, such as reading, math, and writing. These skills are supplemented by critical thinking skills, as well as common skills related to the use of information technologies. Specialized skills, she continued, build on these standard competencies: "And then you get into your advanced technical skills, which then feed into the technology-specific areas like fibers, textiles, additive manufacturing, robotics, et cetera."

Referring to lifelong learning, Grignon said her office also looks at workforce development "from K to grey: We are trying to help employers with that on-the-job training component that helps their employees be more adept in this new environment." She gave the example of the NextFlex institute, which is using the competency model in partnership with two community colleges in the San Jose area. "They have taken existing curriculum, plugged it into the competency model, created joint curriculum across the two community colleges," she explained, "and they are also using that as a basis for a flex factor, which is a program that is in the local high schools."

Veterans' Transition

As the sister and daughter of veterans, Grignon said she is passionate about teaching already competent veterans the skills needed to take on the new

> "What we are doing is changing the dialogue around manufacturing and manufacturing jobs. We are not saying that you have to go to a 4-year university, and then you have to get a master's in mechanical engineering, and then you will get a job, and then you will be able to have a family. We want people to know that you can be adept at a young age in high school, go to a community college for 2 years, have a significantly lower amount of student debt, come out and get a job which is well paying, and support a family. It is possible. To get there, we just have to change the dialogue."
>
> —Brennan Grignon

jobs being offered in advanced manufacturing. She noted that "America Makes has a program called 3D Veterans, which focuses on teaching additive manufacturing skills. They had a pilot already that closed in December 2016 which had a graduation rate above 75 percent. They have three more pilots that are starting this summer."

Grignon also made note of LIFT's Operation Next, which was launched at Fort Campbell, Kentucky. The program targets servicemen and -women 6 months prior to their separation from the military, offering a combination of online and lab-based learning through the local community colleges in three areas certified by the National Institute of Metalworking Skills. "They come out with an industry credential that allows them to be employed in jobs that the local employers have said they need people in…," she elaborated. "Instead of waiting until post-separation for these men and women to figure out what they are going to do and what additional training they might need, we provide them the training prior to separation. And then when they separate, they are employable."

Apprenticeships

Finally, Grignon noted that her team is working with the institutes on relevant apprenticeship models. She explained that "DOL [the Department of Labor] has an apprenticeship model as well as models like the U.S. German Chamber of Commerce is doing with a number of German companies, who have come over to the United States and set up apprenticeship programs similar to what is in Germany. We are looking at what best practices we can utilize from those areas, working with the MEPs."

Essentially, Grignon concluded, the institutes are working with the Department of Defense (DOD), the Department of Energy (DOE), NIST, the National Science Foundation (NSF), and the Departments of Labor and Education to draw in best practices and share ideas, experiences, and lessons learned in order to grow high-value employment, foster regional development, and advance national missions.

A State Perspective from Massachusetts

In her presentation, Katie Stebbins, assistant secretary for technology, innovation, and entrepreneurship for the Commonwealth of Massachusetts, spoke of the need for the institutes to demonstrate to state policy makers a return on investment in terms of regional development and jobs even as they pursue specific technology and mission objectives. As someone who hails from the postindustrial communities of western Massachusetts, she said, "there is a particular compelling drive in me to try and figure out how we really invigorate manufacturing into places that built our states, which built our country and are now literally unfortunately the backbone of a lot of poverty and a lot of disinvestment."

State Investments in Manufacturing USA

Stebbins noted that her state is very fortunate to host a super cluster centered in Boston. The state invests in these institutes in part, she said, to "add more synergy into the story of this super cluster." But she added that a key goal was also to spark this dynamism across the state: "There is a big part of the rest of Massachusetts here waiting for us."

Stebbins reported that Massachusetts participates in some way with nine of the Manufacturing USA institutes. The commonwealth also provides $40 million in support to AFFOA, which is located in the state; $28 million to the American Institute for Manufacturing Integrated Photonics (AIM); $20 million to NextFlex; $20 million to NIIMBL; and $5 million to Advanced Robotics Manufacturing (ARM). Pointing to a map indicating the growth of innovative activity across the state, she observed that "innovation centers are happening in places where manufacturing used to thrive, where manufacturing in some respects still does thrive. These are the real touch points around the state where we see the interaction between innovation and science."

Articulating the Return on Investment

Elaborating on the importance of articulating to state policy makers that there is a clear return on investment for the state cost share, Stebbins acknowledged that this objective can create a tension between the real need to organize a complex national system around a series of emerging manufacturing technologies very quickly and the need to integrate these efforts with state economies and demonstrate tangible benefits to local constituents. "The manual to set these up did not come with this is how you do a technology roadmap alongside a state supply chain," she observed. "That was not really in there. We are inventing it. We are building as we are flying it."

Finally, Stebbins said she would look more closely at how the institutes, working with the MEP centers, can improve the connection to

> "It gets old and it gets frustrating, but it is my job to keep asking because as I watch the institutes go out and chase relationships with universities and companies all over the country, I am sitting back here meeting with a governor who is saying what have we got? How many SMEs [small and medium-sized enterprises] are we engaged with? What are we going to make here? How many jobs are we producing? It is an incredibly complicated relationship."
>
> —Katie Stebbins

regional economic development. This topic would be explored in by the next panel discussant.

Embedding MEPs in Manufacturing USA Institutes

Introducing the MEP program, Jennifer Hagan-Dier, director of the Tennessee MEP program, stated that the program's mission is to "enhance the productivity and technological performance of U.S. manufacturing."[8] She described the program as a national network of 51 MEP centers located in each state and Puerto Rico and as the only public–private partnership dedicated to serving small and medium-sized enterprises (SMEs).[9] Describing its impact, she reported that MEP centers interacted with 25,445 manufacturers in 2016, leading to $9.3 billion in sales, $1.4 billion in cost savings, and $3.5 billion in new client investments.

MEP centers across the nation, Hagan-Dier continued, work with SMEs to identify and address their most critical needs, challenges, and opportunities. They provide comprehensive consulting services at a fraction of the cost of similar services from a private firm; they connect industry to resources, including research assets state- and nationwide; they serve as the "voice of the manufacturers and industry"; and they engage SMEs in the difficult conversations necessary to identify growth opportunities and assist in planning and deployment. The MEP centers also have experience with cluster development initiatives within their state and region as well as nationally with NIST MEP network partners.

Hagan-Dier suggested that the Manufacturing USA institutes and state MEP centers both could benefit from closer collaboration. By partnering with MEP centers, she argued, the institutes could increase their visibility to manufacturers, researchers, and educators. Greater collaboration also could help ensure the involvement of SMEs in the processes and activities associated with

[8] Access at http://www.nist.gov/mep/who-are-we.

[9] For a review of the MEP program, see National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program,* Washington, DC: The National Academies Press, 2013.

informing and developing the research agendas of the institutes, increase SMEs' participation in Manufacturing USA research, and ensure the transition of the results of that research to manufacturers for implementation. (See Box 3-1 for Hagan-Dier's listing of the benefits to the institutes of partnering with MEP.)

Hagan-Dier believes this collaboration can be advanced by embedding MEP staff within the Manufacturing USA institutes. "We currently have nine embedded projects that are standing and [for which staff have] been brought on," she said, adding that "the new institutes will also then have a chance to have MEP embedded staff." She explained that each of these collaborations will be specific to the participating institute; thus "the way that New York is handling their embedding with AIM is different than the way that Tennessee is handling our embedding with IACMI." Lastly, she noted that the nationwide MEP network provides an opportunity to compare notes across the institutes to see what is working, where, and why.

Economic Development: Lessons from New York

Charles Wessner, a professor of global innovation policy at Georgetown University, began his presentation by asserting that policy makers are not paying enough attention to what the rest of the world is doing to promote growth, employment, and national strength. He explained that leading countries of the world are responding to the global competitiveness challenge through sustained policy attention at the highest levels, growing funding for universities and research and development (R&D), encouragement to innovative small

BOX 3-1
Partnering with MEP: Benefits to Manufacturing USA

- Increased collaboration—National Institutes of Standards and Technology (NIST) MEP network partners, Manufacturing USA institutes, Investing in Manufacturing Communities Partnership (IMCP) communities, and other resources
- Increased awareness of networks and services
- Knowledge sharing and increased economic impacts
- Development of subject matter experts for systems and networks
- Scalable and flexible models
- Demonstration of value and return on investment for federal agencies
- Increase in reach and service to small and medium-sized enterprises
- Development of institutional knowledge and ability to test "promising practices" for data sharing

SOURCE: Jennifer Hagan-Dier's workshop presentation.

businesses, and support for new public–private partnerships aimed at supporting manufacturing and bringing new products and services to the market.

A Renewed Focus on Clusters

The synergies of these initiatives are brought together within innovation clusters, Wessner elaborated. He defined clusters as mutually reinforcing geographic concentrations of knowledge and skills. By collocating skilled labor and fixed-cost resources such as laboratories and by developing connecting infrastructure to encourage collaboration and lower transportation costs, these agglomerations, he suggested, could encourage the exchange of tacit knowledge and foster rapid learning from peers and competitors. He cited the work of Michael Porter, who described clusters as "geographic concentrations of interconnected companies and institutions in a particular field."[10] He explained that a self-reinforcing innovation ecosystem features interactions among firms linked to industries; specialized services; connected universities, vocational training centers, and research facilities; and supportive public and private organizations.

Wessner argued that the development of such linked manufacturing clusters is essential to resolve the growing loss of capacity in U.S.-based manufacturing, with its implications for economic growth, innovation, and national security. He described this contraction in manufacturing as the result of the disaggregation of large vertically integrated manufacturers that were traditional mainstays of U.S. manufacturing. As many production functions were outsourced or moved offshore, research activities in the United States also suffered losses.

According to Wessner, the regeneration of manufacturing needs to draw on the lessons of past successes (notably those from the revival of the semiconductor industry in the 1980s through inter alia the formation of Sematech) and on the successful policies and practices of other nations in supporting advanced manufacturing (notably the German Fraunhofer institutes). Also necessary, he argued, is the diffusion of current best practices from the U.S. states.

Growth of the Albany Nanocluster in New York State

Wessner cited the Albany model as an example of what is working in one region of the country, asserting that it deserves to be understood more widely and adapted as a template for public policy. This cluster began to develop when the State University of New York (SUNY)-Albany and Renssalaer Polytechnic Institute created the College of Nanoscale Science and

[10]Michael E. Porter, "Clusters and the new economics of competition," *Harvard Business Review*, November–December Issue, 1998. Access at https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition.

Engineering (CNSE). The college was founded in cooperation with IBM, which lent its reputation, resources, and commitment and served as an anchor tenant for the nascent cluster. The cluster continued to grow as the State of New York and IBM built a 300 mm fabrication facility at CNSE, which in turn lured Sematech to relocate to Albany from Austin, Texas.[11]

As an industry-oriented university, guided by entrepreneurial leadership, CNSE provided the reputation, researchers, and resources while serving as a neutral site for applied research. The construction of an up-to-date, 300 mm fabrication facility in a university setting was "unprecedented," observed Wessner, in that it allowed research, testing, and training on cutting-edge manufacturing equipment to take place in a modern commercial-scale semiconductor fabrication facility.

In turn, Wessner continued, this clustering of specialized talent, research activity, and unique facilities allowed the region to compete for and attract GLOBALFOUNDRIES, a major semiconductor design, development, and fabrication company. GLOBALFOUNDRIES invested $6 billion, and then $2 billion more, and more recently another $15 billion in its vast semiconductor fabrication facility in Malta, New York. The Malta facility created large-scale employment, drew in specialized suppliers, and significantly enhanced the region's reputation as a center of advanced manufacturing, further contributing to regional growth.

Best Practices and Key Lessons from Albany

Wessner listed a number of best practices in clustering emerging from the Albany experience (see Box 3-2). He also identified some key lessons learned from the New York experience about growing innovation clusters:

- **The need for sustained funding**—Sustained funding, Wessner emphasized, is necessary for the effective operation of consortia focused on mid- to long-term development of new materials, processes, and, ultimately, products.
- **The benefits of prepermitting**—This approach is designed to obtain clearance for generic manufacturing projects and to screen out regulatory and political showstoppers early on. Wessner explained that it was intended to address New York's poor reputation for ad hoc regulatory challenges to new manufacturing. Prepermitting helps reduce the risk faced by potential investors that after they have committed substantial time, resources, and reputational capital, a project could suddenly be blocked by the failure to obtain permit

[11]For a review of the development of the Albany cluster, see National Research Council, *New York's Nanotechnology Model: Summary of a Symposium*, Washington, DC: The National Academies Press, 2013.

approvals. These permits were often required by local jurisdictions, some quite small, and most capable of making unpredictable decisions.

- **The role of innovation intermediaries**—According to Wessner, the role of the Center for Economic Growth (CEG), an umbrella group of businesses and regional leaders, was key in helping to brand the region, advocate for investments, share information, and finance studies. He described CEG's ability to work across the fragmented political units of the region as a key contribution, noting that this is an important consideration in other states, such as Ohio and Pennsylvania, that have many small jurisdictions.
- **The importance of professional proposals**—Wessner explained that Saratoga Economic Development Commission (SEDC) assembled a first-class engineering project team of planners, engineers, and technical experts to create a proposal that resonated with semiconductor executives.
- **Robust incentive package**—Wessner observed that the $1.2 billion assembled by the State of New York was seen as too much by some, but fortunately, it was more than the competing amount from Dresden, Germany, which also bid on the GLOBALFOUNDRIES fabrication facility. The region, he said, realized the necessity of competing on a global scale.

BOX 3-2
Best Practices in Clustering from the Albany Nanocluster

- Leadership focusing on new technological opportunities and, as necessary, creating new institutions to exploit them
- Maintaining policy continuity from government across administrations and election cycles
- Ensuring industry leadership as a partner, a co-funder, and a reputational anchor
- Providing substantial and sustained funding to develop facilities not available elsewhere and to attract investment
- Making parallel investments to encourage industry-oriented universities and researchers
- Relying on active, well-led regional development organizations able to develop professional bids and carry out prepermitting
- Encouraging multiple adaptable public–private partnerships
- Creating cooperative programs to develop a skilled workforce with certificates and training directly relevant to industry needs

SOURCE: Charles Wessner's workshop presentation.

Sustaining the Albany Semiconductor Cluster

Wessner asserted that one of the most salient measures of success for high-tech investments is the impact on job creation. The promised return for the incentives package for GLOBALFOUNDRIES was some 1,205 jobs, a total ultimately surpassed by the creation of 3,538 on-site jobs. Given the multipliers for high-tech and industrial employment (i.e., just under 5 times), he said, a net yield of some 17,300 indirect jobs could also be anticipated. Further, the CNSE complex directly provides more than 4,000 jobs, which would yield another 20,000 jobs given this multiplier. Induced employment in the region, including the hospitality sector (restaurants/hotels/gaming), financial services, housing, and consumer goods, is substantial and growing.

