REPORT TO CONGRESS ON PROGRAM PERFORMANCE FY 2017

About this Document

As required by the Revitalize American Manufacturing and Innovation (RAMI) Act of 2014,[1] this report describes the major accomplishments of Manufacturing USA in Fiscal Year 2017. This annual report documents progress in meeting the goals of the program as stated in its Strategic Plan.[2]

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[1] Consolidated and Further Continuing Appropriations Act, 2015, Pub. L. 113-235, Title VII – Revitalize American Manufacturing and Innovation Act of 2014, codified at 15 U.S.C. § 278s, https://www.gpo.gov/fdsys/pkg/PLAW-113publ235/pdf/PLAW-113publ235.pdf.

[2] N*ational Network for Manufacturing Innovation Program Strategic Plan*, Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office (February 2016) https://www.manufacturingusa.com/resources/national-network-manufacturing-innovation-nnmi-program-strategic-plan.

Manufacturing USA Program Performance — Annual Report to Congress, FY 2017

Advanced Manufacturing National Program Office
National Institute of Standards and Technology
United States Department of Commerce

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PROGRAM REPORT

MESSAGE FROM THE U.S. SECRETARY OF COMMERCE

A strong U.S. manufacturing sector is essential to our economic and national security. American manufacturers contributed $2.2 trillion to the U.S. economy in 2017. However, our trade deficit in manufacturing looms large at approximately $700 billion — including a deficit of more than $110 billion in advanced technology products. This deficit in advanced manufacturing is historically unprecedented for a nation that leads the world in science and technology research. We have a great culture of discovery and innovation but inventing here while other nations benefit disproportionately from new jobs and manufacturing is not sustainable.

The Trump Administration is committed to a great revival of American manufacturing. We will accomplish that by addressing unfair trade practices, lowering taxes, and streamlining burdensome regulations. These steps will restore a level playing field to our manufacturing sector. An additional essential in the race for leadership in advanced manufacturing hinges on innovation, which creates the jobs and products of tomorrow. Innovation is an American strength. Competitor nations have significantly increased their efforts in applied research, often leveraging discoveries made by U.S. researchers. Our investments in production innovation help us restore our technological competitive edge in manufacturing, promoting the manufacture of U.S. technological innovations in the United States.

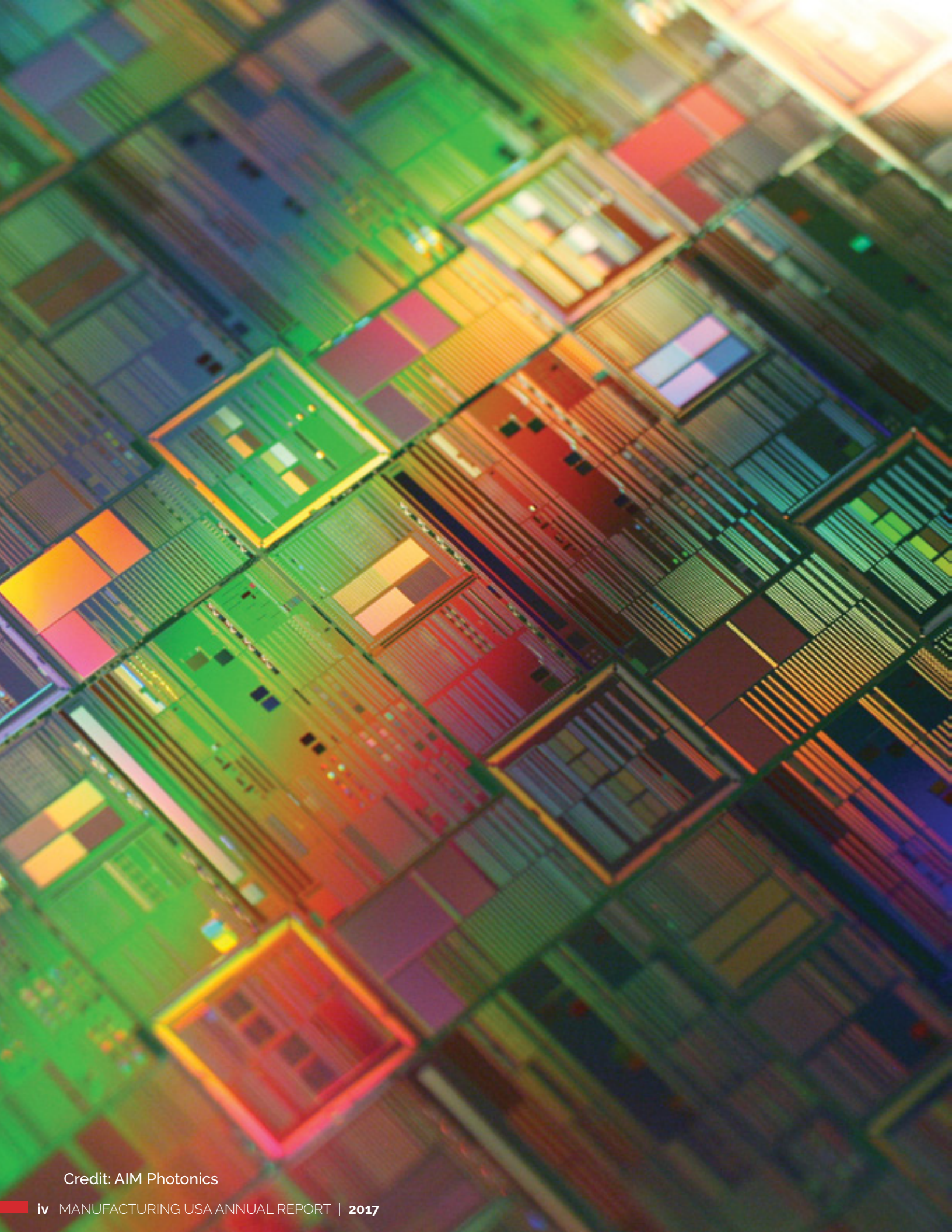
This is what the Manufacturing USA program is about: helping industry to move discoveries in the Nation's universities and research laboratories to the production floor here in America. Federal support creates collaboration spaces where industry and academia can work together on applied research that addresses the most important opportunities facing U.S. manufacturers. Manufacturing USA institutes have a mission to develop both game-changing manufacturing technology and the skills needed to equip our future U.S. manufacturing workforce.

In fiscal year 2017, there were fourteen active manufacturing innovation institutes, sponsored by the Departments of Commerce, Defense, and Energy, focused on nearly 270 major applied research projects of priority to broad industry sectors. The participants in, and beneficiaries of, these projects are Manufacturing USA's 1,291 members, of which 844 are manufacturing firms, and 549 are small businesses — and the American people.

Manufacturing USA institutes established manufacturing hubs here in America, providing real value to industry. These domestic hubs benefit the public by providing workforce development, improved job opportunities, and increased economic opportunity in promising technology areas that result in higher wages for U.S. workers.

Here at the U.S. Department of Commerce (DOC) we are excited to lead this initiative, and to support all the institutes to ensure that the bipartisan objectives Congress defined are well met. Our commitment to a strong U.S. manufacturing sector is unwavering. Our vision is nothing less than U.S. global leadership in advanced manufacturing.

Wilbur Ross
U.S. Secretary of Commerce



Credit: AIM Photonics

EXECUTIVE SUMMARY

Manufacturing USA completed its third year since Congress authorized the program through the Revitalize American Manufacturing and Innovation Act (Public Law 113-235). This Fiscal Year 2017 Annual Report describes the accomplishments and state of Manufacturing USA, including its 14 member institutes.

Manufacturing USA focused on growing the network of institutes, developing manufacturing technology and avenues for technology transfer, and developing education and workforce development programs this year. In all areas, the program has been successful, as summarized below. There has also been a significant growth in key performance metrics indicating a robust Manufacturing USA program.

Focus Area: Manufacturing USA Network Growth

The first focal area this year, growth of the network, follows the original vision for Manufacturing USA. Manufacturing USA grew substantially in 2017, adding 6 new institutes to make a total of 14 institutes. At the same time, commitments of support over the program's life have grown to more than $3 billion, comprised of $1 billion of federal funds matched by over $2 billion of non-federal investment, representing a remarkably effective catalyzation of matching investment. Furthermore, the states contributed over $400 million to Manufacturing USA institutes, in recognition of the importance of advanced manufacturing to the economy and to the future success of state and local communities. This enthusiastic reception by industry, academia, and the states confirms that the Manufacturing USA program is serving a critical need for U.S. manufacturing.

With the increased number of institutes and the increasing number of members in each institute, the total number of memberships grew over 50 percent this year to 1,291. Of this increase, 65 percent are industry members, and of the industry members, 65 percent are small and mid-sized. Industry leads the program, as planned, with the inclusion of small manufacturers in technology innovation as essential members of the supply chain.

The Hollings Manufacturing Extension Partnership (MEP) program completed its goal to embed an MEP center staff member in each of the 14 institutes, further strengthening Manufacturing USA. This program proves invaluable in enhancing the connection of smaller manufacturers across the country to institutes in their technical areas.

Focus Area: Manufacturing Technology and Technology Transfer

The Manufacturing USA institutes focus on developing a broad range of manufacturing capabilities in promising new advanced technologies that have the potential for high impact on the economy and on national security. Bringing together the best minds from industry, academia, and government to tackle tough manufacturing challenges helps to strengthen and expand the manufacturing base of the Nation.