In conclusion, Wessner noted that while substantial progress has been made, real challenges remain. First, he observed, despite achieving great progress, Albany Tech Valley remains highly concentrated in one volatile sector that is subject to the strong winds of global competition. Second, while the Albany strategy has attracted the investment of a major manufacturer, other elements of a robust manufacturing ecosystem are yet to manifest. A startup culture is emerging slowly, Wessner explained, and access to Small Business Innovation Research (SBIR), angel, and venture capital funds backed by incubators and accelerators is still needed. Other challenges center on maintaining the commitment by state and local leaders to continue to focus on the needs of this developing cluster, even as there is pressure from other areas of the state to diversify and reallocate state resources. Regional universities and community colleges also face ongoing financial pressures, Wessner noted. Lastly, he warned that domestic innovation-based economic development can collapse under assault by foreign state-supported firms that are unrestrained by normal market competition.

Discussion

The discussion following this panel centered on the need for the state, private industry, and the workforce, among other actors, to work together to bring about a successful manufacturing innovation cluster. Charles Wessner emphasized the need for leadership and a sizable allocation of resources from the state as a signal to others of the commitment and purpose involved. “You have to do the funding because that is how the game works, he asserted. “What is remarkable about New York is that they are willing to step up to it.” Jennifer Hagan-Dier added that the State of Tennessee similarly reached out to attract a major automobile manufacturer to the state, and that the investment was worthwhile. She recalled that as assistant commissioner to the previous governor of Tennessee, she “got a lot of flak for giving away all our money,” but noted that the “eight times multiplier that came with the Volkswagen plant” validated the decision.

Hagan-Dier added that the state also had to provide leadership in building a skilled technical workforce that could support locally based advanced manufacturing. She noted that many students believe manufacturing work is dirty and are not attracted to manufacturing workforce training programs. She also cited the need "to have some certifications and some consistency and standardization around certifications and technical skills." Finally, she observed that "we do not talk about apprenticeships in a way that is meaningful to our local communities."

Katie Stebbins agreed that making large investments in advanced manufacturing technologies and developing the skilled technical workforce remain big challenges, even in a high-technology state like Massachusetts. Many traditional manufacturers, she noted, struggle with making long-term investments in technology and workforce training, focusing instead on satisfying their immediate hiring needs: "It has been a really difficult conversation all across the state when so many of our legacy manufacturers are still going through temp agencies," she said. "They are not hiring full-time. They are not training from within."

Brennan Grignon noted that it is difficult to fit the skilled workforce needs of advanced manufacturing into a "pretty dense landscape" of existing educational and training organizations. "We are trying to get our arms around all the things that are already in existence," she said, "and where we can help facilitate the dialogue and change the conversation around job replacement into job translation and also help influence curriculum development."

David Hart thanked the panelists and invited the participants to reconvene following the lunch break.

PANEL III: ASSESSING THE MANUFACTURING USA INITIATIVE

Welcoming back the participants, David Hart introduced Brett Lambert, vice president for Corporate Strategy at Northrop Grumman, to moderate the next panel. Lambert observed that the workshop participants included many people who were present at the beginning of the effort to revive U.S.-based advanced manufacturing. He added that "it is the absolute appropriate time to take stock of where we are now and if and how this process and these efforts will move forward, and take any lessons learned from them." He then requested that Susan Helper, a former chief economist at the Department of Commerce and a professor at Case Western Reserve University, begin her presentation.

The Role of the Federal Government in Strengthening American Manufacturing

Helper introduced her presentation by stating that it would answer three key questions: What happened to U.S. manufacturing? Will the market provide a socially optimal manufacturing sector? and What obstacles hinder a better U.S. manufacturing sector?

What Happened to U.S. Manufacturing?

Pointing to Figure 3-3, Helper explained that "we had a fairly constant size manufacturing sector—15 to 17 million people—then it fell off a cliff between 2000 and 2010. We lost a third of manufacturing jobs then, and there has been a comeback—about 900,000—since." Factors behind this decline, she said, have "something to do with globalization, trade agreements, strong dollar, automation, financialization, a focus on short-term corporate results, and a lack of support for sustaining the so-called industrial commons."

Next, Helper shared Figure 3-4, which shows the value added to the economy from manufacturing. She noted that the line showing manufacturing minus computers—which is a small but highly productive sector—shows a

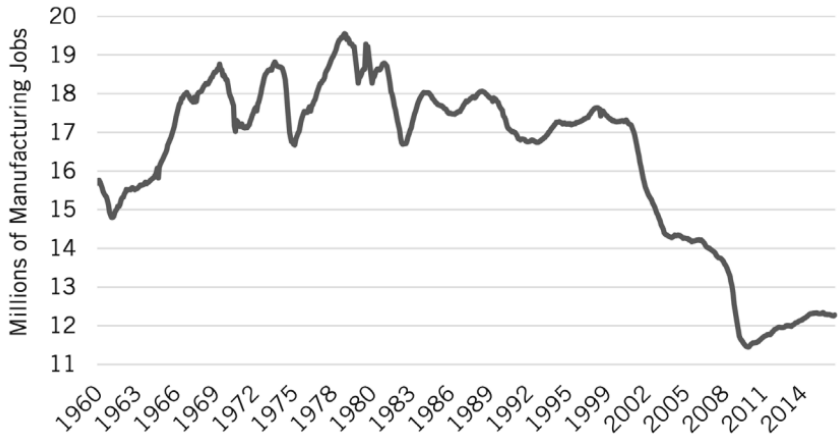

FIGURE 3-3 Manufacturing employment, 1960–2016.
SOURCE: Presentation of Susan Helper, Case Western Reserve University, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA. Adapted from Adams Nager, *Trade vs. Productivity: What Caused U.S. Manufacturing's Decline and How to Revive It*, Washington, DC: Information Technology & Innovation Foundation, February 2017.

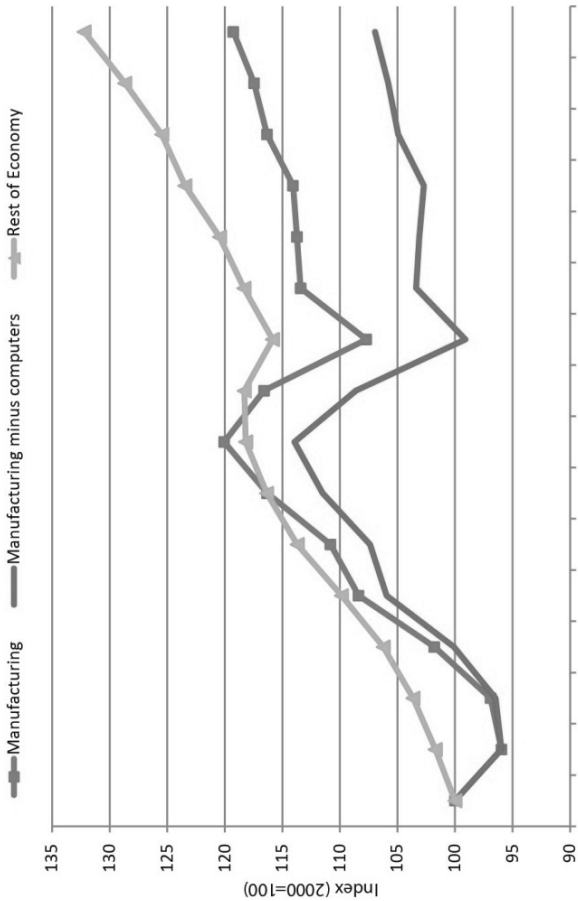

FIGURE 3-4 Real value-added manufacturing and rest of economy, 2000–2015.
SOURCE: Presentation of Susan Helper, Case Western Reserve University, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA. Adapted from Adams Nager, *Trade vs. Productivity: What Caused U.S. Manufacturing's Decline and How to Revive It*, Washington, DC: Information Technology & Innovation Foundation, February 2017.

significant decline in value added relative to 2005. The bottom line, she concluded, is that "manufacturing is doing a lot better than it was in 2010, but still is a little bit challenged."

Helper added that there is nothing inevitable about this decline. Germany and other northern European countries have higher wages than the United States, she pointed out, and 19 percent of their workforce is in manufacturing. According to Helper, this means public policies do make a difference. Other factors that may auger a comeback for manufacturing, she suggested, include a rise in unit labor costs elsewhere and "a realization by a lot of American companies that the hidden costs of a far-flung supply chain are really quite high and larger than they imagined."

Will the Market Provide a Socially Optimal Manufacturing Sector?

Helper noted that because of knowledge spillovers, private companies are likely to underinvest in producing new knowledge. "If you are a profit maximizing investor at a company," she said, "you think about the benefits to your company when you make an investment. You don't think about all the other people that might benefit from your investment, whether those are your suppliers, your workers, the environment, et cetera."

Helper then argued that the benefits to society from R&D are large. In particular, she said, R&D that feeds a healthy manufacturing sector benefits manufacturing workers, advances innovation, and promotes environmental sustainability. She argued that this means there is a role for public policies in encouraging research that underpins advanced manufacturing, especially given that the market will not produce this activity on its own.

What Obstacles Hinder a Better U.S. Manufacturing Sector?

Helper described three types of obstacles to a better U.S. manufacturing sector. The first is what she called the "missing middle" of the innovation process. Pointing to Figure 3-5, she noted the gap between investment by government and universities in maturing technologies in their earliest stages and investment by the private sector in the later stages. She asserted that public–private partnerships such as the Manufacturing USA institutes have a role to play in sustaining investments in manufacturing-related R&D to fill this gap.

The second obstacle derives from weaknesses in the supply chain. As firms restructure to rely more on outside suppliers, Helper explained, incentives to invest in research are diminished because the supplier can also offer the benefits of the innovation to the company's rivals. Smaller firms, which increasingly do the manufacturing and supply the larger companies, also face a variety of obstacles, she added, from securing financing to commercializing new and unknown technologies. As a result, while small manufacturers make up 98 percent of manufacturing establishments, they perform only 33 percent of R&D.

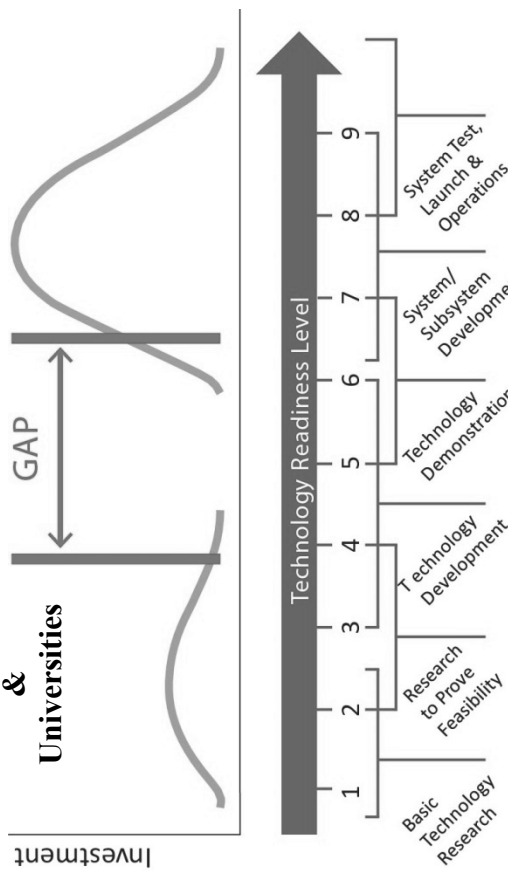

FIGURE 3-5 The investment gap in manufacturing innovation.
SOURCE: Presentation of Susan Helper, Case Western Reserve University, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA. This figure is based on a diagram from the 2012 Advanced Manufacturing Partnership Report.

The final obstacle to a more robust U.S. manufacturing sector is a poorly trained workforce. Helper explained that students and workers face a variety of challenges in linking to and staying with appropriate training programs and in keeping in pace with the changing needs of the manufacturing sector. Lack of training, she elaborated, is related to stigma associated with manufacturing, poor linkages between employers and educational organizations, and inadequate K–12 preparation.

Overall, Helper concluded, "we have a fragmented ecosystem, with a lot of potential for sharing and a lot of interdependence that is not being captured. Manufacturing USA could be a key hub to overcome that and become a key lynchpin of future policy."

Government Accountability Office (GAO) Report: Strengthening Interagency Collaboration

Christopher Murray, assistant director with GAO's Natural Resources and Environment team, began by explaining that his team looked at the status of the Manufacturing USA network and the extent to which manufacturers and other entities have used the institutes. (For a list of institutes and sponsoring agencies, see Figure 3-6.) They also examined the extent to which performance measures are in place to help the Department of Commerce assess progress toward achieving the program's statutory purposes. A final objective of the GAO review was to gauge the extent to which Commerce has taken steps to coordinate the efforts of agencies that contribute to the Manufacturing USA program.[12]

Murray cautioned that the GAO review did not seek to assess the technologies being developed and commercialized by the institutes, as this was not the team's area of expertise. Rather as generalists, they were applying the criteria set out in the legislation to see whether the initiative was effective in maximizing the use of federal dollars.

> "We are consistently impressed by not only the complexity of the program but also how deliberately it has been developed over the course of the last few years, starting from the PCAST reports in 2011 up to the present day, and there are a lot of moving parts."
>
> —Christopher Murray

[12]Government Accountability Office, *Advanced Manufacturing: Commerce Could Strengthen Collaboration with Other Agencies on Innovation Institutes*, GAO-17-320, Washington, DC, 2017. Access at https://www.gao.gov/assets/690/683973.pdf.

Requirements under the Revitalize American Manufacturing Innovation (RAMI) Act

Murray explained that the RAMI Act requires the secretary of commerce to establish a Network for Manufacturing Innovation program within NIST; to establish, also within NIST, a national program office to oversee and carry out the program; to establish a network of centers for manufacturing innovation; and to provide financial assistance for the establishment of more such centers.[13]

Further, Murray continued, the RAMI Act contains a number of provisions related to collaboration between the Department of Commerce and other agencies. In addition, several of the functions of the Advanced Manufacturing National Program Office (AMNPO) under the RAMI Act also pertain to collaboration. This includes establishing such procedures, processes, and criteria as may be necessary and appropriate to maximize cooperation and coordinate the activities of the program with programs and activities of other federal departments and agencies whose missions contribute to or are affected by advanced manufacturing.[14]

Utilization of the Institutes

GAO collected information on the use of the institutes between May and September 2016. The analysis showed that about 520 manufacturers and about 260 other entities were members of the seven operating institutes in 2016, including academic institutions, state government agencies, and MEP centers. Murray explained that these participants joined the institutes at a variety of membership levels. At the highest two membership levels, participation by manufacturers and other entities was fairly evenly divided. At lower levels, GAO found that manufacturers represented a larger proportion of participating members relative to the other entities. Looking more specifically at the size of the manufacturers, Murray reported that GAO found, as expected, that manufacturers that joined the institutes at a higher membership level were typically the large manufacturers, while those at lower levels tended to be the smaller manufacturers.