The new manufacturing methods documented in the Technology Advancement section of the report show, for example, how the time from designing a part to building a product can be reduced by 50 percent, giving competitive advantages to manufacturers in rapidly changing fields. Other results show how manufacturers can reduce weight in mobile automotive or aerospace parts by up to 40 percent, resulting in direct improvements in fuel efficiency. Similarly, weight has been

reduced in non-moving manufactured components, such as the pressure tanks used in hydraulic systems and in gas storage, by up to 70% without sacrificing safety or reliability.

Perhaps most exciting is the ability to manufacture products that can transform the ways Americans work and live. For example, through the NextFlex manufacturing institute a new "smart" bandage for non-healing wounds integrates oxygen delivery in combination with medical sensing systems in a low-cost, flexible dressing. And through the Advanced Functional Fabrics of America (AFFOA) institute, new light-based communication systems allow military personnel to operate more effectively and safely in clandestine operations, or alternatively allow civilian search and rescue operations in buildings where global positioning systems (GPS) systems cannot effectively operate.

The enhancement of the manufacturing infrastructure that benefits all U.S. industry is exemplified by the development of an additive manufacturing roadmap for standards.[3] Different standards developed by numerous, uncoordinated organizations have hampered international trade. This roadmap for standards, led by America Makes, working with the American National Standards Institute (ANSI) and the National Institute of Standards and Technology (NIST) laboratories, brought together all the major standards developing organizations, reducing inefficiency in a previously fragmented standards development environment. Due to Manufacturing USA's leadership, standards development organizations now work toward a common set of additive manufacturing standards.

Focus Area: Workforce Development — Education and Training

As economies evolve, new skills are always needed. Ever since Henry Ford pioneered the assembly line, automation has transformed our work by increasing productivity, thereby enhancing our economy and society. Jobs are lost in old technology sectors, and if a Nation is not competitive in adopting advanced technology areas, manufacturing jobs can plummet. In a healthy economy, workers are trained for new, higher-paying, advanced manufacturing jobs in emerging technology-driven manufacturing sectors. Advanced manufacturing has been the cornerstone of a robust economy and a solid middle class in the United States over the past century.

These new jobs require a workforce with new skills suitable for advanced manufacturing, and thus workforce development and education is a priority for Manufacturing USA. The institutes continued their leadership in workforce training, including increased efforts involving multiple institutes and sharing of best practices. We saw tremendous growth in institute-led workforce efforts in advanced manufacturing, educator/trainer instruction, and science, technology, engineering, and mathematics (STEM) activities, resulting in over 191,000 workers, students, and educators participating in Manufacturing USA-led workforce efforts — an astounding seven-fold increase this year in the number of individuals enriched by the program.

Moving Forward

After this expansion year, Manufacturing USA will focus on enhancing education and workforce development, building sustainable business models, and, of course, advancing and transferring manufacturing technology to U.S. industry.

[3] *Standardization Roadmap for Additive Manufacturing (Version 1.0)*, America Makes & ANSI Additive Manufacturing Standardization Collaborative (2017), https://www.ansi.org/news_publications/news_story?menuid=7&articleid=6a8f99db-84d9-40f8-b70b-78e692f77361.

INTRODUCTION

Background

The importance of the manufacturing sector to the Nation's economic well-being and national security cannot be overstated. Manufacturing makes up 8.5 percent of U.S employment[4] and national security cannot be overstated. Manufacturing makes up 8.5 percent of U.S employment and 11.7 percent of U.S. GDP[5] but drives 35 percent of productivity growth, 60 percent of exports,[6] and 70 percent of private-sector research and development (R&D).[7] Beyond the economy, manufacturing and the strength of the U.S. manufacturing supply chain are also critical to national security.[8]

Our Nation's future is linked to advances in manufacturing, and Manufacturing USA's vision is U.S. global leadership in new technologies, such as additive manufacturing and industrial robotics. Jobs relying on outdated technology are disappearing. Only through advanced manufacturing is productivity enhanced and new high-paying jobs created. Through education and workforce development the United States will be able to keep these jobs from going overseas.

The 21st Century saw dramatic changes in U.S. manufacturing. Manufacturing employment fell by 5.6 million from December 2000 to December 2010 and has recovered 20 percent of this loss since then.[11]

What is Advanced Manufacturing?[9]

Advanced manufacturing involves new ways to create existing products and the creation of new products, emerging from the use of new technologies.

Advanced manufacturing enables increased productivity and at the same time supports newly-created high-paying jobs that can replace unskilled labor positions that are too easily lost to low-wage competitor nations. Furthermore, each advanced manufacturing employee generates up to 16 jobs in the rest of the economy.[10]

By 2015, the U.S. had fallen to become the second largest manufacturer in the world, responsible for 18.1 percent of world manufacturing activity (Figure 1). There are a variety of competing explanations for this decline including trade, outsourcing, and productivity growth through automation. Regardless, since 2002, the U.S. has been a net importer of advanced technology products.

[4] U.S. Department of Labor, Bureau of Labor Statistics, (2017), https://data.bls.gov/timeseries/CES0000000001 and https://data.bls.gov/timeseries/CES3000000001.

[5] Bureau of Economic Analysis, U.S. Department of Commerce, https://www.bea.gov/iTable/iTable.cfm?ReqID=51&step=1#reqid=51&step=51&isuri=1&5114=a&5102===. =

[6] International Trade Administration, U.S. Department of Commerce (2017), http://tse.export.gov/tse/TSEOptions.aspx?ReportID=2&Referrer=TSEReports.aspx&DataSource=NTD

[7] McKinsey Global institute, Making it in America: Revitalizing U.S. Manufacturing, S. Ramaswamy, J. Mayika, G. Pinkus, K. George, J. Law, T. Gambell, and A. Serafino, McKinsey Global Institute p. 75 (2017), https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Americas/Making%20it%20in%20America%20Revitalizing%20US%20manufacturing/Making-it-in-America-Revitalizing-US-manufacturing-Full-report.ashx. Nov 2017

[8] *National Security Strategy of the United States of America*, Executive Office of the President, p. 55 (2017), https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905-2.pdf

[9] *National Network for Manufacturing Innovation Program Strategic Plan*, Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office, p. 42 (February 2016), https://www.manufacturingusa.com/resources/national-network-manufacturing-innovation-nnmi-program-strategic-plan

[10] Manufacturing USA: A Third-Party Evaluation of Program Design and Progress, Deloitte LLP, p. 65 January (2017), https://www2.deloitte.com/us/en/pages/manufacturing/articles/manufacturing-usa-program-assessment.html

[11] U.S. Department of Labor, Bureau of Labor Statistics, https://data.bls.gov/timeseries/CES3000000001

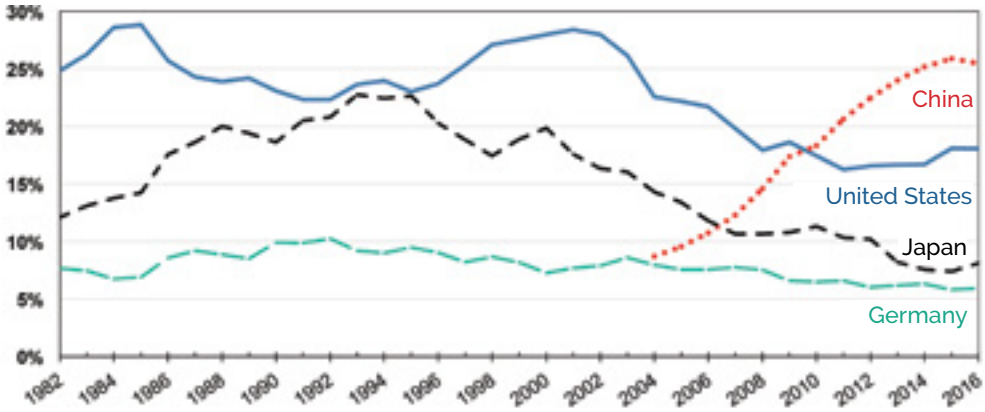


Figure 1. Manufacturing value-added by largest global manufacturers. Sources: United Nations and MAPI Foundation.

Furthermore, degradation of supplier networks has made it difficult for new manufacturers to operate in the U.S.[12]

The U.S. leads the world in innovation and inventions, yet many U.S. research discoveries are translated into manufacturing capabilities and cutting-edge products in other countries. Global competition has made it unaffordable for most individual companies to transition inventions from the lab to mass production. In countries known for their manufacturing strength, such as China and Germany, this transition is facilitated by coordinated planning and national investments in advanced manufacturing programs, supporting the private sector's push to develop new manufacturing processes and products.[13]

Basis of Manufacturing USA: Advance U.S. Manufacturing

The challenges facing U.S. manufacturing jobs and supply chain have been recognized at the highest levels in the Administration. The National Security Strategy proclaims "support for a vibrant manufacturing sector, a solid defense industrial base and resilient supply chains is a national policy." In addition to encouraging investments, the National Security Strategy states "where possible, the U.S. government will work with industry partners to strengthen U.S. competitiveness in key technologies and manufacturing capabilities."[14] Furthermore, in order to strengthen the U.S. ability to maintain manufacturing, defense industrial base, and associated supply chains, the President signed Executive Order 13806, on July 21, 2017, proclaiming strategic support for a vibrant domestic manufacturing sector.[15]

With passage of the bipartisan RAMI Act,[16] Congress authorized the establishment of the National Network for Manufacturing Innovation Program, now widely known as Manufacturing USA. This law authorizes the Secretary of Commerce to establish

[12] Producing Prosperity: Why America Needs a Manufacturing Renaissance, G. Pisano and W. Shih, Harvard Business Review Press (2012).