Small manufacturers often cited networking opportunities as a key benefit of participation, Murray noted. Membership helped them establish connections with large manufacturers and other small manufacturers and suppliers, and enabled them to obtain contracts they might otherwise have been unable to secure. Large manufacturers cited being able to accelerate their technology by 2 to 5 years and to get their products ready for commercial release more quickly.

[13]Some of the Manufacturing USA institutes were established prior to the passage of the RAMI Act.
[14]Government Accountability Office, *Advanced Manufacturing: Commerce Could Strengthen Collaboration with Other Agencies on Innovation Institutes*, 2017.

Performance Measurement

Quoting from the GAO report, Murray said that "while the Department of Commerce, DOD, and DOE developed an initial set of performance measures for the program, reporting on institute performance is the responsibility of the sponsoring agency, and institutes are required to report only on measures that have been agreed upon with their sponsoring agencies. The RAMI Act does not include reporting requirements for institutes sponsored by DOD and DOE, but does require the secretary of commerce to report annually on the performance of the program."[15]

Institute	Technology focus	Year established / Agency Sponsor	Agency sponsor
National Additive Manufacturing Innovation Institute (America Makes)	Additive (3D printing) technologies	2012	DOD
Digital Manufacturing and Design Innovation Institute (DMDII)	Digital design	2014	DOD
Lightweight Innovations for Tomorrow (LIFT)	Lightweight metals technology	2014	DOD
The Next Generation Power Electronics Manufacturing Innovation Institute (PowerAmerica)	Wide bandgap semiconductors	2014	DOE
Institute for Advanced Composites Manufacturing Innovation (IACMI)	Advanced polymer composites	2015	DOE
American Institute for Manufacturing Integrated Photonics (AIM Photonics)	Integrated photonic circuits	2015	DOD
America's Flexible Hybrid Electronics Manufacturing Institute (NextFlex)	Advanced flexible electronics	2015	DOD
Advanced Functional Fabrics of America (AFFOA)	Novel fibers and textiles	2016	DOD
National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL)	Biopharmaceutical technologies and standards	2016	Commerce
Advanced tissue Biofabrication Manufacturing Innovation Institute (ATB-MII)	Making human tissue and related products	2016	DOD
Clean Energy Smart Manufacturing Innovation Institute (CESMII)	Smart sensors and digital process controls	2016	DOE

FIGURE 3-6 Status of the Manufacturing USA network as of April 2017.
NOTE: DOD = Department of Defense; DOE = Department of Energy.
SOURCE: Presentation of Christopher Murray, Government Accountability Office, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA.

[15]Ibid.

Murray added that the Department of Commerce "has taken steps or has identified options to address challenges in measuring program performance. At the same time, he acknowledged that some of the program's statutory purposes (e.g., creation or preservation of jobs) are inherently difficult to measure because the timeline for measuring progress may be too short, and agencies also may face challenges in collecting performance information from institutes after their agreements end."[16]

Mechanisms for Program Coordination

Murray reported that the Department of Commerce uses a variety of mechanisms to help coordinate the Manufacturing USA program. He noted the efforts of AMNPO and other agencies involved in the program to develop the December 2016 Manufacturing USA network charter, and asserted that the Manufacturing USA strategic plan and governance system represent important steps toward enhancing interagency collaboration under the program. In particular, he observed, the Manufacturing USA governance system defines roles and responsibilities for the agencies contributing to the program.

Murray explained that the program's governance system identifies the network functions and subfunctions for which agencies that sponsor institutes (DOD, DOE, and Commerce), as well as those that do not sponsor institutes (NSF, DOL) are responsible, accountable, informed, and consulted. For example, as part of the function to sustain, strengthen, and grow the network under the governance system, agencies that sponsor institutes are responsible for identifying and helping to establish long-term nonfinancial support mechanisms for the program, which the program's governance document notes should provide valuable nonfinancial support to help institutes succeed and thrive. Murray added that non-sponsoring agencies are responsible for one general function under the framework: promoting advanced manufacturing to a variety of external stakeholders, such as Congress and the public.

To enhance interagency collaboration on the Manufacturing USA program, Murray continued, GAO recommends that AMNPO work with non-sponsoring agencies whose missions contribute to or are affected by advanced manufacturing to revise the Manufacturing USA governance system so that it fully identifies the roles and responsibilities for these agencies in contributing to the program.[17]

Bringing R&D Innovation to Manufacturing

Mark LaViolette, specialist leader for Deloitte, opened his remarks by saying he was honored to share a third-party assessment of the Manufacturing USA program. This assessment was conducted between August 2016 and

[16]Ibid.
[17]Ibid.

January 2017, and so includes the eight institutes that were operating at that time. LaViolette noted that Deloitte looked at the theory of the program, its progress to date, its metrics for impact, and its sustainability strategies and made some recommendations for how the program or institutes could evolve to further improve their performance and effectiveness.

LaViolette explained that the study's methodology included collecting information from each institute that had data on project calls, members, and member interactions. Members of the research team also visited each of the institutes and interviewed its director and other senior staff. Finally, Deloitte conducted interviews with external experts and others with experience operating and participating in the program.

LaViolette emphasized the importance of advanced manufacturing for the U.S. economy, supporting trillions of dollars of production in other parts of the economy through a multiplier effect that comes from purchasing from and selling to more than 80 different industries, ranging from transportation to education. He then displayed a visualization of the interactions among the various institutes (Figure 3-7), pointing to the "scrum" or "mosh pit" of collaboration found in the center of the diagram. "What you can see here," he said, "is that although there are only 753 organizations that have formal membership, there are almost 1,200 that have some sort of affiliation and want to be part of this. And then what you're looking at right there is over 9,000 relationships amongst the organizations." This type of visualization, he added, could enable the institutes to help stakeholders at the local and state levels understand the scope of the institutes' economic reach.

LaViolette then outlined the six major findings of the Deloitte analysis. First, the Manufacturing USA program provides the focus and collaboration needed to invest in and develop new manufacturing technologies. Second, the institutes accelerate innovation by providing access to equipment, pooling project costs, and developing roadmaps that coordinate research activities. Third, by moving a series of complementary technologies forward at the same time, the program has a portfolio approach that captures complementarities and reduces risk. Fourth, and relatedly, the network of institutes promotes connectivity among firms, research organizations, and other actors in the manufacturing ecosystem. Fifth, this networking activity strengthens the growth of regional economic clusters. Finally, the institutes are helping to identify and develop the skilled technical workforce necessary to sustain advanced manufacturing in the United States.

Concluding his presentation, LaViolette itemized the recommendations of the Deloitte report.[18]

[18]Deloitte, *Manufacturing USA: A Third-Party Evaluation of Program Design and Progress*, January 2017. Access at https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-mfg-manufacturing-USA-program-and-process.pdf.

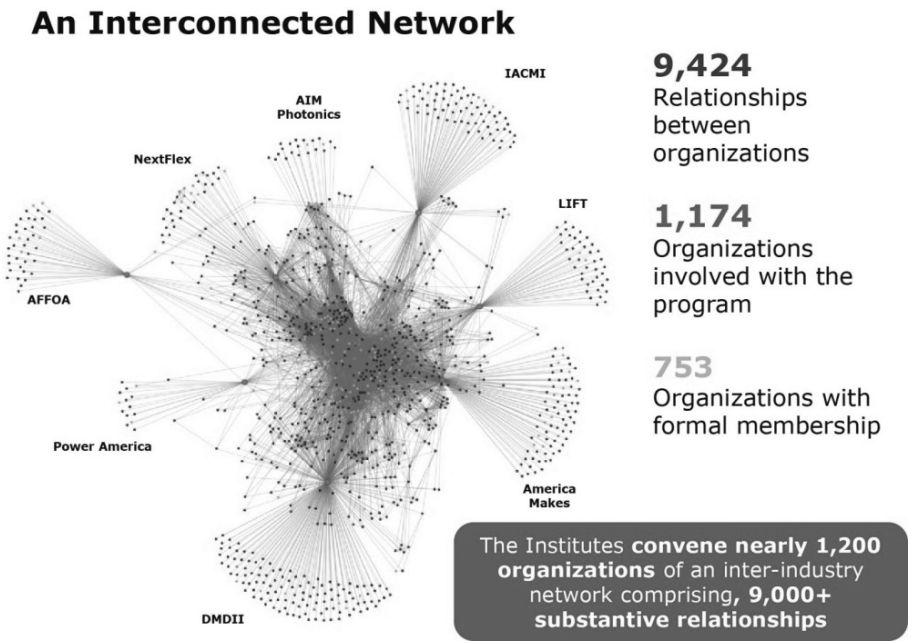

FIGURE 3-7 Manufacturing USA: An interconnected network.
SOURCE: Presentation of Mark LaViolette, Deloitte, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA.

- Develop and execute an overarching growth strategy for the institute portfolio, accounting for new institute formation, member overlap, and competition. Going beyond the published strategy documents, institutes need to address a myriad of issues, from the pooling of intellectual property rights to ensuring that the institutes complement each other's efforts.
- Facilitate further connections to relevant organizations and resources, especially among institutes, to increase program impact.
- Provide shared services to promote quality operations.
- Ensure an enduring focus on U.S.-centric goals. The program should create more robust plans for maintaining U.S. government involvement with and support of the institutes. Multiple levers are available for this purpose, including providing additional funding, referring institutes to other government customers, and offering high-value support services.
- Increase activities that emphasize transition and deployment activities that expand commercialization efforts.
- In creating contracting and membership agreements, the institutes should encourage a less restrictive approach to contracting and membership agreements.
- Further align institute workforce programs with existing federal, state, and local programs

From Concept to Practice: The Manufacturing USA Annual Report

Mike Molnar, founding director of AMNPO, described the Manufacturing USA program as a journey. He noted that the most difficult part of any trip is the take-off and landing. The Manufacturing USA journey started in 2012 with the Advanced Manufacturing Partnership report issued through PCAST that called for a coordinated government effort. Since then, Molnar observed, an interagency team has come together, breaking down barriers and establishing the first set of advanced manufacturing institutes.

As described by Molnar, the Manufacturing USA journey is guided by a vision of U.S. global leadership in advanced manufacturing. In turn, he said, the mission of the program is to "connect people, ideas, and technology to solve industry-relevant advanced manufacturing challenges, thereby enhancing industrial competitiveness and economic growth and strengthening our national security." He added that this mission is driven by the objectives specified in the RAMI Act, which fall within the four program goals of competitiveness, technology advancement, workforce development, and sustainability.

The initiative thus far has developed 14 institutes. To describe the program's accomplishments to date, Molnar said he would draw on the results of a fiscal year (FY) 2016 report produced by AMNPO, and also report on how the Manufacturing USA program is responding to the recommendations of the Deloitte and GAO studies.

Measuring Performance

According to Molnar, the interagency team driving the Manufacturing USA program has worked hard to create top-level metrics. He pointed to a slide summarizing the key categories, metrics, and units of measure used in tracking the progress of the institutes and the overall program against its vision and mission (see Figure 3-8).

Molnar reported that in terms of impact as of 2016, the Manufacturing USA program had 830 members, two-thirds of which were manufacturers, and that two-thirds of these were small manufacturers. Other participants included 177 universities, community colleges, and other academic institutions. There were also 105 other entities, including federal, state, and local government agencies; federal laboratories; and not-for-profit organizations.

In terms of financial leverage, FY 2016 matching was nearly 2 to 1, Molnar reported. Of the $333,808,455 in total institute expenditures, 66 percent of institute funding came from nonfederal matching funds and 34 percent from non-program matching expenditures. This funding supports all aspects of institute operation, including technology advancement projects, education and workforce training efforts, and capital equipment.

In terms of technology advancement, Molnar reported that in FY 2016, there were 191 active R&D projects at the institutes. As an example of this research, he cited development of a prototype high-power inverter for hybrid motors in heavy-duty construction vehicles and trucks—a partnership between researchers from John Deere and PowerAmerica. Based on this advance, Deere plans to hire American production workers in Fargo, North Dakota, to manufacture and sell inverters starting in 2019. A second example is a competition organized by DMDII to analyze data provided by Indiana's ITAMCO and to develop software applications and other tools. Molnar noted that "ITAMCO learned so much about their operations that they would never have had without this deep dive into their data."

Finally, in terms of developing an advanced manufacturing workforce, Molnar said he was stunned to find that nearly 28,000 participated in institute-led workforce programs, including 23,560 students involved in institute R&D projects, internships, or training. A further 3,386 workers completed institute-led certificate, apprenticeship, or training programs, while the program drew in 1,023 teachers and trainers in institute-led training for instructors. As a network, Molnar added, Manufacturing USA also recognized that certain common skills are needed across advanced manufacturing technologies. Thus the program developed a common training model built around those core competencies, with each institute then working to adopt, refine, or develop technology-specific modules to meet its industry's needs.

Building on External Assessments

Molnar continued by noting that AMNPO is working on responding to the recommendations resulting from the Deloitte and GAO reviews, in the spirit

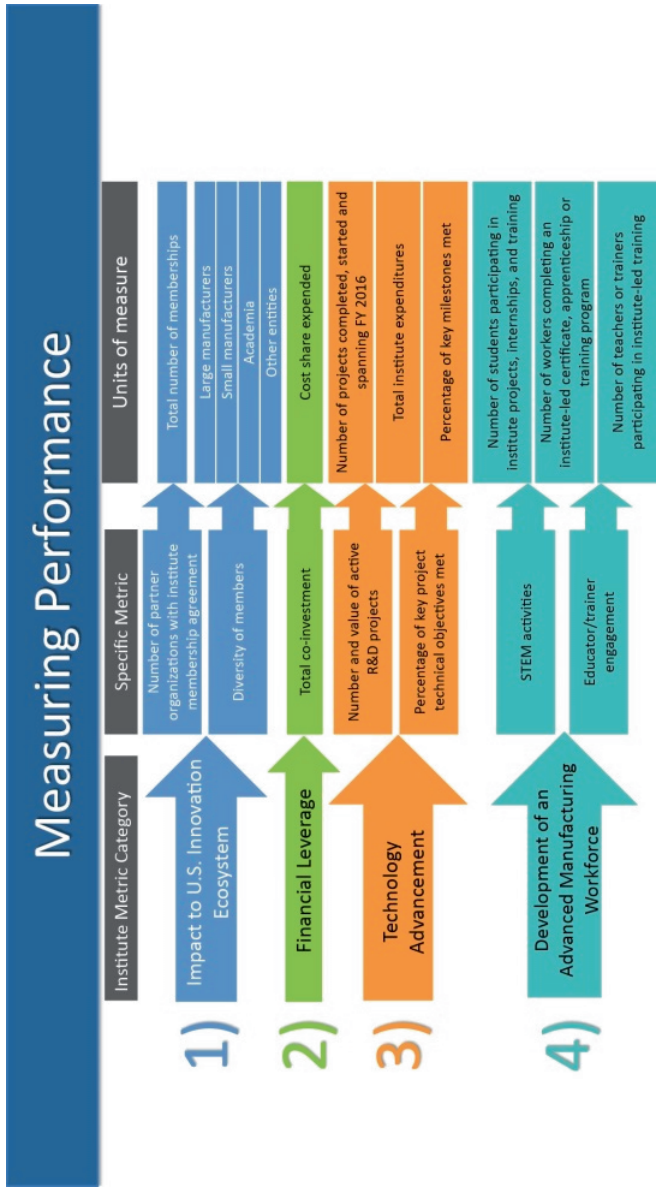

FIGURE 3-8 Manufacturing USA: Measuring performance.
SOURCE: Presentation of Mike Molnar, NIST, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA.

of continuous improvement. He reported that, building on Deloitte's recommendation, the program will expand and modify its metrics as the program matures. He added that, to address GAO's concern about including nonsponsoring agencies whose missions contribute to or are affected by advanced manufacturing, Manufacturing USA now includes DOL and the Department of Health and Human Services (the Food and Drug Administration and the Biomedical Advanced Research and Development Authority) on its interagency working team.