[13] See Invented in America, Scaled Up Overseas, E. Reynolds and H. Samel, Mechanical Engineering Magazine (2013), https://www.asme.org/engineering-topics/articles/manufacturing-processing/invented-america-scaled-up-overseas and Restoring American Competitiveness, G. Pisano, and W. Shih, Harvard Business Review (2009). https://hbr.org/2009/07/restoring-american-competitiveness.

[14] National Security Strategy of the United States of America, pg. 55 December (2017), https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.

[15] Executive Order 13806, Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States, Executive Order 13806 (2017), 82 FR 34596, https://www.gpo.gov/fdsys/pkg/FR-2017-07-26/pdf/2017-15860.pdf.

[16] Consolidated and Further Continuing Appropriations Act, 2015, Pub. L. 113-235, Title VII – Revitalize American Manufacturing and Innovation Act of 2014, codified at 15 U.S.C. § 278s, http://uscode.house.gov/view.xhtml?req=(title:15%20section:278s%20edition:prelim).

U.S. Manufacturing in the 20th Century

Advances in manufacturing led to much of the U.S. economic dominance in manufacturing throughout the 20th Century.[17] Advanced manufacturing, including the latest and most useful equipment and new workforce talent, has kept the U.S. in a leadership position in manufacturing.

- At the turn of the 20th Century, Henry Ford's innovations dramatically enhanced the Nation's leadership in manufacturing, using electrification and assembly lines to reduce the price of a Model T from $900 to $360 over a period of seven years, and at the same time doubling wages to $5 per day.[18]
- In the 1930s, manufacturing pulled the country out of the Great Depression and prepared the U.S. for success in World War II.
- In the 1960s, advanced production allowed the U.S. to build the Interstate Highway System and to send men to the moon.
- In the final decades of the last century, our innovation in technology and manufacturing in semiconductors led to the information technology revolution.

and coordinate manufacturing innovation institutes and to collaborate with federal departments and agencies whose missions contribute to or are affected by advanced manufacturing.

Manufacturing USA, established by the Department of Commerce (DOC) and run by the National Institute of Standards and Technology (NIST), the Department of Energy (DOE), the Department of Defense (DoD), and other government agencies working with the private sector, enhances the impact of individual institutes by helping to: share best practices; amplify a shared vision of manufacturing excellence; identify and address gaps in the U.S. manufacturing technology base; identify common interests and activities that can help train the next-generation of skilled workers; transition newly developed manufacturing technologies and processes to the U.S. industrial base; and leverage expertise across multiple disciplines and contributing agency programs. The Advanced Manufacturing National Program Office (AMNPO), headquartered at NIST, is designated as the primary office to oversee and carry out the statutory program.

Vision, Mission, and Goals

Manufacturing USA seeks to address the complex technology transition challenges associated with advanced manufacturing that exist between early-stage research and technology adoption. To provide ongoing focus and guidance for its stakeholders, Manufacturing USA's vision, mission, and goals were documented in the program's first Strategic Plan.[19]

The program's four goals are to: 1) increase the competitiveness of U.S. manufacturing;

[17] U.S. Manufacturing: Understanding its past and its potential future, M. Baily, B. Bosworth, *Journal of Economic Perspectives* 28: 3-26 (2014), https://www.brookings.edu/wp-content/uploads/2016/06/us-manufacturing-past-and-potential-future-baily-bosworth.pdf.

[18] *Mass Production, the Stock Market Crash and the Great Depression: The Macroeconomics of Electrification*. B. Beaudreau New York: Authors Choice Press. p. 152. (1996).

[19] *National Network for Manufacturing Innovation Program Strategic Plan*, Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office, p. 44 February (2016), https://www.manufacturingusa.com/resources/national-network-manufacturing-innovation-nnmi-program-strategic-plan.

Figure 2. Manufacturing USA is guided by a vision, mission, and four program goals.

2) facilitate the transition of innovative technologies into scalable, cost-effective, and high-performing domestic manufacturing capabilities; 3) accelerate the development of an advanced manufacturing workforce; and 4) support business models that help the Manufacturing USA institutes to become stable and sustainable after the initial federal startup funding period.

The institutes are the core of Manufacturing USA. Each institute addresses a focused manufacturing technology theme. Each is a public-private partnership with representatives from industry, academia, state and local governments, and the Federal Government that co-invest in world-leading technologies and capabilities.

Each institute provides the state-of-the-art facilities needed to allow collaborative, precompetitive development of promising technologies and to promote the creation of stable and sustainable innovation ecosystems for advanced manufacturing. Institute activities include:

- Conducting (or funding) pre-competitive applied research and development projects to reduce the cost, time, and technical uncertainty related to new manufacturing technologies and to improve existing technologies, processes, and products.
- Developing and implementing education, training, and workforce recruitment courses, materials, and programs.
- Developing innovative methodologies and practices for supply chain integration and introduction of new technologies into supply chains.
- Engaging with small and mid-sized manufacturers, including women and minority-owned manufacturing enterprises, and larger-sized manufacturing firms.

The partnerships forming the institutes must commit non-federal resources that equal or exceed the federal contribution during a five- to seven-year establishment period. Institutes are expected to become self-sustaining following this initial establishment period.

Each institute is established by a lead federal funding agency following open

Table 1. Manufacturing USA Institutes cover a broad range of critical technology areas.

Technology	Institute	Lead Funding Agency	Headquarters	Established
Additive manufacturing	**America Makes** — The National Additive Manufacturing Innovation Institute	DoD	Youngstown, Ohio	August 2012
Digital manufacturing and design	**DMDII** — Digital Manufacturing and Design Innovation Institute	DoD	Chicago, Illinois	February 2014
Lightweight metals manufacturing	**LIFT** — Lightweight Innovations for Tomorrow	DoD	Detroit, Michigan	February 2014
Wide bandgap power electronics manufacturing	**PowerAmerica** — The Next Generation Power Electronics Manufacturing Innovation Institute	DOE	Raleigh, North Carolina	January 2015
Fiber-reinforced polymer composites	**IACMI** — Institute for Advanced Composites Manufacturing Innovation	DOE	Knoxville, Tennessee	June 2015
Integrated photonics manufacturing	**AIM Photonics** — American Institute for Manufacturing Integrated Photonics	DoD	Rochester and Albany, New York	July 2015
Manufacturing thin flexible electronics devices and sensors	**NextFlex** — America's Flexible Hybrid Electronics Manufacturing Institute	DoD	San Jose, California	August 2015
Fiber materials and manufacturing processes	**AFFOA** — Advanced Functional Fabrics of America Institute	DoD	Cambridge, Massachusetts	April 2016
Smart manufacturing	**CESMII** — Clean Energy Smart Manufacturing Innovation Institute	DOE	Los Angeles, California	December 2016
Biofabrication and manufacturing	**BioFabUSA** — Advanced Regenerative Manufacturing Institute	DoD	Manchester, New Hampshire	December 2016
Robotic manufacturing	**ARM** — Advanced Robotics for Manufacturing Institute	DoD	Pittsburgh, Pennsylvania	January 2017
Biopharmaceutical manufacturing	**NIIMBL** — The National Institute for Innovation in Manufacturing Biopharmaceuticals	DOC	Newark, Delaware	March 2017
Modular chemical process intensification for clean manufacturing	**RAPID** — Rapid Advancement in Process Intensification Deployment Institute	DOE	New York, New York	March 2017
Sustainable reduction carbon emission and manufacturing with clean energy.	**REMADE** — Reducing EMbodied-energy And Decreasing Emissions	DOE	Rochester, New York	May 2017

competition under individual agency statutory authorities and appropriations. In addition to the eight institutes established between FY 2012 and FY 2016, six new institutes were added to Manufacturing USA in FY 2017 (Figure 3). The institutes have members in all 50 states and Puerto Rico. A complete list of the institutes, their locations and dates of establishment are included in Table 1.

Reporting Period

This annual report describes the activities of the Manufacturing USA program including institute activities and network performance during FY 2017 (October 1, 2016 to September 30, 2017). Prior year accomplishments or activities planned for after September 30, 2017, are included as appropriate and noted as such.

Figure 3. Six new institutes were established in FY 2017, bringing the total to 14 Manufacturing USA institutes.

Credit: America Makes

ORGANIZATION AND MANAGEMENT

Functions, Governance, and Coordination

Manufacturing USA's four governance operating principles are:[20]

1. The network of Manufacturing USA supports member institutes in meeting the goals of the program and creates a collective impact greater than the sum of constituent parts. Individual institute governance is within the purview of the lead funding agency and respective institute members. Legislatively reporting on individual institute performance is the responsibility of the respective lead funding agencies.

2. Network governance is a shared responsibility amongst the network membership of Manufacturing USA. Mechanisms and structures are necessary to collect inputs of key stakeholders, including the private sector.

3. Decisions concerning inter-institute issues in the network should be made at the lowest responsibility level. In resolving issues, there should be a general preference toward empowering action at the institute level.