Discussion

Brett Lambert asked Mark LaViolette and Chris Murray to compare and contrast their assessment efforts. LaViolette noted that while he knew of the GAO audit, Deloitte's broad third-party assessment was an independent effort; he not aware of GAO's process and methods. Murray agreed that these were essentially two separate reviews, with the GAO review focused on compliance with the criteria established in legislation and elsewhere.

Lambert then asked Susan Helper and Mike Molnar about where they think the program will be 5 years from now. Molnar responded that while the institutes have a common framework, they are characterized by a diversity of approaches that adapt to the needs of their industries and technologies. Even so, he believes there is significant scope for learning from each other and expects that going forward, learning across the institutes will be more rapid. To this end, he noted, the program has established the Institute Directors' Council to allow the directors to talk with each other on a monthly basis. He added that he looks forward to being able to gauge project impacts as they begin in time to bear fruit.

Helper expressed the hope that, as the program's outcomes become apparent, it will be possible to demonstrate its broad social and economic benefits. There are now a "lot of cool institutes," she said, and "they are working together." But "they are small and their funding is not assured. So can we scale up these institutes and give them some kind of long-term lease on life?" Helper also noted that, beyond advancing new technologies, there are challenges to be addressed in facilitating their transition to the marketplace. In some cases, she observed, rules and norms governing particular markets create silos, inhibiting fuller participation by small innovative firms, while in other cases, purchasing incentives of some firms may not be consistent with their innovation objectives. She asserted that more work needs to be focused on the organization of firms and the market to understand, among other dynamics, how the structures of supply chains and linkages binding local and regional clusters affect the adoption of new technologies.

A participant raised the issue of the roles of states in augmenting the impact of the institutes and helping to ensure their long-term survival. Molnar emphasized that the institutes should do more than carry out successful projects,

saying that "the ultimate goal of every successful institute is to really catalyze that regional manufacturing hub to have national impact." Helper expressed the view that economic development policies pursued by states and regions need to evolve from simply offering tax breaks that encourage a "race to the bottom" to reflecting a strategy of investment in shared assets—including resident advanced manufacturing institutes—to create a "stickiness" so that companies will want to grow, thrive, and contribute to a locally based but globally linked productive cluster. She said she was encouraged to learn about initiatives in New York and Massachusetts in this regard.

PANEL IV: ADVANCED MANUFACTURING AROUND THE WORLD

Bill Bonvillian, lecturer at the Massachusetts Institute of Technology and the panel's moderator, began this session by arguing that the United States needs to move ahead in advanced manufacturing because that is where its competitors are going. "Tracking the metrics on our international competitors—especially Germany and China—and what they are moving on is going to be crucial," he asserted, "in part to understand our own position, but in significant part to understand lessons that we are going to need to understand and learn from abroad." He then introduced the panelists and invited Erica Fuchs, a professor at Carnegie Mellon University, to explain why the United States needs to lead in developing and commercializing advanced technologies.

Manufacturing Abroad and Innovation in the United States

Fuchs began her presentation by making three points. First, the capacity to innovate and manufacture leading technologies in the United States is important for national security. Second, developing and commercializing advanced technologies in the United States is necessary for the nation to remain a global leader. And third, in order to lead, the United States needs to understand the capabilities and potential of different organizational forms for advancing innovation and manufacturing.

Fuchs next provided some data to animate these points (Figure 3-9). She noted that while the United States' manufacturing value added has slowly increased over time, "what has changed is the percentage of the global pie that we are producing." This phenomenon, she observed, is driven largely by the rapid growth of Chinese manufacturing, reducing the U.S. market share.

Fuchs observed that this shift in manufacturing presents several problems. The first, she said, concerns what the United States is no longer manufacturing—a variety of products that support the defense industrial base. She noted that IBM has sold off its last trusted foundry, meaning that the U.S. government can no longer ensure the integrity and confidentiality of integrated circuits used for applications in national security during their design and

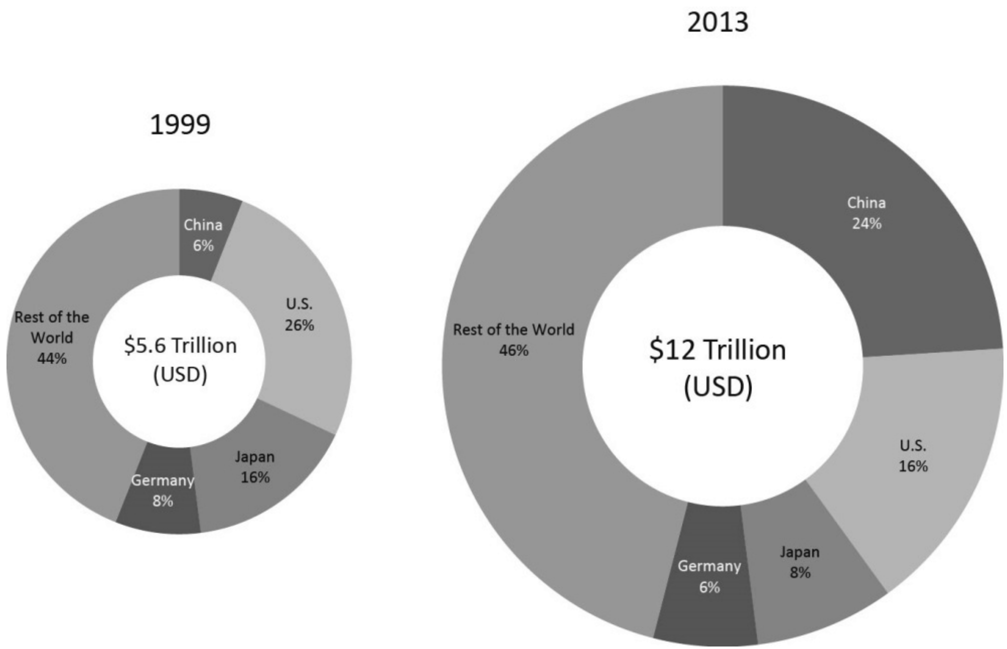

FIGURE 3-9 The global redistribution of production.
SOURCE: Presentation of Erica Fuchs, Carnegie Mellon University, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA.

manufacture. The second problem she identified concerns an erosion of the capacity to innovate as the center of gravity in advanced manufacturing for a number of leading technologies moves overseas due to lower production costs. "Technological superiority has repeatedly been a fundamental part of military security and military dominance," Fuchs observed. Third, she noted that "when you move manufacturing overseas, it becomes unprofitable for firms to pursue the technological frontier and the most advanced technologies." Citing her research on the shift in production by optoelectronic firms from the United States to countries in East Asia, she pointed out that public companies increasingly face incentives to produce old technologies overseas and abandon the development of new technologies in the United States.[19] As a result, she said, "it is only the private venture and government supported firms that actually attempt to pursue the new technology back in the United States, as in the optoelectronics case." If this the case, she asked, what role should the state play in advancing manufacturing?

Addressing her third point, Fuchs briefly examined different models of public–private partnerships to support U.S.-based advanced manufacturing:

- **The Defense Advanced Research Projects Agency (DARPA) model**—Central to this model, Fuchs said, is the role of the program manager, who is appointed to a 3- to 5-year term, serving primarily as a network agent, matching ideas and people, and connecting emerging research themes to future military needs. She characterized the DARPA model as designed primarily to prevent technological surprise rather than to develop the broad platform of advanced manufacturing technologies.
- **The Semiconductor Research Corporation**—Fuchs described this as a technology research consortium in which industry, with public support, funds research projects in universities to carry semiconductor technologies forward. She noted that, while this model has been successful in coordinating precompetitive research through the development of shared technology roadmaps, this paradigm faces a major challenge as it approaches the end of Moore's Law and the availability of a common complementary metal oxide semiconductor (CMOS) technological platform.
- **Manufacturing USA**—Fuchs characterized this model as seeking to develop platform technologies in a variety of emerging areas that "economists tell us are going to be underfunded" by the private market. The challenge, she explained, is that when the costs are targeted and the benefits are diffuse, it is difficult to align incentives among firms in an industry to contribute to this work.

[19]Erica Fuchs and Randolph Kirchain, "Design for location? The impact of manufacturing offshore on technology competitiveness in the optoelectronics industry," *Management Science* Vol. 56, Issue 12, pp. 2323–2349, 2010.

Commenting on the limited toolset available compared with the importance of manufacturing for economic growth and national security, Fuchs asked if these available options are right or adequate for scope of the challenge. These remarks set the stage for the next group of panelists to consider what other countries do to support the development and domestic manufacture of advanced technologies.

Germany's Fraunhofer Institutes and the Industrie 4.0 Initiative

Patrick Bressler introduced himself as executive vice president of Fraunhofer USA. He said Germany understands the importance of manufacturing as a key engine that stimulates not only production but also R&D in a virtuous cycle. "That is one of the reasons why Germany has always kept the manufacturing sector up and running," he observed.

Fraunhofer-Gesellschaft

Bressler described Fraunhofer-Gesellschaft (the Fraunhofer Society) as a network of German institutes for applied research. Its primary mission is to perform contract research for German industry, particularly SMEs, which translate basic research from universities and nonuniversity research organizations into commercial products and industrial processes.

Fraunhofer's research activities are conducted by 69 institutes and research units at locations throughout Germany. System-wide, it employs a staff of 24,500, the majority of whom are qualified scientists and engineers. Bressler explained that each Fraunhofer institute specializes in a particular technology or sector, and an institute exists for virtually every sector of significance to a modern industrial economy, ranging from renewable energy, to aerospace, to automotive manufacturing, to microelectronics and information technology. He added that institutes working in related subject areas cooperate in Fraunhofer Groups and foster a joint presence on the R&D market.

Collaboration with Universities

Bressler explained that each Fraunhofer institute is paired with a German university and can utilize the most promising students as part-time researchers, thereby giving students practical experience in commercially oriented research and manufacturing environments. He noted that this partnership gives the Fraunhofer institutes access to basic research conducted at the partner universities while also providing a ready pool for the recruitment of students and junior scientists. It also provides opportunities for Fraunhofer employees to gain additional scientific qualifications. In sum, Bressler said, "The institutes generate technology for commercial products and processes, enable companies to test equipment and industrial processes on pilot

manufacturing lines, and foster a continual flow of trained engineers and technicians to the private sector."

Funding Scale and Stability

Bressler reported that Fraunhofer's funding is derived from diverse sources, including federal, state, and European Union public funding; fees from contract research for industry and public organizations and foundations (see Figure 3-10); and licensing fees for intellectual property. The annual research budget totals 2.1 billion euros. Of this sum, 1.9 billion euros is generated through contract research. One-third of Fraunhofer's funding consists of "core" funds provided by the German federal and state governments; roughly another third comes from research contracts with government entities; and one-third is provided through research contracts with the private sector, which are frequently supported by government grants and other financial assistance.[20] Bressler drolly described this high level of ongoing public funding to support large and midlevel manufacturing, embedded along with the German system of dual education and vocational training, as "un-American," but noted that it has provided great stability over the 70-year life of Fraunhofer-Gesellschaft.

Together, Bressler said, the Fraunhofer institutes operate in a "dynamic equilibrium between application-oriented fundamental research and innovative development projects." He explained that industry can commission research, development, and validation projects; gain access to cost-intensive state-of the-art laboratory equipment; and hire experts experienced in the newest and most relevant technologies. The institutes also help maintain "critical mass" in technologies; train interns, students, and postdoctoral fellows on relevant technologies; provide validated solutions; and secure and manage intellectual property.

Industrie 4.0

Bressler explained that Industrie 4.0 is the name given to a strategic initiative to establish Germany as a lead maker and purchaser of advanced manufacturing solutions. Heralding the next industrial revolution, he elaborated, this initiative seeks to integrate digitization, new manufacturing processes, and the interconnectivity needed to develop sustainable and efficient manufacturing platforms that enable the mass manufacture of tailor-made, individualized new products. He went on to say that this initiative has the potential to be disruptive, creating new value chains and business models.

[20]National Research Council, *21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program*, 2013, Appendix A2: "Fraunhofer-Gesellschaft: The German Model of Applied Research."

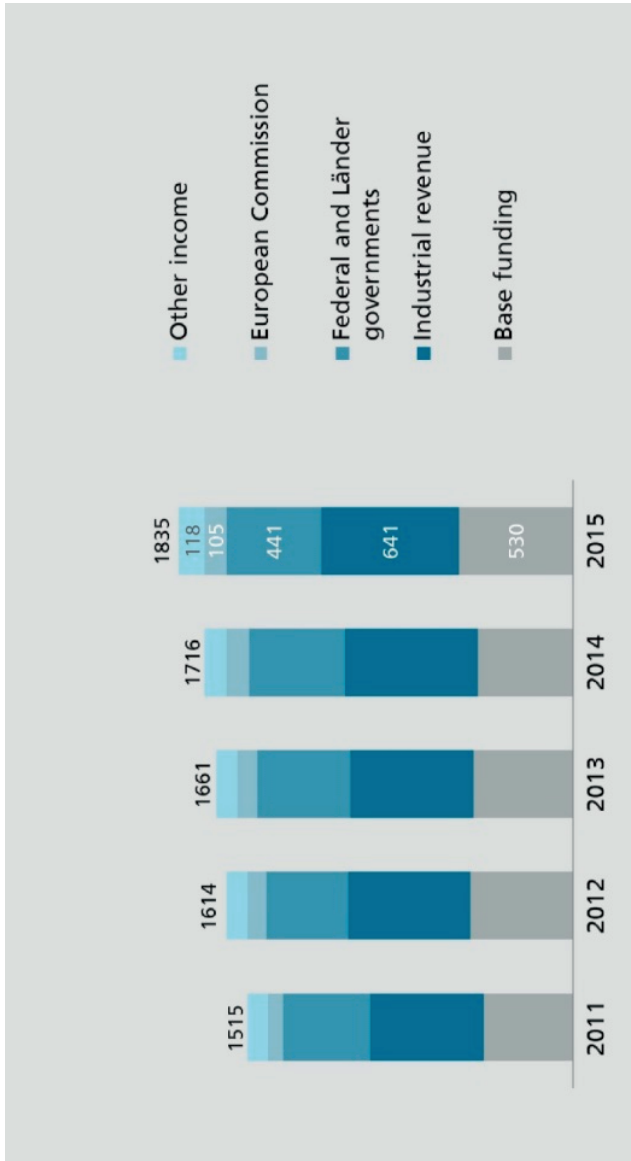

FIGURE 3-10 Fraunhofer-Gesellschaft's contract research: 2011–2015 (in millions of euros).
SOURCE: Presentation of Patrick Bressler, Fraunhofer USA, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA. Adapted from Fraunhofer-Gesellschaft.