4. The AMNPO is responsible for supporting the network functions of Manufacturing USA.

The Network Charter also established that the AMNPO, working with its federal agency partners, is responsible for reporting to Congress on the Manufacturing USA program and related institutes. The AMNPO also plays a key role in facilitating peer-to-peer collaboration, and serves as an information clearinghouse for internal and external communications.

Collaboration among the federal agency members through AMNPO has been productive. Biweekly meetings for planning the management and coordination of Manufacturing USA have led to effective policy decisions for defining and improving the network functions.

The nine federal agencies[21] supporting Manufacturing USA coordinate their efforts through the AMNPO in support of the program's national purposes, as described in the RAMI Act, and in recognition that those national purposes are best realized by an integrated whole-of-government effort.

The lead funding agencies embrace this unified effort while ensuring that value delivered by their respective institutes remains closely aligned with their agencies' statutory requirements. Maintaining this balance between Manufacturing USA's national programmatic goals and each respective agency's needs helped to ensure that all major stakeholder base requirements were addressed.

[20] *Network Charter: Manufacturing USA Program*, Advanced Manufacturing Series (NIST AMS) - 600-2, Section D, Network Operating Principles, https://www.manufacturingusa.com/resources/network-charter-manufacturing-usa-program.

[21] The Departments of Commerce, Defense, Education, Energy, Health and Human Services, and Labor; the National Aeronautics and Space Administration; the National Science Foundation; and the U.S. Department of Agriculture.

Manufacturing USA institute directors also coordinate activities and share best practices through the Institute Directors Council. Formalized in the "Charter of the Institute Directors Council: Manufacturing USA,"[22] the Council directly supports the goals of the Manufacturing USA program and facilitates cooperation and collaboration among the institutes, with advice as needed from the federal institute sponsors, agencies providing additional support to the institutes, and the AMNPO. Financial and staff support for the Council is provided by AMNPO.

Public Clearinghouse of Information

The AMNPO provides information to the public about Manufacturing USA primarily through the website, www.ManufacturingUSA.com. The AMNPO also maintains Twitter and LinkedIn accounts to communicate status updates about Manufacturing USA to the public.

Manufacturing USA Secure Collaboration Site

The AMNPO has developed a Manufacturing USA web-based portal to support intra-network collaboration; utilization of this portal has expanded and the AMNPO continues to improve the portal's capabilities. This site facilitates communication for all institute and agency partners. The Manufacturing USA Secure Collaboration Site supports the growing number of institutes and program activities by providing information and resources to members.

Funds Expended by the Department of Commerce for Manufacturing USA in FY 2017

The DOC spent approximately $4.4 million for the provision of network services supporting Manufacturing USA, the operation of the National Program Office, and management of the Advanced Manufacturing Technology Consortium (AMTech) program, whose activities were merged into the Manufacturing USA program during FY 2016. In addition, the DOC used these funds for compliance with legislative reporting requirements, including responses to the biennial Government Accountability Office assessment of Manufacturing USA and the preparation of the FY 2016 annual report.

[22] Charter of the Institute Directors Council: Manufacturing USA, NIST Advanced Manufacturing Series (NIST AMS) - 600-1, C. Blue, L. Brown, Y. Fink, N. Justice, M. Liehr, E. Morris p. 3 (2016), https://www.manufacturingusa.com/resources/charter-institute-directors-council.

Manufacturing USA Performance

During the past year, Manufacturing USA has grown from 8 to 14 institutes, supporting progress toward the strategic goals of the program.[23] Metrics provided in this section provide evidence for the success of the program. Highlights include an increase of membership by 50 percent while preserving a diverse representation of the U.S. manufacturing ecosystem, with a 2:1 ratio of small to large business participation. In FY 2017, co-investment was significantly above the program's annual 1:1 target, with $1.50 of associated financial leverage for every $1 of Manufacturing USA federal program funding. Over 191,000 individuals moved through the education and workforce training programs, a remarkable seven-fold increase over FY 2016.

In this report, performance is assessed in both quantitative and qualitative terms. Fiscal year 2017 is the second year for which program-level, quantitative metrics are reported. These quantitative measures offer opportunities to assess trends from the first year.

As described in the Strategic Plan, the evaluation strategy for Manufacturing USA and its components is anchored by the following principles and best practices:

- Establish or leverage existing data infrastructures that can manage information needed to address the extent to which Manufacturing USA is meeting its mission and purposes.
- Focus data collection on areas that can best provide rigorous and repeatable analysis.
- Leverage lessons learned from evaluation efforts underway within individual institutes, and from other similar programs and related interagency groups.
- Provide a trusted measure of Manufacturing USA's performance that is broad enough to support process improvement analysis for the future design and activities of Manufacturing USA.
- Leverage partnerships to improve data quality, e.g., linking of the Manufacturing USA to external sources where appropriate and to building a community of practice for evaluation.

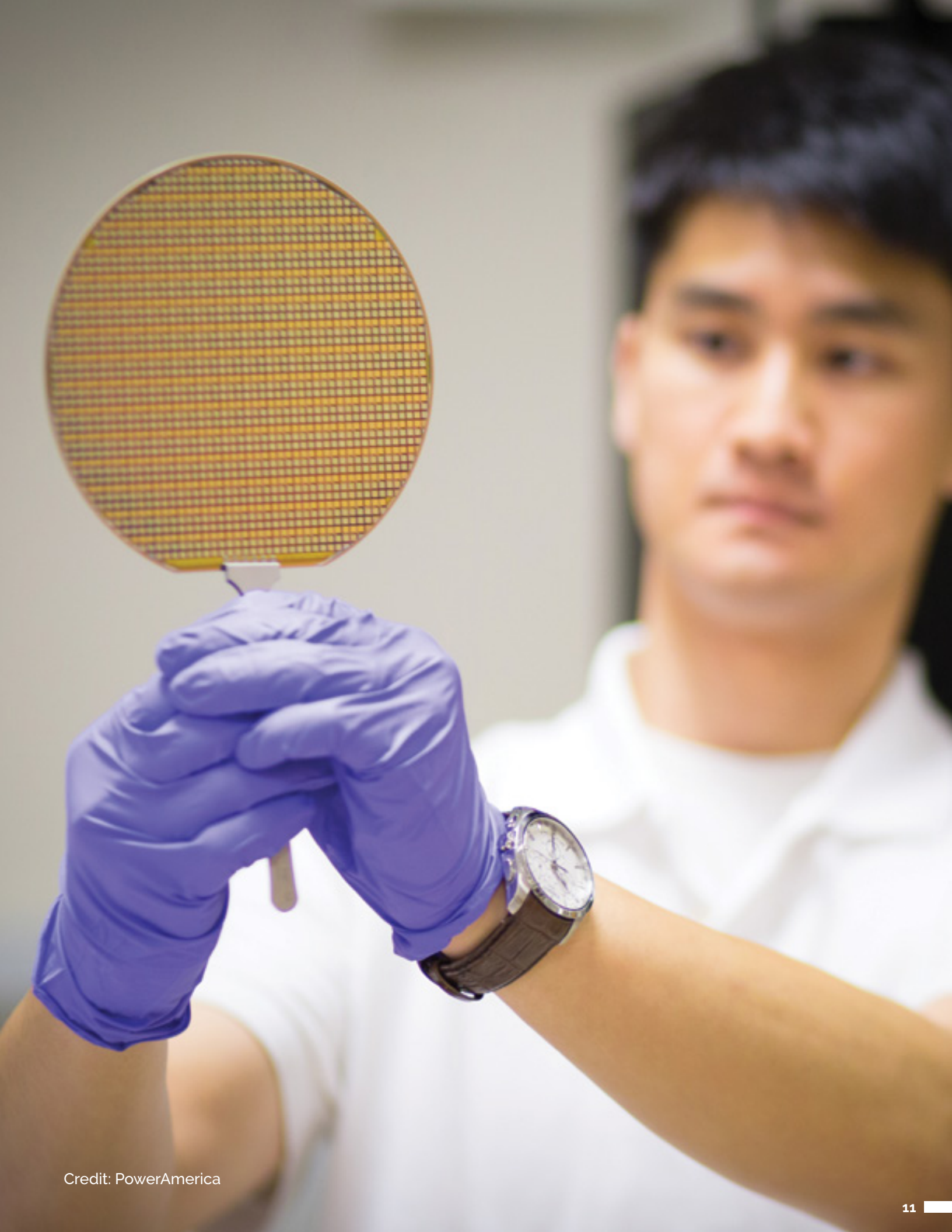
As Manufacturing USA grows and matures, metrics used for evaluation will evolve. While this evolution may introduce difficulties in comparing certain metrics over time, Manufacturing USA's leadership remains committed to continuous improvement to properly assess Manufacturing USA over the long term.

As in previous annual reports, the specific activities highlighted in this report provide a rich and descriptive qualitative measure of Manufacturing USA performance. The many narratives woven throughout this year's report illustrate the program's performance in support of the goals of Manufacturing USA.

Measuring Overall Performance of the Manufacturing USA Program

Since November 2016, the network expanded to 14 institutes, with DOC establishing the first institute operating under the authorities of the RAMI Act. In addition,

[23] *National Network for Manufacturing Innovation Program Strategic Plan*, Executive Office of the President, National Science and Technology Council, Advanced Manufacturing National Program Office, February 2016, https://www.manufacturingusa.com/resources/national-network-manufacturing-innovation-nnmi-program-strategic-plan.