Bressler noted that Fraunhofer has a strong focus on Industrie 4.0 technologies throughout the entire production value chain. Together with university research partners, experts at Fraunhofer are working to develop the smart factory of the future, including in such areas as deep-drawing to laser applications, and services related to the Internet of Things.

Citing a recent publication by Reimund Neugebauer and colleagues, Bressler said that "key enablers for harnessing the benefits of digitization for Industrie 4.0 are widely accepted standards, extreme low latency in digital communication as well as safety and security for data analytics and data exchange."[21] The "Fraunhofer layer model," he added, has been developed to translate these challenges and developments into corresponding technologies.

China's Specialization in Innovative Manufacturing

Jonas Nahm, assistant professor at The Johns Hopkins University, began by observing that "it is no news to anyone that China has rapidly added to its manufacturing capacity and increased its manufacturing value added. But we often forget that for the last 10 or 15 years, the Chinese central government has been trying to get away from manufacturing and into innovation based on earlier stage research." This top-down push has failed, however, because the incentives of localities and firms were not aligned with this approach. Nahm explained that a new strategy introduced in 2015 entails a shift from forging industrial leadership through innovation toward a more German-inspired model of upgrading manufacturing through a rolling series of technological advances.

China's Indigenous Innovation Policy

Nahm described the Indigenous Innovation Policy as focused on gaining independence in technological innovation from foreign partners, with innovation being defined as invention and the government seeking to advance it by increasing R&D expenditures in basic research. This strategy, Nahm opined, has achieved some mixed success: "I think China is on track to meet its R&D expenditure goals, but it probably is not on track to meet its basic research expenditure goals." Nahm went on to observe that this policy reached its pinnacle in the 2010 Strategic Emerging Industries Initiative, which identified a number of critical sectors for technological independence from foreign partners, "focused again on this idea of innovation as invention."

Researching how this policy was being implemented in the wind and solar energy sectors, Nahm found that Chinese firms focused on bringing new technologies to scale very quickly at lower cost by substituting materials, upgrading product architectures, and often integrating new technologies at a rapid pace. He added that "a lot of this engineering was performed on

[21]Reimund Neugebauer, Sophie Hippmann, Miruim Leis, and Martin Landher, "Industrie 4.0—From the perspective of applied research," *Procedia CIRP* Vol. 57, pp. 2–7, 2016.

technologies that were coming from abroad." In short, he said, "the Chinese firms basically figured out they could buy the technology and they were going to invest their time and resources in trying to bring this stuff to scale."

These firms were responding to incentives promulgated by local governments in China, Nahm continued, which differed from the strategic goals announced by the central government to foster indigenous innovation. As an example, he cited wind turbine manufacturer Goldwind, which used 863 Program funds not to replace foreign partners but to improve capabilities in commercialization and scale-up. In summary, "local governments in China are incentivized to produce short-term economic growth, which means that they are not investing in some grand innovation strategy that may or may not work out. It is funding mass production."

Made in China 2025

Nahm explained that the lessons and limitations of this strategy led the central government to announce a new Made in China 2025 policy, starting in 2015. Describing this as "a very top-down policy framework that comes out of the State Council in Beijing," he said it reflects a "shift in focus from the sort of U.S. model of research-driven innovation, as China saw it in 2006, to a much more German or Japanese model of trying to upgrade within manufacturing, rather than upgrade out of manufacturing." He described the current policies as seeking to address "a huge concern about getting stuck in the middle-income trap"—not being able to compete on cost with other developing economies as wages in China rise, while at the same time being squeezed from below by higher efficiencies in the advanced economies. He added that "it is clear that this is very much about import substitution and not buying the German production equipment anymore."

According to Nahm, the Made in China 2025 strategy targets a number of technology platforms and industrial sectors that are seen as critical to the future of China's economy, revealing a comprehensive investment and competitiveness strategy (see Figure 3-11). Leading features of the new push include

- the creation of a network of manufacturing centers, similar to the U.S. effort;
- the forging of industry consolidation to ensure that firms make money;
- a focus on green manufacturing; and
- initiation of a large research program on high-end manufacturing equipment.

Nahm added that these initiatives are backed by "massive investments in these technologies":

- A $3 billion Advanced Manufacturing Fund has already made investments in firms that produce electric vehicles and robots.
- The Ministry of Industry and Information Technology has pledged to open 40 Manufacturing Innovation Centers. A battery innovation center opened in 2016, with $400 million in funding through 2020.
- The central government claims to have spent $3 billion on 300 enterprise-level experimentation programs focused on various sorts of advanced manufacturing–related technologies, from radio frequency identification (RFID) in components to cloud technologies and beyond.
- There has been a pledge to open 40 industrial parks—just for robots.
- Subsidies worth 40 billion yuan have been pledged for advanced manufacturing products. Guangdong, for example, has promised $150 billion to upgrade its domestic local manufacturing plants.

Some Notes of Caution

Nahm reminded the audience that advanced manufacturing in China is progressing in different stages. He noted that many Chinese firms have not yet fully upgraded to integrating computers and automation into production, much less anticipated the current trend of developing intelligent cyber-physical systems, often called Industry 4.0, to create smart manufacturing. "When you talk about advanced manufacturing in China," he continued, "it is worth paying attention to what they are actually talking about. Certainly, if we look at the use of industrial robots, for instance, China is far behind anybody else and is not catching up very much."

Concluding his remarks, Nahm suggested several notes of caution, China's remarkable ambitions and investments notwithstanding.

- *Policy misalignment*—The goals of the central government, the incentives faced by regional bodies, and the capacity of enterprises to execute on plans continue to be misaligned.
- *Limited absorptive capacity*—Many firms lack the absorptive capacity to participate in the new programs to foster advanced manufacturing.
- *Limited training*—The workforce training needed to support the scale of advanced manufacturing being planned is lacking. "If this amount of robotics manufacturing is going to happen," Nahm asserted, "we need a lot more people who know how to use CNC [Computer Numerical Control] machines."
- *Overcapacity*—Duplication of effort at the local level can lead to problems of overcapacity.

Overall, Nahm observed, Chinese firms are finding ways to integrate themselves into global innovation networks through a very nationalistic strategy.

FIGURE 3-11 Made in China 2025.
NOTE: BYD =BYD Auto Co., Ltd. CNY = Chinese Yuan; EV = Electric Vehicle; RFID = radio frequency identification.
SOURCE: Presentation of Jonas Nahm, Johns Hopkins University, at the 23 May 2017 National Academies of Sciences, Engineering, and Medicine workshop on The Role of Manufacturing USA.

The scale and ambition of the effort require attention, not least for its potential to disrupt, he concluded, even as "I am both worried and skeptical about how it is going to work."

Discussion

Bill Bonvillian thanked the speakers and summarized some of their key points. He said that Erica Fuchs "taught us about the consequences for 'innovation here' by 'outsourcing there.'" It is necessary, he added, to look more closely at the relationship between "production strength" and "innovation capability," and doing so requires understanding the role of other innovation players and partnerships.

Citing Patrick Bressler's presentation, Bonvillian suggested that there is a lesson to be learned from Germany, which, through its Industrie 4.0 initiative, is utilizing the resources, facilities, and talents of its research institutes to develop a technology roadmap for the next generation of advanced production. He posed the question of whether there is "a way of bringing our institutes together to think more broadly, not just about their sector, but more broadly about the whole system of advanced manufacturing that is going to entail [gathering] a lot of their particular strands into an overall effort." His point was that the future factory would include many advanced manufacturing elements, and the network could play a role in pulling these individual elements into a system. In regard to workforce training, he added that the Fraunhofer Academy is a valuable mechanism for advancing specialized skills for manufacturing, and that this model may offer ideas for the U.S. institutes, including operations at a network level.

In response to a question from the audience, Bressler explained that the Fraunhofer institutes can create alliances among themselves to advance technologies that cut across disciplines. He gave the example of an advanced hip implant, in which institutes with a complement of competencies cooperated to address the needs of a German company.

Finally, Bonvillian thanked Jonas Nahm for furthering an understanding of China's "quite dynamic model for innovation change." He observed that the results of China's previous strategy of indigenous innovation may not have worked as central planners had expected, but still led China to dominate world production. What would be the impact of China's new strategy more directly focused on manufacturing? He added that "the levels of money that are being discussed here are almost unimaginable."

Charles Wessner drew attention to Nahm's statement that China has allocated $150 billion to the development of a vertically integrated semiconductor industry. Nahm noted in this regard that the semiconductor fund is one of the major items in China's Advanced Manufacturing Fund, which was kicked off in 2016. He cautioned that even though there are inefficiencies in the Chinese system," it is enough money that some if it will be productive."

PANEL V: POLICY ROUNDTABLE

David Hart invited Mike Russo of GLOBALFOUNDRIES to moderate the final panel. Russo began by suggesting that the Manufacturing USA institutes play an important role not only in extending American leadership in R&D but also in growing an educated and trained workforce and in forging linkages across the supply chain. He added that his own company, GLOBALFOUNDRIES, a large contract chip maker, "is driven to make sure that the ecosystems that we need to compete are in place wherever we set up shop."

Introducing his panel, Russo noted that while other panels had addressed the issues from the perspective of innovation, employment, and economic development, this panel would "look at things more from a national security perspective and a manufacturing industrial base perspective." He then introduced Sridhar Kota, a professor of mechanical engineering at the University of Michigan and an early champion of developing a network of advanced manufacturing institutes, and invited him to speak.

Connecting the Dots

Kota began his presentation by asserting that the United States needs a strong advanced manufacturing base to carry out national missions in defense and to promote economic growth and that the Manufacturing USA institutes are designed to build and reinforce this base. He added that a strong domestic manufacturing base is essential for national security. While critical elements of the U.S. defense infrastructure need to be produced in secure and trusted production facilities, he continued, there are serious gaps, an observation he illustrated by citing the finding of a 2012 report of the Senate Armed Services Committee that there are numerous examples of counterfeit products and parts in the nation's military equipment. "As more and more advanced work is conducted abroad," he argued, "the U.S. will increasingly rely on others to provide our weapons."

Kota also stressed that a strong domestic manufacturing base, as a part of a functional innovation and technology ecosystem, is essential for the nation's economic well-being. Suggesting that a focus on inputs alone is not sufficient, he noted that the United States invests $140 billion in science and technology as an input but has as one outcome a $100 billion trade deficit in advanced technology products. "We can't possibly have that," he said; "we should have a trade surplus in advanced technology products and we should have trusted sources."

Kota continued by asserting that "while we are still the best in the world when it comes to science, if we do the invention and someone else does the manufacturing, then there is no real return on the taxpayers' investment." Recalling the market failures described by Susan Helper earlier in the day, he averred that "the government has a role to nurture and mature these technologies

and reduce the technical and market risk." And beyond this, "we want to ensure that we anchor manufacturing of these technologies here; you cannot just mature the technology and give it to your friends and competitors overseas."

Kota noted that other leading countries have robust and well-funded national strategies to support advanced manufacturing. In the United States, by contrast, the manufacturing institutes and the MEP system are the only real policy tools currently available to build the nation's industrial base. While these programs can be improved, Kota argued, "we should absolutely double down on them. How could we not afford to have funding for these two entities?" "So, we really need strategic and coordinated investment," he continued. "We are so good at science because we have an incredible scientific infrastructure in this country. We really need to build an infrastructure for engineering, technology, and innovation, sustained by strategic and coordinated investment—that's what it is all about." DOD, DOE, NIST, NSF, and other agencies all play a role, he added, but "we just need to connect the dots."

Rebuilding the Manufacturing Commons

André Gudger, founder and CEO of Eccalon, began by suggesting that the Manufacturing USA institutes are showing signs of regenerating the manufacturing commons. This commons began to degrade starting in the late 1980s, he continued, when U.S. businesses began to disinvest in large-scale, billion-dollar research organizations such as Bell Labs. These research organizations generated intellectual property, anchored the innovation ecosystem, and served to provide technological advantages to the warfighter. However, Gudger explained, "such long-term research and development investments didn't look good on corporate balance sheets, so out they went. As a result, we eroded that part of our industrial base." To recover from this legacy of disinvestment in manufacturing innovation, Gudger argued that what is needed now is "a resurgence of technical innovation, technical dominance, and technical superiority—whether it is governmental or commercial."

According to Gudger, the Manufacturing USA institutes are helping to fill that void. While many of the institutes are in their early years, he observed, the recent reviews show signs that the institutes are working. Already there are new activities in workforce development; growing intellectual property portfolios; and early activity in connections among industry, academia, local governments, and the federal government in ways that have not been seen before, including cooperative agreements that help these actors work together to rebuild the industrial commons. These signs indicate, Gudger said, "that we need to do more, not less, of what we have been doing."

In comparing the scale of the U.S. effort with that in China reported by Jonas Nahm, Gudger reminded the audience that "our investment may not be as high as some people who are starting from scratch. We are actually building on a strong platform and with a workforce that is knowledgeable. We are bending that workforce so that we can then bring back the high-paying jobs. We are

solidifying our technical dominance across both commercial and federal markets." Concluding his remarks, Gudger challenged the audience to stay the course, to rebuild the innovation commons to ensure the future of advanced manufacturing in the United States.

Manufacturing Strength and National Security

Kirk McConnell, professional staff member on the staff of the Senate Armed Services Committee, acknowledged that as someone who handles intelligence and cybersecurity for that committee, he was a newcomer to manufacturing policy. Still, he said, what struck him about the day's deliberations was the systemic problems in the manufacturing sector and more broadly in the innovation system. Given the importance of manufacturing and innovation for national security, he asserted, these problems require national action.

McConnell described the collapse of manufacturing employment in the first decade of the 21st century as having serious negative social impacts, including—in some areas—rising mortality rates and high levels of opioid addiction among working-class white Americans. He observed that the decline of the manufacturing sector also has coincided with poor gains in productivity, adding that "if you don't gain in productivity, you have a moribund economy. And if you don't have a healthy economy, you don't have a strong defense."

McConnell cited Germany as an example of a country that pays attention to nurturing a thriving manufacturing sector. While this is possible for the United States, he suggested, policy makers here are focused on reforming the tax system, rewriting trade policies, and pulling back regulations rather than paying attention to manufacturing and other engines of economic growth. There are some systemic problems with U.S. innovation policy, he concluded, which he characterized as disturbing.

Communicating the Value of the Institutes

Arun Seraphin, professional staff member on the staff of the Senate Armed Services Committee, asserted that for the Manufacturing USA initiative to survive, it must make the case for its value to Congress, to decision makers in the Pentagon, to universities, and to incumbent firms. He suggested that members of the Senate Armed Services Committee are likely to support the institutes if they think that the advances in manufacturing the institutes enable are lowering costs and speeding acquisition and procurement. These senators, he added, are grappling now with the challenge of meeting the surges in equipment required for the war efforts in Afghanistan and elsewhere, and are likely to support the institutes if the case is made that advanced manufacturing is responding to current mission needs.

In general, Seraphin added, members of Congress also like to support efforts in their states or districts that create jobs and support economic activity.

He expressed the view that the Manufacturing USA model of distributing institutes across the country works to this advantage. In any event, he urged the institutes to develop a better communication strategy to reach members of Congress. In particular, he suggested, members need to be able to recall a good story related to something that was produced by a manufacturing institute. For congressional staff, he continued, the institutes need to determine how to communicate succinctly the advantage of sending an extra dollar to a manufacturing institute over other alternative and competing mechanisms. The question they must answer, he said, is, "Why is this dollar better spent at an institute rather than with a prime contractor, programs like SBIR that draw out innovative solutions from small businesses, or university research programs?"

Seraphin argued that the institutes also need to reach out to the organic industrial base—the shipyards and arsenals where much of the work of producing and repairing gear used by the armed forces is carried out. The institutes need to emphasize these connections, he advised, and develop programs so that they are more visible to leadership in the Pentagon and on Capitol Hill.

As a final point, Seraphin observed that the manufacturing ecosystem being developed by the Manufacturing USA institutes is only as robust, rich, and interconnected as its dollar flows. "If we don't actually come up with ways to flow dollars among all these actors we are trying to interconnect—the universities, the industry, the government labs—we don't have the ecosystem we are looking for," he asserted. He urged the audience to think hard about the challenge of moving and sharing dollars among these organizations.

Discussion

Mike Russo asked the panelists for their thoughts on improving and sustaining the Manufacturing USA institutes. "If the conclusion is that this is a tool in the toolbox that we need to keep," he said, "then we need to figure out how to make them more effective. With other nations making huge investments, we need to figure out how to sustain the model."

Sridhar Kota suggested that an important lesson from the German Fraunhofer institutes is the role of government in providing matching funds to reinforce private investment. Kirk McConnell emphasized that public investment in the manufacturing institutes plays an important role in a space where venture capitalists are not willing to make large and sustained investments in startups planning to manufacture "hard" technologies. He added that large companies, reacting to incentives that reward short-term returns to shareholders, have also retreated from performing manufacturing R&D in house.

André Gudger observed that addressing workforce development is essential if advanced manufacturing is to take root on U.S. soil. In part, he said, this challenge requires educating students and workers about what manufacturing looks like today: "The next generation of shop-floors doesn't look like it did 20 years ago."

Arun Seraphin noted the "tension between wanting to do good science and technology and manufacturing research at a place like an institute, and then doing nothing to ensure that it actually creates American jobs in America." While the institutes find support on Capitol Hill for their role in strengthening U.S. competitiveness and in ensuring access to trusted technologies, he warned that there will be "frustration if we start to see the intellectual property generated out of the institutes appearing in overseas production lines."

Bringing the workshop to a close, David Hart thanked the panelists and the audience, saying, "The one thing we can say is that the conversation will continue."

4

Key Points Made at the Workshop

This chapter summarizes key points made by workshop presenters and discussants. These statements reflect the views and opinions of individual workshop participants and do not necessarily represent the views of all workshop participants; the planning committee; or the National Academies of Sciences, Engineering, and Medicine.

- **A number of speakers emphasized that U.S.-based manufacturing is important for the nation's security and economic growth.**

  - Erica Fuchs, Sridhar Kota, and others argued that a strong manufacturing base is essential for national security.
  - Susan Helper showed evidence that a strong domestic manufacturing base is also essential for the nation's economic well-being. She noted that manufacturing plays a central role in creating wealth and high-value employment in the United States.

- **Speakers also pointed out that past disinvestment in the manufacturing sector has harmed the United States.**

  - André Gudger noted that the outsourcing of manufacturing over the longer term has led to the degradation of the manufacturing commons. He asserted that this has contributed to the decline in manufacturing jobs, as well as the decline in innovative capacity associated with manufacturing.
  - Kirk McConnell observed that the United States underwent a major disruption of its social fabric, in part because of the decline in U.S. manufacturing, in the period 2000–2010. He cited rising mortality rates and high levels of opioid addition among working-class Americans as symptoms of this problem.

- Erica Fuchs drew a direct connection between U.S. production capability and ongoing innovation in the United States. When production is moved abroad to take advantage of lower wages and costs, she observed, U.S. firms can become dependent on this system of production and cancel work on needed innovations in the product line.

- **Most speakers observed that the nation's competitors are doing more than the United States to invest in advanced manufacturing.**

  - Patrick Bressler reported that the annual budget of the Fraunhofer institutes is approximately 2 billion euros. By comparison, the Manufacturing USA institutes are funded through cooperative agreements with the Department of Defense (DOD), the Department of Energy (DOE), and the National Institute of Standards and Technology (NIST) totaling about $1 billion in federal commitments, matched by $2 billion in private funding for the 14 institutes thus far, spread over a 5- to 7-year period.
  - Sridhar Kota noted that an important lesson from the German Fraunhofer institutes is the role of long-term commitment of the federal and state governments in providing matching funds to reinforce private investment.
  - Bill Bonvillian stressed the importance of understanding that the nation's competitors—the two most successful manufacturing nations, China and Germany—are pursuing advanced manufacturing all out. If the United States wants to stay in the game, he added, it has little choice but to pursue advanced manufacturing.
  - Jonas Nahm reported that the new China 2025 strategy includes a $3 billion Advanced Manufacturing Fund.
  - Ravi Shanker said he believes the nation needs to make some "big bets" in advancing manufacturing for the good of the country.
  - Brett Lambert observed that "we need to understand where we will be in 5 years on advanced manufacturing, because that's where our competitors are going." Other countries have robust and well-funded national strategies to support advanced manufacturing, he noted.
  - Susan Helper suggested that while the American and German systems differ in key respects, Germany's leadership in advanced exports and manufacturing employment demonstrates the positive impact of sustained policy attention to manufacturing.

- **Many speakers described the Manufacturing USA initiative as a needed strategy for drawing innovation to the manufacturing sector and developing the innovation ecosystem.**

  - Jeff Wilcox suggested that the institutes enable manufacturing firms to cross over and access emerging developments in a variety of technological fields. For large companies, the Manufacturing USA institutes help draw in innovation by facilitating cooperation with universities and small businesses.
  - He added that the institutes have demonstrated their ability to promote collaboration across firms, to link participating firms to new suppliers, to coordinate technological roadmapping in new areas, and to introduce new technologies across different industrial sectors.
  - André Gudger noted that the manufacturing institutes represent a means to bring about "a resurgence of technical innovation, technical dominance, and technical superiority" in U.S. manufacturing.
  - According to Mark LaViolette, the Manufacturing USA institutes are helping to overcome fragmentation among U.S. manufacturers that has prevented firms from undertaking collective action to develop new technologies. He added that the workforce education role of the institutes helps resolve local shortages of skilled technical workers.
  - Erica Fuchs stressed the role that the institutes can play in connecting other research and development (R&D) agencies to the advanced manufacturing agenda. While the institutes can fund platform technologies, she emphasized that the foundational work behind those technologies is also critical. This means, she suggested, that ways should be found to engage other R&D entities, through the development of research agendas and technology roadmaps with the institutes, which will be important to the success of an advanced manufacturing strategy in the United States.

- **Some speakers noted that the idea of a public–private partnership to strengthen manufacturing is not new. In fact, they observed, the United States has a long tradition in public–private partnerships for manufacturing.**

  - Jeff Wilcox described Alexander Hamilton's role in promoting a U.S. economic strategy around manufacturing capability, linking the new nation's political and economic independence with capabilities in domestic manufacturing.

- He noted that Hamilton also established the first public–private partnerships in Passaic, New Jersey, to stimulate U.S.-based manufacturing.

- **A number of workshop participants presented results of recent assessments showing that the institutes, while still new, are making an impact.**

  - Mark LaViolette said the Deloitte review found that the institutes are enabling companies to overcome fragmentation in the manufacturing sector that has hindered them from collaborating to innovate new products and to train the skilled technical workforce.
  - Christopher Murray of the Government Accountability Office said he was impressed by the progress made by the Department of Commerce in coordinating the Manufacturing USA effort across the sponsoring agencies. He suggested that Commerce also reach out to other federal agencies that are not sponsors of the institutes.
  - With regard to fulfilling the mission of his institute, Yoel Fink said that connections among different types of producers and innovators are enabling a Moore's Law for fabrics, with rapid prototyping that would not otherwise be possible in a disconnected sector with little history of collaboration. AFFOA, he indicated, has a special focus on bringing in startup firms in collaboration with other member firms, to scale up new fiber technologies; this approach could provide lessons for other institutes.
  - Yoel Fink also suggested that by acting as unpaid licensing agents for university participants' intellectual property, institutes could enable better IP sharing and collaboration across institute companies.
  - Nick Justice and Lawrence Brown described their institutes as key enablers for small and medium-sized manufacturers, which would otherwise lack the resources to access and implement innovation.
  - Mike Molnar said the institute network is educating the workforce by imparting common skill sets across the institutes. He added that an institute-wide effort is under way to develop training modules around core competencies.

- **Participants also offered advice and suggestions for improving the institutes and their networks.**

  - Jeff Wilcox called for speeding up and standardizing membership agreements with firms and developing industry roadmaps to coordinate the work of industry partners.

- Erica Fuchs suggested that the institutes connect actively with other public and private research organizations to take full advantage of the value of the network and to elicit new ideas for innovation for the institutes to build on.
- Mike Molnar suggested that the institutes can learn much from each other's experiences in research, information exchange, and innovation, which suggests that the network role needs to continue to be strengthened.
- Jeff Wilcox noted that Manufacturing USA must be a "national network because these [technologies] are not one-off things." He noted we can't have "metals over there and composites over there, and robots over there." He suggested the network needs to play a growing role in integrating the work of its individual institutes into larger systems. Bill Bonvillian reiterated this point, noting that the German Fraunhofer institutes provide lessons on how to bring the various advanced manufacturing strands together into such a system.

- **Given the importance of their mission and evidence that their approach is proving effective, several participants urged that the institutes develop strategies for remaining viable following the initial period of federal support.**

  - Speaking in the first panel, several institute directors described their plans for ensuring the sustainability of the institutes, even as work is ongoing to establish them. For example, Lawrence Brown of Lightweight Innovations for Tomorrow (LIFT) said his institute seeks to become a provider of advanced engineering services and workforce development as a way of providing value for the members of its network.
  - Arun Seraphin emphasized that Manufacturing USA has to make the case for why it is valuable. He suggested that the institutes develop a strategy for communicating to policy makers, including both anecdotal information and data on new technologies that are incorporated into new military products and systems.
  - Similarly, Katie Stebbins suggested that the institutes and their networks engage more broadly with state policy makers and officials on their contributions to the regional economy.

APPENDIXES

Appendix A

Workshop Agenda

Innovation Policy Forum

Securing Advanced Manufacturing in the United States:
The Role of Manufacturing USA

May 23, 2017

National Academies Keck Center
Room 100
500 Fifth Street, NW
Washington, DC

AGENDA

9:00 AM	**Welcome:** David Hart, *George Mason University and Innovation Policy Forum co-chair*
9:05 AM	**Opening Keynote**: Jeffrey Wilcox, *Lockheed Martin*
9:35 AM	**Panel I: A Roundtable on the Manufacturing USA Institutes** Moderator: Ravi Shanker, *Dow Chemical* Lawrence Brown, *LIFT* Yoel Fink, *AFFOA* Maj.-Gen Nickolas Justice, USA, Ret., *PowerAmerica* Kelvin Lee, *NIIMBL*
10:50 AM	**Coffee Break**

11:00 AM **Panel II: Manufacturing USA and Regional Economic Development**

Moderator: David Hart, *George Mason University and Innovation Policy Forum co-chair*

Workforce Development and the Institutes
Brennan Grignon, *Department of Defense*

State Perspective
Katie Stebbins, *Commonwealth of Massachusetts*

Small and Medium-sized Enterprises
Jennifer Hagan-Dier, *MEP Tennessee*

Economic Development: Lessons from New York
Charles Wessner, *Georgetown University*

12:30 PM **Lunch**

1:30 PM **Panel III: Assessing the Manufacturing USA Initiative**

Moderator: Brett Lambert, *Northrop Grumman*

The Role of the Federal Government in Strengthening American Manufacturing
Susan Helper, *Case Western Reserve University*

Bringing R&D Innovation to Manufacturing
Mark LaViolette, *Deloitte*

Strengthening Collaboration
Christopher Murray, *Government Accountability Office*

From Concept to Practice: The Manufacturing USA Annual Report
Mike Molnar, *National Institute of Standards and Technology*

3:00 PM **Coffee Break**

3:15 PM **Panel IV: Advanced Manufacturing Strategies around the World**

Moderator: William Bonvillian, *MIT*

Manufacturing Abroad and Innovation in the United States
Erica Fuchs, *Carnegie Mellon University*

Germany's Industry 4.0 Initiative and Fraunhofer Institutes
Patrick Bressler, *Fraunhofer USA*

China's Specialization in Innovative Manufacturing
Jonas Nahm, *Johns Hopkins University*

4:30 PM **Panel V: Policy Roundtable**

Moderator: Michael Russo, *GLOBALFOUNDRIES*

André Gudger, *Eccalon*
Sridhar Kota, *University of Michigan and MForesight*
Kirk McConnell, *Senate Armed Services Committee*
Arun Seraphin, *Senate Armed Services Committee*

5:30 PM **Adjourn**

Appendix B

Biographies of Speakers and Planning Committee Members*

WILLIAM BONVILLIAN**

William B. Bonvillian is lecturer at the Massachusetts Institute of Technology in the Science, Technology, and Society and Political Science Departments, and advises on research projects at MIT's Industrial Performance Center and its Office of Digital Learning. Prior to this position, from 2006 to 2017, he was Director of MIT's Washington, DC Office, reporting to MIT's President. In this position he worked to support MIT's strong and historic relations with federal R&D agencies, and its role in national science policy.