Credit: PowerAmerica

the DoD established two new institutes and DOE established three. Manufacturing USA's reach and effectiveness is discussed in the following sub-sections, spanning several major functional areas:

- Refinement and execution of the Manufacturing USA's network-level functions and its governance model;
- Technical and non-technical collaboration, including cross-agency, cross-institute, and cross-member collaboration;
- Network-level refinement and progress in advanced manufacturing education and workforce development;
- Engagement and leveraging the capabilities of related federal programs and agencies; and
- Responsible obligation and expenditure of appropriations.

Through the AMNPO, the three major funding agencies (DoD, DOE, and DOC) expanded their strong coordination with other federal agencies, actively cooperating in a range of institute stand-up and support activities.[24] This highly integrated collaboration stems from recognition that Manufacturing USA's national goals, while well aligned with each individual agency mission, are best realized by a whole-of-government effort that focuses broadly on increasing U.S. advanced manufacturing competitiveness.

Table 2. Manufacturing USA Quantitative Performance Metrics Categories Mapped to the Manufacturing USA Program Goals

Institute Metric Category	Goal 1: Increase the competitiveness of U.S. Manufacturing	Goal 2: Facilitate the transition of innovative technologies into scalable, cost-effective, and high-performing domestic manufacturing capabilities	Goal 3: Facilitate the development of an advanced manufacturing workforce	Goal 4: Support business models that help institutes to become stable and sustainable
Impact to U.S. Innovation Ecosystem				
Financial Leverage				
Development of an Advanced Manufacturing Workforce				
Technology Advancement				

Performance Metrics

Effective quantitative performance metrics are tied to measuring progress toward validated goals and objectives. As seen in Table 2, each institute metric category described in the Strategic Plan provides information for tracking progress toward multiple high-level goals.[24]

Table 3 reflects an aggregation of certain institute-level metrics.

Several of the specific metrics required the collection and reporting of additional measures, increasing the total number of performance measures to 12. Table 4 contains the aggregated institute metrics data (actual values), including a description of the 12 specific units of measure used to define the values for each specific metric.

Refining the Evaluation of Manufacturing USA

As noted earlier, FY 2017 is the second year in which an initial and relatively modest set of quantitative, program-level performance metrics is being reported. The AMNPO, working with agency partners and leadership from across the institutes, will continue to refine an overall Manufacturing USA program performance management system that identifies the highest impact measures and appropriately integrates qualitative and quantitative outcomes. This approach will also balance the value of data collection with the resources required to collect and assess the data.

Table 3. Manufacturing USA Quantitative Performance Metrics Categories and Specific Metrics

Institute Metric Category	Specific Metric
Impact to U.S. Innovation Ecosystem	Number of partner organizations with institute membership agreements
	Diversity of members
Financial Leverage	Total co-investment in each fiscal year
Development of an Advanced Manufacturing Workforce	STEM activities
	Educator/trainer engagement
Technology Advancement	Number and value of active research and development projects in each fiscal year
	Percentage of key project technical objectives met in each fiscal year

[24] The four goals in the National Network for Manufacturing Innovation (Manufacturing USA) Strategic Plan are interrelated elements of a robust strategy supporting manufacturing innovation and are based primarily on the eight objectives of the Revitalize American Manufacturing and Innovation Act of 2014, (Pub. L. 113-235, codified in relevant part at 15 U.S.C. Section 278s(a)(2)).

2017 Highlights

Table 4. Aggregated Institute Performance Metrics Values

Institute Metric Category	Specific Metric	Unit(s) of Measure	FY 2016	FY 2017
Impact to U.S. Innovation Ecosystem	Number of partner organizations with institute membership agreement	Total number of memberships	830	1291
	Diversity of members	Number of large manufacturers (more than 500 employees)	187	295
		Number of small manufacturers (500 or fewer employees)	361	549
		Number of academic members (universities, community colleges, etc.	177	297
		Number of other entities (members, government laboratories, not-for-profit organizations, etc.)	105	150
Financial Leverage	Total co-investment in each fiscal year	Amount of cost share expended in each fiscal year and any federal funding not part of the base federal funding	$218.9 M*	$177.8 M
Technology Advancement	Number and value of active research and development projects	Number of projects ongoing in each fiscal year (projects completed, started, and spanning each fiscal year)	191	273
		Total institute expenditures in the fiscal year	$333.8 M	$298.5 M
	Percentage of key project technical objectives met in each fiscal year	Percentage of key FY 2016 and FY 2017 milestones met in each fiscal year	82	79
Development of an Advanced Manufacturing Workforce	STEM activities	Number of students participating in institute projects or institute internship programs/training	23,560	185,425**
		Number of individuals in the workforce completing a certificate, apprenticeship or training program led by the institutes	3,386	4,302
	Educator/trainer engagement	Number of teachers or trainers participating in institute-led training	1,023	1,299

* Large investments in capital equipment and manufacturing facilities were enabled by a surge in non-federal co-investment at one institute, AIM Photonics, for FY 2016. Similar variations in expenditures in future years are expected, due to co-investments associated with capital-intensive equipment purchases.

** One institute's STEM efforts are responsible for over 85 percent of the student participation. The LIFT Education and Workforce Development initiatives have leveraged a novel online curriculum and resources to reach students across the country. See the advanced manufacturing workforce section below for details.

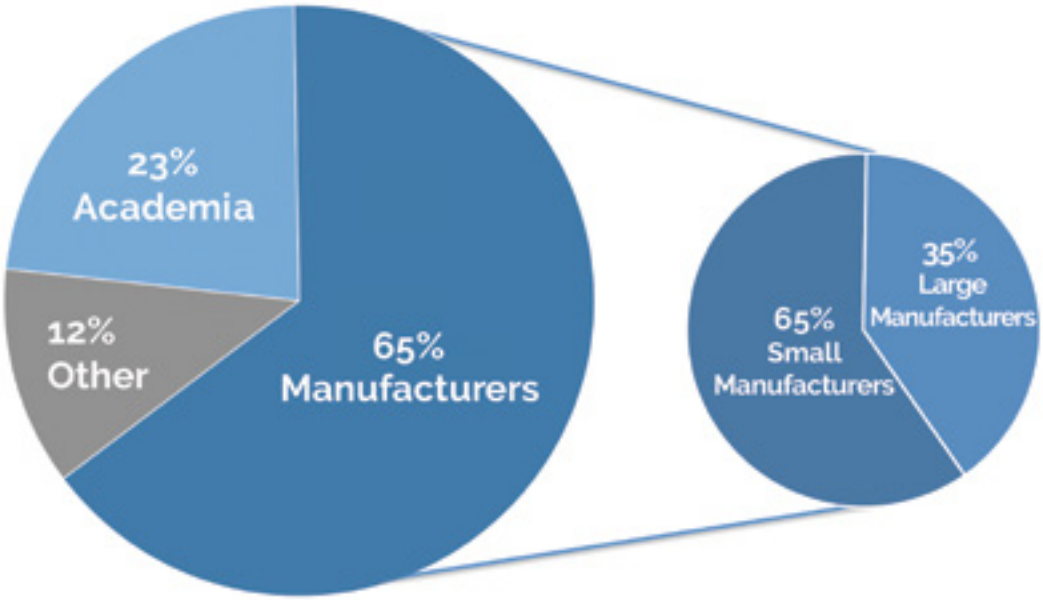


Figure 4. Manufacturing USA institute membership demographics.

Impact to the U.S. Innovation Ecosystem: Manufacturing USA Institutes Have 1,291 Members — 65 Percent are Manufacturers

Industry and academia are responding positively to the Manufacturing USA public-private partnership model. In FY 2017, twelve Manufacturing USA institutes had 1,291 members; two newer institutes began accepting members in the first quarter of FY 2018. Institute members included 844 manufacturing firms, 297 educational institutions (universities, community colleges, and other academic institutions), and 150 other entities, including federal, state, and local government, federal laboratories, and not-for-profit organizations (Figure 4). Of the manufacturers, 549 (65 percent) were small businesses with 500 or fewer employees and 295 (35 percent) were large manufacturers.

Total membership grew over 50 percent from FY 2016 to FY 2017, while the diversity of membership remained similar in terms of the percent of manufacturers, small businesses, educational institutions, and other entities.

Illustrative examples of the impact to the U.S. manufacturing ecosystem include:

- America Makes partnered with the American National Standards Institute (ANSI), DoD, and NIST, in collaboration with the over 150 partner organizations of the Additive Manufacturing Standards Collaborative, to publish the first Standardization Roadmap for Additive Manufacturing.
- Lightweight Innovations for Tomorrow (LIFT) and the Michigan Manufacturing Technology Center (the Michigan MEP center) launched the "LIFT Off" webinar series, which is open to the public and supports small and medium-sized manufacturers and start-up manufacturers by providing them a platform to showcase their lightweighting innovations.

- Advanced Functional Fabrics of America (AFFOA) and NextFlex partnered to launch the Fabric Discovery Center, presenting the opportunity for the functional fabrics supply chain to mingle and innovate with the flexible hybrid electronics supply chain for the mutual goal of revolutionary fiber and textile manufacturing. Projects are already underway, pulling together innovative entities throughout New England, including Raytheon (Waltham, MA), small business SI2 (Billerica, MA), and University of Massachusetts Lowell.

- National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) opened its membership in April 2017. Since that time, NIIMBL has continued to attract new members and as of September 30, 2017, NIIMBL had 68 member institutions in 17 states.