Prior to that position, Bonvillian served for 17 years as a senior policy advisor in the U.S. Senate. His legislative efforts included science and technology policy and innovation issues. He worked extensively on legislation creating the Department of Homeland Security, on intelligence reform, on climate change, on defense and life science R&D, and on national competitiveness and innovation legislation leading to the America Competes Act in 2007. He is the author of a forthcoming book on advanced manufacturing from MIT Press and has written extensively on innovation and manufacturing topics.

In addition to teaching at MIT, Bonvillian is on the adjunct faculty at Johns Hopkins Paul H. Nitze School of Advanced International Studies (SAIS). He graduated with honors from Columbia University, and has an M.A.R . (in

*Biographies as distributed at the workshop.
**Member of the workshop planning committee.

religion) from Yale University Divinity School and a J.D. from Columbia University School of Law.

PATRICK BRESSLER

Patrick Bressler has been executive vice president of Fraunhofer USA since October 1, 2014. He manages the operations of the seven Fraunhofer USA Centers. Tasks include developing technology transfer and innovation partnerships with U.S. universities and companies, and strengthening transatlantic collaboration in applied science and technology between the United States and Germany. Bressler serves on scientific review panels and international expert groups, in particular, in materials research and transatlantic cooperation and science and technology. He is an adjunct professor of electrical and computer engineering at Michigan State University.

From 2010 to 2014, Bressler was the director of Fraunhofer Brussels and a member of several advisory committees to the European Commission (EC) on science and innovation, in particular, proposal review panels and as an independent expert on the EC's Key Enabling Technologies High Level Group and Electronics Leadership Group. He chaired the European Science Foundation's Materials Science and Engineering Committee from 2012 to 2015.

Earlier career stages include academia and industrial research jobs and over a decade as senior scientist at the Berlin synchrotron radiation facility in the field of synchrotron radiation instrumentation and condensed matter physics. Bressler holds a Ph.D. in semiconductor and surface physics from the Technical University Berlin, Germany.

LAWRENCE BROWN

Lawrence Brown is executive director of the American Lightweight Materials Manufacturing Innovation Institute (ALMMII), which operates LIFT (Lightweight Innovations for Tomorrow). In this role, he is responsible for day-to-day management and leadership of the organization, including interface with the Office of Naval Research Contracting Officer's Technical Representative (COTR).

In most recent employment, Brown was with EWI for more than 14 years, and most recently served as the organization's Director of Government Technology Programs. Prior to this role he held leadership positions as director of the Project Management Office and Director of Engineering. He also has served as the director of the Navy Joining Center (NJC), where his responsibilities included planning and control of NJC technology development projects in support of the Office of Naval Research ManTech Program. Prior to joining EWI, Brown worked for Rolls-Royce Corporation as Senior Materials Joining Developing Engineer in the Materials and Processes Laboratory. He also worked for Allied Signal, Energy Controls Division, as a Manufacturing Welding Engineer.

Brown is the recipient of the 2005 ManTech Achievement Award. He also serves on the Metals Subpanel of the Joint Defense Manufacturing Technology Panel (JDMTP). Brown has been awarded six patents that support aircraft gas turbine engine manufacturing. He holds a B.S. in Welding Engineering from The Ohio State University and an M.S. in Management from Indiana Wesleyan University, and is a Certified Project Manager (PMP).

YOEL FINK

Yoel Fink is chief executive officer of Advanced Functional Fabrics of America (AFFOA), MIT Professor of Materials Science and Engineering, and Joint Professor of Electrical Engineering and Computer Science. Fink's work is in fiber devices and harnessing weaving and knitting technologies to create integrated fabric systems, with the aim of redefining what a fabric is.

Fink is the recipient of multiple awards, among them the National Academies Initiatives in Research (2004), the MacVicar Fellowship (2007) for outstanding teaching, and the Collier Medal (2016). He is a co-founder of OmniGuide Inc. (2000) and served as its chief executive officer from 2007 to 2010. He presided over its commercial launch, established an 80 percent gross margin business, and grew it to $20 million. He is the coauthor of more than 80 scientific journal articles and holds more than 50 issued U.S. patents on multimaterial fibers and devices. As director of the Research Laboratory of Electronics, he initiated the Translational Fellows Program, a postdoctoral venture program to facilitate research-derived ventures, and the Low Cost Renovation effort, and during his tenure, the lab became fully endowed.

Fink recently led MIT's $317 million winning proposal for the creation of the Revolutionary Fibers and Textiles Manufacturing Innovation Institute (RFT-MII), located near MIT. The Advanced Functional Fabrics of America (AFFOA) Institute is backed by industry, academia, government, and venture capital and is aimed at accelerating widespread commercialization of highly functional fabrics.

Fink holds a B.A. in physics and a B.Sc. in chemical engineering from the Technion, and a Ph.D. from MIT's Department of Materials Science and Engineering.

ERICA FUCHS

Erica R. H. Fuchs is a professor in the Department of Engineering and Public Policy at Carnegie Mellon University (CMU). Her research focuses on the development, commercialization, and global manufacturing of emerging technologies, and national policy in that context. Fuchs was selected in 2012 as World Economic Forum Young Scientist (top 40 under 40, internationally). Her National Science Foundation (NSF) CAREER award–supported research focuses on rethinking national innovation systems.

Over the past decade, Fuchs has been playing a growing role in national and international meetings on the future of advanced manufacturing, including advising the President's Council of Advisors on Science and Technology during a 1-day workshop that led to the creation of the Advanced Manufacturing Partnership, and serving on the expert group that supported the White House in the 2016 Innovation Dialogue between the United States and China. She currently serves on the National Academies' Committee for Evaluation of the Advanced Research Projects Agency-Energy (ARPA-E), the National Academies' National Materials and Manufacturing Board (NMMB), and the World Economic Forum's Future of Advanced Materials Global Agenda Council. She is a member of the Advisory Editorial Board for Research Policy.

Before coming to CMU, Fuchs completed her Ph.D. in Engineering Systems at MIT in June 2006. She received her master's and her bachelor's degrees, also from MIT, in Technology Policy (2003) and Materials Science and Engineering (1999), respectively.

BRENNAN GRIGNON

Brennan Grignon currently serves as senior advisor and program director in the Office of the Assistant Secretary of Defense for Manufacturing and Industrial Base Policy (ODASD MIBP). She strategically coordinates efforts among the 14 Manufacturing USA institutes, with Department of Defense (DOD) counterparts and with other government agencies, to create a holistic strategy for education and workforce development efforts in manufacturing. She leads engagement between DOD and industry, facilitating dialogue to support a communicative and collaborative relationship between small, medium, and large defense industrial base companies and the Department. Grignon also leads efforts regarding strategic use of additive manufacturing (AM, also known as 3D printing) throughout DOD.

Prior to her role at MIBP, Grignon was the program manager of LMI's Research Institute, managing a multi-million dollar R&D budget and coordinating more than 40 internal and external R&D projects on a variety of technologies. She also supported government clients (civilian and defense) in strategic planning, communications, change management, technology transfer and implementation, competency management, and workforce development efforts. Grignon served as LMI's additive manufacturing lead.

Grignon's early career was as a financial advisor and retirement plan analyst, managing large personal estates and retirement plans for individuals, companies, and private equity firms.

ANDRÉ GUDGER

André Gudger is the founder and CEO of Eccalon with more than 20 years of experience leading middle-market technology companies and senior positions within the federal government. From 2011 to 2017, he served as

President Barack Obama's Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy (MIBP) and the Director of the Office of Small Business Programs.

As the Deputy Assistant Secretary of Defense, Gudger provided detailed analyses of the increasingly global and financially complex industrial supply chain and took appropriate actions to maintain the health, integrity, and technical superiority of the industrial base. In his many roles, Gudger was also the Defense Department's lead for President Obama's National Network of Manufacturing Innovation, through which he led the establishment of eight manufacturing institutes that focus on additive manufacturing, lightweight metals technology, robotics, and biotechnology. He is credited with reshaping MIBP by creating programs that focus on Business Intelligence, Analytics, and Global Markets to modernize the office's programs and realign its focus areas for the 21st century. Previously, he served as the Director of the Office of Small Business Programs, where he acted as the principal advisor to the Secretary of Defense on all matters related to small business, and oversaw more than $120 billion of annual awards to small companies.

In the past, Gudger has worked on key technical and financial initiatives with the Federal Deposit Insurance Corporation, Union Bank of Switzerland, and AT&T, and founded Solvern Innovations, a cybersecurity solutions company, where he served as its chairman and CEO. Gudger received his B.S. degree from the University of Maryland at Baltimore County and his M.B.A. from the University of North Carolina at Chapel Hill.

JENNIFER HAGAN-DIER

Jennifer Hagan-Dier is the director of the Tennessee National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (TMEP) Program for the University of Tennessee Center for Industrial Services (UT CIS). She joined UT CIS in September 2013 as the Solutions Consultant Team Leader and TMEP Director. In 2015, she led the successful proposal for the TMEP Program in the first round of the national recompetition of the NIST MEP network, resulting in a $3.6 million increase in federal funding and reorganization of the TMEP Program. In the past year, under Hagan-Dier's leadership, TMEP developed two pilot projects generating more than $1.9 million in additional funding for UT CIS and expanded service offerings to focus on workforce development and technology acceleration.

Hagan-Dier has extensive experience in economic and community development and incentives, client and project management, business development, strategic planning, and outreach. As the director of the TMEP Program, Hagan-Dier is responsible for constructing the vision of TMEP and ensuring its financial viability through strategic planning, implementation, and partnership development. Through her work on the UT CIS and TMEP leadership teams, Hagan-Dier works to promote the importance of the manufacturing sector and expand the awareness of UT CIS's capabilities

throughout Tennessee and across the country. Hagan-Dier also manages UT CIS's connection to the NIST MEP national system and its nationwide network of industry resources. In this role, Hagan-Dier serves as a member of the NIST MEP Brand Council and a member of the Education and Workforce Working Groups for LIFT and MForesight.

Prior to joining the State of Tennessee in 2007, Hagan-Dier served 2 years as a federal judicial clerk for the Honorable Judge Thomas A. Wiseman in the Middle District of Tennessee and 4 years as an associate with Mayer Brown Rowe & Maw, LLP in Chicago. Hagan-Dier received her J.D with honors from DePaul University College of Law in 2001 and a bachelor's in communications from the University of Tennessee in 1997.

DAVID HART[**]

David M. Hart is professor and director of the Center for Science and Technology Policy at the Schar School of Policy and Government at George Mason University. He is a senior fellow on clean energy innovation policy at the Information Technology and Innovation Foundation, where he also is a member of the board of directors, and a nonresident senior fellow in the Metropolitan Policy Program at the Brookings Institution. Hart served as senior associate dean of the School of Policy, Government, and International Affairs in 2013–2015 and as assistant director for innovation policy, with a focus on advanced manufacturing, at the Office of Science and Technology Policy, Executive Office of the President, in 2011–2012. Hart's books include *Unlocking Energy Innovation* (MIT Press, co-authored with Richard K. Lester), *The Emergence of Entrepreneurship Policy* (Cambridge University Press), and *Forged Consensus: Science, Technology, and Economic Policy in the U.S., 1929–1953* (Princeton University Press).

SUSAN HELPER[**]

Susan Helper is the Frank Tracy Carlton Professor of Economics at the Weatherhead School of Management at Case Western Reserve University. She was formerly chief economist at the U.S. Department of Commerce and a member of the White House Staff. She has served as chair of the Economics Department, and has been a visiting scholar at the University of Oxford, the University of California (Berkeley), Harvard University, and the Massachusetts Institute of Technology (MIT). Her research focuses on the globalization of supply chains, and on how U.S. manufacturing might be revitalized. Helper received her Ph.D. in economics from Harvard and her B.A. from Oberlin College in economics, government, and Spanish.

[**]Member of the workshop planning committee.

MAJ. GEN. NICKOLAS JUSTICE, USA (RET.)

Major General Nickolas Justice (ret.) is executive director of PowerAmerica, a public–private power electronics manufacturing institute led by North Carolina State University, focusing on accelerating the adoption of advanced semiconductor components into a wide range of products and systems. General Justice served in the U.S. Army for 41 years, capping his career as commanding general of RDECOM, the Army Research, Development, and Engineering Command, headquartered at the Aberdeen Proving Ground in Maryland. He previously led the Program Executive Office Command, Control and Communications Tactical at Fort Monmouth, New Jersey, and served in both Operation Desert Storm and Operation Iraqi Freedom.

General Justice received his B.A. in history from the University of Maryland, a master's degree in institutional management from Pepperdine University, and a master's degree in international relations from Salve Regina College. In addition, General Justice has earned numerous military awards and decorations, including the Legion of Merit and the Bronze Star.

SRIDHAR KOTA

Sridhar Kota is the Herrick Professor of Engineering, Professor of Mechanical Engineering at the University of Michigan. He is the founding Director of MForesight: Alliance for Manufacturing Foresight—a federally funded national think-and-do tank focused on accelerating technological innovation to enhance U.S. manufacturing competitiveness.

Between 2009 and 2012, Kota served as the assistant director for Advanced Manufacturing at the White House Office of Science and Technology Policy (OSTP). In this role, he developed policy recommendations and implementation strategies to enhance U.S. manufacturing competitiveness, and to foster innovation-based manufacturing and commercialization of emerging technologies. Kota played an instrumental role in initiating and launching National Manufacturing Innovation Institutes. He orchestrated other initiatives, including the National Robotics Initiative and National Digital Engineering and Manufacturing.

Kota has authored more than 200 technical papers and 30 patents on product design, bio-inspired engineering systems, and soft robotics. He is the recipient of the American Society of Mechanical Engineers (ASME) Machine Design Award, Leonardo da Vinci Award, and Outstanding Educator Award. His research work has been featured in the popular press, including *Aviation Week*, BBC, *Business Week*, CBS, CNN, Fox, NASA Films, *New York Times*, NPR, *Popular Science*, *Scientific American*, etc. He is the founder and CEO of FlexSys Inc., which developed the world's first modern aircraft with shape-changing wings.

BRETT LAMBERT**

Brett B. Lambert is vice president of Corporate Strategy at Northrop Grumman. Prior to joining the firm he was an executive-in-residence with Renaissance Strategic Advisors, a senior associate at the Center for Strategic and International Studies (CSIS), and a senior fellow at the National Defense Industrial Association (NDIA) and served on several corporate boards involved in national security.