- BioFabUSA hosted an energizing launch event on July 28, 2017, that was attended by 400 people from the regenerative medicine community.

- A Clean Energy Smart Manufacturing Innovation Institute (CESMII) membership drive took place in late FY 2017 resulting in a rapid increase in members at all levels. Many new organizations have decided to join rounding out a membership that includes a cross section of academia, industry, non-profits, and national labs. CESMII members include small and medium-sized enterprises who are both solution providers and users (software and hardware). The CESMII Roadmap was completed in the summer of 2017, after a collaborative process by partners and members. It is a blueprint for CESMII's technology priorities, business practices and workforce training needs.

- Boeing was introduced to Chromera (a small business developing printed electronics) via their attendance at several of NextFlex's technical events. Based on those interactions, these two companies formed a partnership which successfully gained project funding to develop a condition monitoring sensor array.

Financial Leverage: Non-Federal Institute Research and Development Co-Investment Exceeded Federal Program Funds by 50 percent

In FY 2017, Manufacturing USA exceeded its design target of a 1 to 1 match for the funding of its annual institute expenditures. Total institute expenditures were $298.5 million, with non-program matching expenditures totaling $177.8 million and federal program funds totaling $120.7 million — a matching ratio exceeding 1.5 to 1. This funding went toward all aspects of institute operation, including technology advancement projects, education and workforce training efforts, and capital equipment acquisitions.

Examples of the leveraging of federal resources include:

- In partnership with Deloitte, America Makes led a collaboration with the Air Force, Army, Defense Logistics Agency, and Department of Navy on developing the first ever DoD-wide Additive Manufacturing Roadmap.

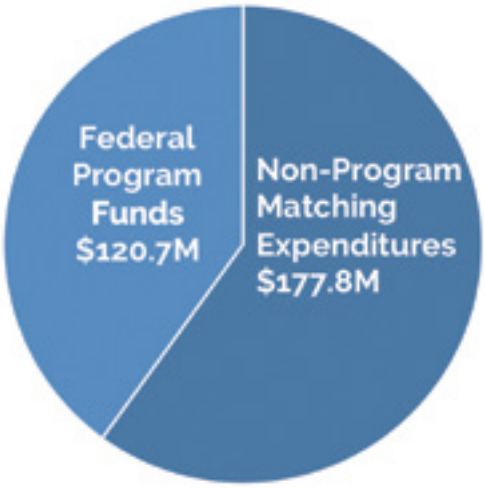


Figure 5. Financial Leverage.

- LIFT and the Institute for Advanced Composites Manufacturing Innovation (IACMI) — The Composites Institute, neared completion of their shared manufacturing innovation facility in Detroit — a combined investment of nearly $50 million.
- AIM Photonics capacity building will accelerate with the 2018 opening of the Test, Assembly, and Packaging Facility in Rochester, New York, reflecting New York State's investment of more than $190 million in the Facility through 2020.

Technology Advancement: Advancing Technology and Improving the Innovation Ecosystem

Across the 14 institutes established by the end of FY 2017, ten[25] had active research and development (R&D) activities, with 273 projects among them. While many technology R&D projects can take several years to conclude, the high level of participation by industry and the progress in meeting technical objectives are early indicators of success. An average of 79 percent of key technical objectives were met on projects, per institute. Institutes leverage a planning process with extensive stakeholder input, through technology roadmapping sessions and workshops on defining and prioritizing projects, to arrive at a balanced portfolio of projects. This planning process, along with sound project management of the applied research and development projects, continues to foster new and closer relationships among the member organizations. These relationships in turn strengthen the innovation ecosystem and improve the likelihood that the projects will have positive industrial outcomes for U.S. manufacturers. Illustrative examples of Manufacturing USA technology advancements include:

- At America Makes, General Electric (GE) Global Research Center led a project team that created software that can improve design techniques, reducing additive manufactured/3D printing design-to-build cycle times by 50 percent.
- LIFT completed work on redesigning and conducting initial tests on a cast-iron truck component in which the weight of the component was reduced by 40 percent without sacrificing performance or reliability.
- IACMI project partners created the first composite overwrapped pressure vessel made from recycled carbon fibers. Such pressure vessels are widely used in

[25] These included all eight institutes that were active in FY 2016, as well as CESMII and BioFabUSA, two of the institutes that were established in FY 2017. The remaining four new institutes R&D project activities will be described in the FY 2018 report.

industry for gas storage and hydraulic systems. Steelhead Composites fabricated the container from Vartega's (Golden, CO) recycled carbon fibers prepped by Michelman (Cincinnati, OH), in a collaboration enabled by IACMI. These new vessels are a remarkable 70 percent lighter than traditional steel containers.

- An AIM Photonics integrated photonics foundry improvement project led to the development and installation of new inline controls and test equipment, significantly improving yield and enabling commercial applications for companies as well as allowing companies to share expensive silicon wafer space on multi-project wafer runs.
- NextFlex members partnered to develop a flexible smart wound dressing demonstrator that integrates an oxygen delivery and sensing system into a single low-cost, manufacturable, and flexible dressing.
- A Power America project led by ABB (Raleigh, NC) improved the efficiency of a 100 kilowatt uninterruptible power supply unit by upgrading to silicon carbide solid-state switches, reducing power losses by 50 percent.

Figure 6. A Composite overwrapped pressure vessel made from recycled carbon fiber made by Vartega and Michelman as part of a collaboration enabled by IACMI. Credit: Michelman

- A Digital Manufacturing and Design Innovation Institute (DMDII) project created a software platform that links machining, casting, die casting, and welding modules. The software allows design iterations to be viewed over time and offers manufacturing options, enabling more efficient product development.

AFFOA Enables New Capabilities for Civilian and Defense Communications

Optical communication has advantages over traditional radio waves because light can transmit more data, more securely, using less power. For DoD, new fabrics can enable unique unit identification, so troops can operate more effectively and safely in clandestine situations. In commercial applications, this technology can facilitate indoor navigation in GPS-denied environments, such as hospitals or stores, where satellite signals are not available but LED lights are present in overhead lighting. AFFOA developed and demonstrated caps with light detecting fibers that can guide the wearer through unknown corridors.

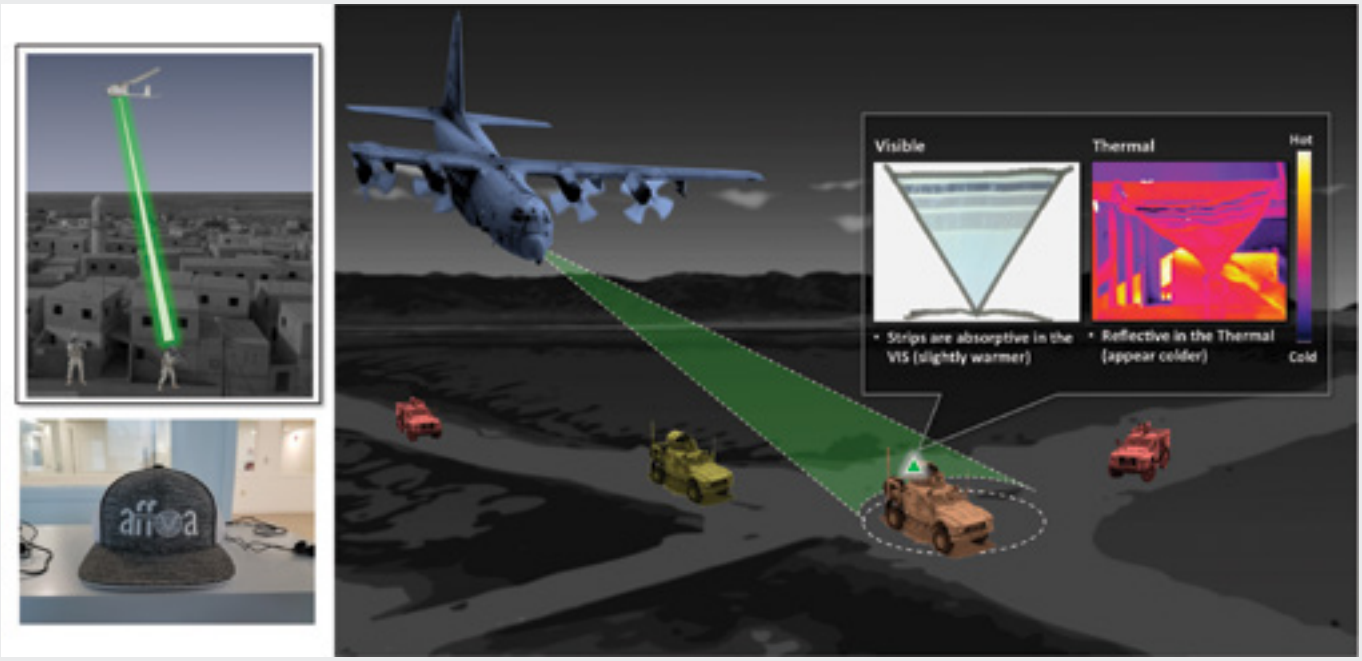


Figure 7. Free Space Optical Communications. Fabrics can be engineered with spectral features spanning ultraviolet through longwave infrared. Embedded sensors can enable fabric-based communications transmitters and receivers. Credit: AFFOA

Figure 8. Development of an Advanced Manufacturing Workforce

Development of an Advanced Manufacturing Workforce: Nearly 200,000 Participated in Institute-Led Education and Workforce Development Training Programs

The Manufacturing USA institutes provide guidance, education, and workforce development activities that increase and improve workforce preparedness for the advanced manufacturing jobs of the future including technicians, skilled production workers, manufacturing engineers, scientists, and laboratory personnel. Each Manufacturing USA institute supports the development of an advanced manufacturing workforce in its respective advanced technology area.

In total, 191,877 individuals participated in institute-led workforce programs. These included 185,425 students who participated in institute research and development projects, internships, or training. In addition, 4,302 individuals already in the workforce completed a certificate, apprenticeship, or training program led by the institutes. Finally, 1,299 teachers and trainers participated in institute-led training for instructors.

The institutes' education and workforce development programs have enjoyed excellent support from industry, community colleges, universities, surrounding communities, and states. Several of these programs are highlighted on the individual institute websites, which can be found on ManufacturingUSA.com. Further, with all institutes pursuing workforce development efforts, it has been an early topic for cross-institute collaboration, as detailed in the Manufacturing USA Education and Workforce Development Activities sub-section below.

Institutes and their partners have developed business and operational plans, informed by their sponsoring agencies' missions. Each institute has developed its own creative programs that meet the Manufacturing USA goals. Examples include:

Students participating in institute projects and programs:

- IACMI's internship program has impacted 20 member and partner projects in its first 2 years. It has supported 37 students selected from applicants from 91 participating colleges and universities.

In 2017, the LIFT education and workforce development initiatives leveraged several highly successful learning systems and networks to reach over 160,000 students across the Nation, advancing their STEM and advanced manufacturing-related knowledge and skills. Some examples include:

- **LIFT, leveraging the nationwide success of the "Learning Blade" interactive, web-based STEM curriculum system, created a lightweight metals and materials-focused, mission-oriented curriculum. More than 140,000 students in 28 states have completed this online curriculum that explores the science and technology used by welders, machinists, industrial designers, drafters, engineers, and materials scientists.**
- **LIFT, in collaboration with ASM International, developed new curricula on lightweight metals, materials and manufacturing processes for the ASM Materials Science Summer Camps for Teachers. The camps were attended by over 200 master teachers in 22 states, who then trained 1,000 teachers to integrate the material into their classrooms.**
- **LIFT launched the Tennessee Student Video Contest in the Greater Memphis area with Shelby County School Districts. Over 25,000 students participated, filming in local manufacturing companies and learning about careers and opportunities in advanced manufacturing.**
- **LIFT, in partnership with Tennessee Tech University, created the "MakerMinded" web portal, that delivers to students and schools a diverse portfolio of proven STEM education activities. In its launch year in Tennessee, over 1,000 students in 132 schools completed activities.**

- NextFlex's FlexFactor® student innovation program has engaged 650 students over the past two years in the Silicon Valley area. The program is being expanded to other partner states this coming year.
- Future Leaders Program 2017 has worked with 11 rising seniors from across the country who participated in research internships at the Massachusetts Institute of Technology (MIT); the State University of New York Polytechnic Institute; the University of California, Santa Barbara; and the University of Arizona.

Individuals completing a certificate, apprenticeship, or training program led or created by the institute

- LIFT graduated their first group of seven soldiers from its "Operation Next" Advanced Manufacturing Certification Program. Participants earned national credentials based on industry standards from the National Institute for Metalworking Skills for critical functions in computer numerical control (CNC) machining or industrial technology maintenance.

- AIM Summer Academy engaged 70 participants, mainly from industry, in a one-week intensive program at MIT AIM Photonics Academy. Additional programs are scheduled for FY 2018.
- America Makes created curricula for three undergraduate courses and one graduate level course to be taught at Lehigh University, University of Pittsburgh, and University of Notre Dame.

Teachers or trainers participating in institute-led training

- LIFT, working with the Kentucky Federation for Advanced Manufacturing Education, has been expanding its Kentucky Teacher Externships throughout the state. The program helped 135 teachers and instructors connect classroom learning to actual manufacturing experiences.

Credit: AIM Photonics

Manufacturing USA Coordination and Collaboration

Manufacturing USA provides mechanisms for all institutes to share best practices and to coordinate both technical research and education, as well as workforce development programs. The value of the network has steadily increased through the years, as more institutes join the network and relationships develop. This section provides highlights of these collaborative activities.

The previously described quantitative metrics are complemented by this and subsequent subsections describing key specific activities. These accomplishments, at both the overall program and individual institute levels, should provide a comprehensive picture of the Manufacturing USA program's performance in FY 2017.

The Manufacturing USA Education and Workforce Development Team grew dramatically in both numbers and activities in FY 2017. The team started with fewer than 20 members at the beginning of the year and currently has more than 50 members. Member participation includes institute education and workforce directors, human capital and STEM-educational experts, and representatives from seven participating federal agencies.[26] The Department of Labor's Employment and Training Administration and the Department of Education became active members this year.

The group holds teleconferences monthly and meets in-person quarterly to develop partnerships and share success stories, lessons learned, and initiative updates. It has provided a cohesive platform for newer institutes to partner with older institutes and to develop processes based on proven models. The team's sharing of roadmapping models has led to project partnerships and to the creation of advisory committees across many of the institutes.

The Education and Workforce Development Team will focus on the following goals in the coming year:

- Organize a Manufacturing USA Education and Workforce Development Day.
- Create a database of education and workforce development activities and programs.
- Establish funding or programmatic partnerships between the U.S. Department of Labor Employment and Training Administration and the institutes, with a focus on apprenticeships.

Education and Workforce Development Shared Service Portal

This year, the Education and Workforce Development Team launched a collaborative online portal for knowledge management, in partnership with the NIST AMNPO office. The portal has allowed for sharing of hundreds of items, including: institute workforce assessment reports, project call guides, presentations, meeting reports, and industry reports. This intra-network collaboration facilitates communication for all institute and agency partners.

Network Meetings

From biopharmaceuticals to next-generation electronics to functional fibers, Manufacturing USA's institutes bring together industry and academia to advance new, pre-competitive manufacturing technologies to a level of maturity that is attractive for adoption by U.S. industry. The network of fourteen institutes represents a strong start on providing a comprehensive spectrum of advanced manufacturing technologies, resources, and education. Twice a year, members of the network come together to collaborate and

[26] The Departments of Commerce, Defense, Energy, Labor, and Education; the National Science Foundation, and the National Aeronautics and Space Administration.

Composites Internships for University Students

The IACMI Internship Program is designed to support the anticipated growth of the advanced manufacturing composites industry and accelerate the development of low-cost, energy-efficient manufacturing technologies. The program is designed to engage budding engineers and scientists in five technology areas — wind, vehicles, compressed gas storage, composite materials and processes, and design, modeling and simulation. Interns are hosted at various IACMI member locations including industry partner facilities.

In FY 2017, 22 students were selected for IACMI internships out of hundreds of applicants spanning 91 universities across 36 states. Selected interns were placed at one of 12 IACMI member and partner locations across the country. IACMI Interns work closely with assigned mentors — many of whom are world-renowned experts in the composites field — to conduct research projects that respond to the need for faster, cheaper, and more energy efficient composites manufacturing.

share lessons learned, generate new ideas and collaborations, and identify cross-institute functions that enable established institutes to focus on their mission, and newer institutes to come up to speed quickly.

In the past year, AMNPO has worked closely with its agency partners and institute leadership to convene the Manufacturing USA Network, with Network meetings in Raleigh, NC and Gaithersburg, MD.

The April 2017 network meeting, with 100 attendees, was hosted by Power America. The meeting included discussions and presentations on measuring economic impact, the various intellectual property models used across the network, and the Manufacturing USA common services functions, a series of presentations by ANSI, MForesight, and the NIST Manufacturing Extension Partnership, and an introduction to the U.S. Department of Labor's apprenticeship program. The meeting also included parallel working sessions for specific interest groups, for both the Education and Workforce Development, and Grants and Contract Agreement Officers.

The August 2017 network meeting, with 120 attendees, was held at NIST in Gaithersburg, MD. Three sub-committees held parallel working sessions: Education and Workforce Development, Grants and Contract Agreement Officers, and Communications. The Manufacturing USA Education and Workforce Development Team engaged the U.S. Department of Labor in their meeting to discuss collaboration opportunities including apprenticeships, and the Workforce Innovation and Opportunity Act.

Figure 9. Briefing on counterintelligence from FBI Special Agent Lou Velasco at the spring 2017 network meeting.
Credit: PowerAmerica

The FlexFactor®

NextFlex created the FlexFactor platform to enable young people and other groups to become informed, inspired, and recruited into the incredible worlds of technology, entrepreneurship, and innovation. In 2017, NextFlex completed 19 program iterations across six school districts and eight schools throughout Silicon Valley. During each month-long program, small teams of students identified a human health- or performance-related problem, conceptualized a flexible hybrid electronics device to solve it, and developed a viable business model for commercialization.

After research, coaching in entrepreneurship, product design, and customer discovery work, students pitched their product and business models to a panel of industry professionals in a "Shark Tank" style setting. Students who complete all requirements earn college credit with either Evergreen Valley College or San Jose City College which were both early adopters of FlexFactor. Beginning as a whiteboard exercise in the Fall of 2016 with a pilot of eight students at Lincoln High School in San Jose, CA, FlexFactor ultimately reached 650 students in its first year, generated 88 product ideas enabled by flexible hybrid electronics, and is now poised to expand nationally.