From 2009 to 2013, Lambert was the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy. In this position Lambert served as the principal advisor to the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD [AT&L]) on all matters relating to the defense industrial base, including industrial capabilities and assessments; defense industry mergers, acquisitions and consolidation, preservation of essential industries and technologies, and other industrial-related matters.

In 2011 Lambert led President Obama's effort at the Department of Defense (DOD) to establish the first National Network for Manufacturing Innovation site, which culminated in the selection of additive manufacturing (3D printing) as the focal point for the administration's pursuit of a manufacturing renaissance.

Prior to joining DOD, Lambert spent 20 years working with defense and intelligence firms. From 1989 until 2007, Lambert held positions of increasing responsibility at DFI International, a national security consultancy that he built with the founder and that he assisted in selling in 2007. Before joining DFI, Lambert worked for the U.S. Department of State at the American Embassy in New Delhi. Prior to this, he attended graduate school at Jawaharlal Nehru University on a Rotary Graduate Scholarship he received during his senior year at Kansas State University. He also worked as an independent journalist in India, Pakistan, and Burma.

MARK LAVIOLETTE

Mark LaViolette is a specialist leader in Deloitte's Supply Chain and Manufacturing Operations practice and retired United States Marine Corps Colonel with more than 30 years of experience solving cross-functional challenges facing both commercial and government clients. He is an expert on the Department of Defense (DOD) decision-making process with hand-on experience working inside resourcing, requirement, acquisition governance, and congressional engagement processes. LaViolette has a proven record in high-profile, fast-paced, complex, and demanding roles that require sound decision making, strategic vision, and problem solving.

At Deloitte, LaViolette has worked extensively advising and supporting clients involved in public–private partnerships in the advanced manufacturing

**Member of the workshop planning committee.

space. His work includes developing DOD additive manufacturing (AM) technology roadmaps and most recently, leading a team to conduct a third-party assessment of the Manufacturing USA program. That effort provided an analysis of the program and its progress toward achieving its strategic goals, and included a series of recommendations for the future program.

LaViolette holds a master's in National Resource Strategy from the National Defense University, a master's in logistics management from the Naval Postgraduate School, and a B.S. in systems engineering from the University of Virginia. He is a Certified Professional Logistician (CPL), a Supply Chain Operational Reference Model Professional (SCOR-P), and a Project Management Professional (PMP).

KELVIN LEE

Kelvin H. Lee is director of the Manufacturing USA National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL), and he is the Gore Professor of Chemical and Biomolecular Engineering at the University of Delaware. He previously served as director of the Delaware Biotechnology Institute. He received a B.S.E. in chemical engineering from Princeton and a Ph.D. in chemical engineering from Caltech. He spent several years in the Biotechnology Institute at the ETH in Zurich, Switzerland, and also completed a postdoctoral fellowship in Caltech's Biology Division.

Prior to his current appointment, he was on the faculty at Cornell University, where he held the titles of Samuel C. and Nancy M. Fleming Chair Professor, professor in the School of Chemical and Biomolecular Engineering, director of the Cornell Institute for Biotechnology, and director of the New York State Center for Life Science Enterprise.

KIRK MCCONNELL

Kirk McConnell is a professional staff member on the staff of the Senate Armed Services Committee, where he is responsible for oversight of and legislation concerning Cyber Command and DOD cyber security, intelligence programs and activities, and information technology, and for liaison with the Senate Select Committee on Intelligence and the Homeland Security and Government Affairs Committee.

Previously, McConnell was a staff member on the staff of the Senate Select Committee on Intelligence, where he was responsible for Committee oversight of the National Security Agency and DOD military intelligence programs. Prior to this, he was a staff member on the House Permanent Select Committee on Intelligence, with oversight of national intelligence agencies and military intelligence activities, and also on the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China.

McConnell received his bachelor's degree in history and political science from the University of Rochester.

JENNIFER MCNELLY**

Jennifer McNelly serves as the president of 180 Skills, LLC, an online technical education experience supporting our nation's manufacturers. 180 Skills offers the only industry-defined, competency-based, high-quality, low-cost solution to advance the manufacturing workforce. McNelly has extensive experience in workforce development, employer engagement, and business.

Prior to joining 180 Skills, McNelly was the president and executive director of the Manufacturing Institute, the nonprofit affiliate of the National Association of Manufacturers (NAM), where she advanced a national agenda to close the manufacturing skills gap and make manufacturers in America globally competitive. She is a proven leader at the Institute as the chief architect of one of the organization's flagship initiatives, the NAM-endorsed Manufacturing Skills Certification System. McNelly is a member of the Senior Executive Services (SES) and served as an administrator for the U.S. Department of Labor's (DOL) Employment and Training Administration. Her strong private-sector experience includes serving as senior vice president of Strategic Partnerships, LLC, an international consulting firm specializing in helping Fortune 500 corporations build strategic partnerships with government agencies in support of workforce development.

In 2012, McNelly was recognized as one of the 100 inaugural Women in STEM, and she is the immediate past chair of the World Economic Forum's Global Agenda Council on Advanced Manufacturing. McNelly previously served as a member of the American National Standards Institute (ANSI) Personnel Certification Accreditation Committee, the Precision Metalforming Association (PMA) Education Foundation, and the SME Education Foundation Board.

MIKE MOLNAR

Mike Molnar is the founding director of the Office of Advanced Manufacturing (OAM) at the National Institute of Standards and Technology (NIST). In this capacity, he is responsible for NIST extramural advanced manufacturing programs and liaison to industry and academia. Molnar is also the founding director of the Advanced Manufacturing National Program Office (AMNPO), an interagency team with core staff hosted at NIST. This interagency team works to coordinate federal activities in advanced manufacturing, and is the congressionally designated National Program Office for Manufacturing USA—the National Network for Manufacturing Innovation.

**Member of the workshop planning committee.

Molnar joined NIST in 2011. Prior to federal service, he had a 30-year industry career in advanced manufacturing, with leadership roles in manufacturing technology development, corporate manufacturing engineering, capital planning, metrology, quality systems, automation, computer integrated manufacturing, and industrial controls for manufacturing competitiveness. Midcareer, Molnar served as the manufacturing policy Fellow in the White House Office of Science and Technology Policy.

Molnar is well known in industry and academia, with more than 30 years of leadership roles in manufacturing professional societies and associations—most recently as the President of the Society of Manufacturing Engineers. He is a licensed Professional Engineer and Certified Manufacturing Engineer, and was elected Fellow of both the American Society of Mechanical Engineers and the Society of Manufacturing Engineers. Molnar earned an executive M.B.A. from the University of Notre Dame, and a bachelor's in mechanical engineering and master's in manufacturing systems engineering from the University of Wisconsin.

CHRISTOPHER MURRAY

Chris Murray is an assistant director with the Natural Resources and Environment team of the U.S. Government Accountability Office (GAO). Since joining GAO in 2001, he has worked on evaluating federal programs in a variety of areas, including hazardous waste site remediation, renewable energy, and safe drinking water. Over the past several years, he has focused on science and technology issues related to federal support for research, advanced manufacturing, and the patent system, among other issues. Prior to joining GAO, he received a master's degree in public policy analysis from the University of Wisconsin-Madison and a bachelor's degree in political science from the University of Massachusetts-Amherst.

JONAS NAHM

Jonas Nahm is assistant professor of Energy, Resources, and Environment at the Johns Hopkins School of Advanced International Studies. His research focuses on the political economy of development and industrial upgrading in green industries, the politics of innovation, and the political economy of the energy sector. In addition to China—his primary focus for the exploration of these themes—his research draws on cases in Germany and the United States. His current book project, *Varieties of Innovation: The Creation of Wind and Solar Industries in China, Germany, and the United States*, examines the mechanisms through which distinct patterns of innovation have emerged in renewable energy sectors in each of these locations.

Before joining the faculty, Nahm was a postdoctoral fellow for International and Public Affairs at the Watson Institute at Brown University. He completed a Ph.D. in political science at MIT, holds an M.A. in political science

and Asia-Pacific studies from the University of Toronto, and graduated with a B.A. in social and political sciences from the University of Cambridge.

MIKE RUSSO[**]

Mike Russo leads the corporate office of Government Relations, Regulatory Affairs and Strategic Initiatives in the United States for GLOBALFOUNDRIES (GF), the nation's largest contract semiconductor chip maker. In his role, Russo is responsible for strategic plan development and execution to support business needs, policy development, and lobbying, directly interfacing with top administration officials and lawmakers on the federal and state levels. Russo is currently leading initiatives that are focused on developing and scaling innovations in the areas of education and workforce development; full-spectrum, distributed power grids; supply chain development; cyber security; and ensuring technology access for the U.S. government. Russo serves as a private-sector advisor to the U.S. Government in the areas of Manufacturing and Industrial Base Policy (MIBP) and Advanced Manufacturing, providing an in-depth understanding on issues central to the nation's defense and maintaining its leadership in technology development and innovation.

Prior to joining GF, Russo was a senior congressional staffer, running offices in both the U.S. Senate and House. Prior to his work in Congress, he spent nearly three decades in manufacturing and as an Executive Officer for the nation's oldest industrial union, and was responsible for all of the union's operations in the Northeastern United States. An expert in organizational development and effectiveness, Russo has led initiatives in total workplace redesign and the development of innovative workplace safety cultures, helping to make U.S. manufacturers and businesses globally competitive. Russo holds a B.S. degree in interdisciplinary studies from the State University of New York, majoring in political science and labor relations.

ARUN SERAPHIN

Arun A. Seraphin is a professional staff member on the staff of the United States Senate Committee on Armed Services. His areas of responsibility include acquisition policy, Pentagon management issues, Department of Defense science and technology programs, information technology systems, technology transition issues, defense laboratories, the Small Business Innovation Research program, manufacturing programs, and test and evaluation programs.

From 2010 to 2014, Seraphin served as the principal assistant director for National Security and International Affairs at the White House Office of Science and Technology Policy (OSTP). During this time, he both led (in an acting capacity) and served as the deputy director of the OSTP National Security and International Affairs division. His areas of responsibility included

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In 1996, Seraphin earned a Ph.D. in electronic materials from the Massachusetts Institute of Technology, where he performed research on silicon nanotechnology. He also holds bachelor's degrees in political science with a concentration in American government and in engineering science with a concentration in materials science from the State University of New York at Stony Brook.

RAVI SHANKER

Ravi Shanker is the vice president for Dow Lightweighting and was recently named to the Chairman and CEO's Team on the Manufacturing Jobs Initiative for the United States. Previous to this role, Shanker served in various business leadership roles, such as the president and CEO of Dow Kokam. Shanker has many years of experience building, growing, and running businesses within the Dow Chemical Company. He was also part of the AMP 2.0 team working on Advanced Manufacturing Strategy and Initiatives with colleagues from industry and academia.

Shanker holds a Ph.D. in mechanical engineering from the University of Delaware and a B. Tech. in mechanical engineering from B.I.T. Sindri, in India. He also has an M.B.A. from the University of Houston.

KATIE STEBBINS

Katie Stebbins is the Massachusetts Assistant Secretary for Technology, Innovation and Entrepreneurship and leads the state's efforts in the areas of cyber security, robotics, digital health, advanced manufacturing, the Internet of Things, marine technology, and the startup ecosystem. In this role, Stebbins convenes sector leaders and prioritizes investments on behalf of the Baker Administration and diligently exposes community leaders across the state to the economic opportunities being generated in Massachusetts.

Stebbins has served the public sector for more than 20 years, playing a leadership role in community-based economic development, specifically in low-income communities. Through this work, she honed her expertise in workforce development, community engagement, environmental science and public health, and real estate development. Technology and innovation have been a consistent theme throughout Stebbins' career as she made it a priority to deliver the most cutting-edge science and technology to populations that are generally the last to receive such benefits.

Stebbins is an avid entrepreneur and mentor, having started three companies of her own and dozens of community-based programs and projects. Her former consulting company played a lead role in establishing and growing the Holyoke Innovation District in Holyoke, Massachusetts, one of the first innovation districts in the state and the only one located within a high-poverty community.

Stebbins received her undergraduate degree from the University of Colorado at Boulder and her graduate degree in city planning from the University of Massachusetts at Amherst. *Boston Business Journal* named Katie one of the top 10 "2016 Women to Watch in Science and Technology."

CHARLES WESSNER

Charles Wessner teaches Global Innovation Policy at Georgetown University and is a powerful advocate for effective innovation policies. Previously, he served for two decades as a National Academies Scholar, a position in which he directed the Innovation Policy Forum. He is recognized nationally and internationally for his expertise in innovation policy, including public–private partnerships, entrepreneurship, early-stage financing for new firms, 21st-century universities and manufacturing, and the special needs and benefits of high-technology industry. As an outgrowth of his work with the U.S. government, he advises technology agencies, universities, and government ministries in Europe and Asia. In addition, he cooperates closely with international organizations and lectures at major universities in the United States and abroad. The overarching goal of his work is to develop a better understanding of how we can bring new technologies forward to address global challenges in health, climate, energy, water, infrastructure, and security. Reflecting his commitment to international cooperation, he was recently named an Officer of the Order of Merit by the President of France.

Currently, Wessner is leading a comprehensive study of the development of the successful New York Nanocluster. The analysis involves extensive field interviews, original source material, and close cooperation with leading companies such as IBM and GLOBALFOUNDRIES, as well as the Center for Economic Growth. The analysis is focused on the build-out of the cluster through the development of new educational institutions, public–private partnerships to provide cutting-edge manufacturing equipment, and the policies and substantial investments required to attract and retain high-tech industry. This work includes a chapter in an upcoming volume on Smart Specialization supported by the European Commission's DG-REGIO. Wessner was also tasked by the European Commission's Institute for Prospective Technological Studies (IPTS) to prepare the *Overview of the Current Trends in the U.S. Innovation System* (2016). His most recent publication, *Innovating for the Future: Helping Italian Firms Cross the Valley of Death*, was published by the Fondazione G. Brodolini in Cities as Engines of Innovation and Inclusive Growth in March 2017.

JEFFREY WILCOX

Jeffrey (Jeff) Wilcox is vice president for Engineering and Program Operations for Lockheed Martin. In this capacity, he is responsible for the effectiveness and efficiency of the engineering, program management, production operations, and sustainment functions across the enterprise.

Previously, Wilcox served as vice president for Corporate Engineering. In that role, he was responsible for the engineering enterprise, ensuring that the right people, processes, tools, and technologies were in place to successfully deliver innovative engineering solutions to customers' most complex challenges.

Prior to joining Lockheed Martin, Wilcox served for 17 years with Science Applications International Corporation (SAIC). During his tenure at SAIC, he progressed through the executive ranks, holding technical, program, and business management leadership roles, including senior vice president of the company's Sensor Systems operation.

Wilcox earned his B.S. degree in biomedical engineering from Case Western Reserve University and his M.S. degree in electrical engineering from Drexel University. He holds an honorary doctorate of engineering from Stevens Institute of Technology.

Appendix C

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Appendix D

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