***"In support of our commitment to the future of advanced manufacturing, NextFlex created a program that energizes youth, industry, and local communities around the importance of technologies such as flexible hybrid electronics as they relate to everyday life. By showcasing the vibrancy and reach of modern-day manufacturing, NextFlex, community colleges, and local manufacturers are simultaneously dispelling false perceptions and catalyzing an important group of future industry leaders — especially young women and other underrepresented populations. Our FlexFactor program is at the center of this growing movement."*—Dr. Malcolm J. Thompson, NextFlex Executive Director**

Figure 10. Branham High School students receiving an overview of modern manufacturing capabilities at the Jabil Blue Sky Center in San Jose, CA. Credit: NextFlex

Figure 11. The August 2017 Manufacturing USA Network Meeting was held at NIST in Gaithersburg, MD.

Federal agencies that are members of AMNPO continue to collaborate, ranging from biweekly meetings for planning the management and coordination of the Manufacturing USA program, to higher level policy decisions for defining and advancing the network functions.

Network Engagement by Government Agencies across the Industrial and Research Base

Manufacturing USA and its associated institutes provide coordinating resources for manufacturing innovation from fundamental research in advanced manufacturing to business development and market access.

The Manufacturing Extension Partnership —Serving Small and Medium-Sized Manufacturers

Smaller manufacturing establishments represent an increasing share of the manufacturing landscape and are critical to local economies and the U.S. supply chain. There are more than 291,000 manufacturing establishments in the U.S., with 99 percent of them being small and medium-sized manufacturers (SMMs) with fewer than 500 employees.[27] The SMMs are a critical part of the supply chain, yet often face significant challenges in adopting new manufacturing technologies.

The NIST Hollings Manufacturing Extension Partnership (MEP) focuses on helping SMMs generate business results and thrive in today's technology-driven economy. The MEP National Network includes 51 MEP Centers located in all 50 states and Puerto Rico. The RAMI legislation directed the AMNPO to incorporate MEP into the Manufacturing USA program planning to ensure that the results of the program reach small and mid-sized companies.[28] MEP entered into memoranda of understanding with DoD[29] in 2015 and with DoE[30] in 2017 to define how institutes and MEP Centers should work together to: 1) facilitate awareness and outreach of institutes'

[27] https://factfinder.census.gov/bkmk/table/1.0/en/BP/2016/00A1

[28] Revitalize American Manufacturing and Innovation Act of 2014 (Pub. L. 113-235, codified in relevant part at 15 USC 278s(f)(5)).

[29] Memorandum of Understanding Between the U.S. Department of Defense, Office of The Secretary of Defense, Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy and The U.S. Department of Commerce, National Institute of Standards and Technology, Hollings Manufacturing Extension Partnership (2015), https://www.nist.gov/sites/default/files/documents/mep/about/MOU-NIST-OSD-Signed-Executed-2015.pdf

[30] Memorandum of Understanding Between the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office and the U.S. Department of Commerce, National Institute of Standards and Technology, Hollings Manufacturing Extension Partnership (2017), https://www.nist.gov/sites/default/files/documents/2017/04/26/doe_amo-nist_mep_mfgusa_mou_-_final_-_signed.pdf

Multiple Partners Create and Debut New Lightweight Specialty Car Frames

Two institutes, LIFT and IACMI, worked with Michigan's MEP, the Michigan Manufacturing Technology Center, and top industry partners to launch a collaborative project in 2017, leading to the invention of a lightweight aftermarket car frame.[31] Although not yet in production, this lightweight alternative is ideal for replacing car frames on nearly any specialty vehicle and offers an affordable, stiffer, and safer car frame option. Models of the C2 Corvette prototype frames, shown for the first time at the 2017 Specialty Equipment Market Association Show, were met with an enthusiastic response by industry peers.

The inventive lightweight car frame requires no welding, which reduces material cost. Engineers use morphing software to allow the lightweight frame to fit virtually any body. "We were proud to join leaders from Michigan Manufacturing Technology Center and industry partners who applied advanced engineering to this project, including an innovative combination of materials and joint adhesives, inventing a product we feel is umatched on the market today," said John Gelmisi, Director of Business Development at Detroit Engineered Products, a Michigan-based engineering solutions and product development company.

"Partnering with MEP Centers and Manufacturing USA institutes was a new approach for our team and we're thrilled with the final product. It's a great example of the breakthrough innovation that can be achieved when working collaboratively." **—Gregg Peterson, Principle Materials Engineer, Michigan Manufacturing Technology Center**

Figure 12. C2 Corvette (1963 to 1967) lightweight alternative frame. Credit: Michigan Manufacturing Technology Center

technical areas to SMMs; 2) involve SMMs in institute R&D planning; 3) encourage SMMs to participate in institute R&D; and 4) implement institute R&D results.

In 2017, MEP completed the process of embedding MEP Center staff within each Manufacturing USA institute. These MEP staff are accelerating the transition of the latest and most compelling technological innovations into the manufactured goods produced by SMMs.

Transferring Technology to Small Manufacturers

- Ohio MEP, in partnership with America Makes and the Air Force Research Lab, worked with Humtown Products, a small family-owned Ohio manufacturer, to create a 3D-printed sand mold. The mold was in turn utilized by Youngstown State University to cast an aluminum aircraft replacement part. While traditional metal part castings typically have a four- to six-week turnaround and can cost up

[31] Lightweight vehicle frames Michigan Manufacturing Technology Center, http://www.the-center.org/lightweight-frames.

Small Company Becomes Key Supplier for Integrated Photonics

Through outreach efforts by the New York MEP staff embedded at AIM Photonics, Mosaic Micro LLC is working to position itself as a key supplier for users of integrated photonic components. The company's growth tactics, developed in collaboration with New York MEP, include an increase in capital expenditures, hiring additional staff, and expanding their facilities in the Finger Lakes, Upstate New York Region. Mosaic Micro's plans include leveraging the assets, resources, and capabilities from the AIM Photonics' Test, Assembly, and Packaging facility.

to $15,000, the part was successfully produced via additive manufacturing in three days for under $1,000.

- Purdue MEP, Indiana's MEP Center, in partnership with NextFlex, engaged with an Indiana manufacturer to develop a wireless smart sensor based on flexible hybrid electronics that can fit in limited spaces and conform to the inner surface of rotating parts within hydraulic assembles and components.

- Tennessee MEP (TN MEP), in partnership with IACMI, worked with an after market automotive parts manufacturer to identify technology for the company along the full spectrum of R&D, resulting in one automated fiber placement technology already integrated and several process investments under consideration.

- TN MEP, in partnership with Ohio MEP and IACMI, worked with a tier one automotive supplier to use 3D printing as an alternative to aluminum tooling in their thermoforming process. By determining the correct material and process combination, the company was able to switch to composite tooling, and expects an estimated 50 percent reduction in lead-time as well as a 50 percent reduction in cost for the tool.

Strengthening Supply Chains

- North Carolina MEP (NCMEP), in partnership with the Texas Manufacturing Assistance Center (the Texas MEP Center) and PowerAmerica, is helping a Texas semiconductor firm to consider moving its wafer plating from Germany to the U.S. By bringing the supply chain back to the U.S., the Texas semiconductor firm could save time and money by shortening time to market.

- NCMEP, in partnership with PowerAmerica, has collaborated with GENEDGE (Virginia MEP Center) and the Texas MEP Center to utilize PowerAmerica's wide bandgap supply chain funnel, resulting in the development of a wide bandgap roadmap. This roadmap provides a better understanding of the associated supply chain to determine a path for service delivery and highlights where the SMM fits into the supply chain.

- The Embedding Project between Oregon MEP and the Rapid Advancement in Process Intensification Deployment (RAPID) Institute, launched in September 2017, began a new effort to establish a modular manufacturing supply chain and engage SMMs, which normally would not interact with the institute's work. Oregon MEP has already identified and

contacted several dozen precision metal stampers to qualify them for the first of several anticipated modular chemical process intensification manufacturing components.

Advancing the Workforce

- IMEC, in partnership with DMDII, has developed both in-person and online training by which MEP Centers can deliver digital manufacturing and design awareness, assessment, and solutions to SMMs. This training and resulting outreach represents a key mechanism by which SMMs can understand, adopt, and benefit from digital manufacturing and design.

- The California MEP Center, in partnership with CESMII, conducted smart manufacturing education and assessment with a California manufacturing firm. As a result, the SMM is planning to deploy an enterprise resource planning system, develop a metrics platform, and utilize data and information management techniques to address identified challenges.

- Pennsylvania MEP and Ohio MEP, in partnership with America Makes and the Youngstown Business Incubator, have created additive manufacturing working groups in southwest Pennsylvania and northeast Ohio to help educate SMMs about the benefits of additive manufacturing as well as to help them utilize additive manufacturing for productivity enhancements. Quarterly working group meetings are held in each region, and regional manufacturers represent a majority of more than 200 total members.

- Though the project between Pennsylvania MEP and the Advanced Robotics for Manufacturing (ARM) Institute was launched in September 2017, the effort has already begun working to facilitate the exploration and adoption of robotics among SMMs in southwest Pennsylvania and beyond. Subsequent initiatives will include the creation of a Southwest Pennsylvania Advanced Robotics Working Group for local manufacturers, suppliers and integrators, to be accompanied by

SPOTLIGHT: Developing a Next-Gen Workforce for Next-Gen Technology

NCMEP, in partnership with PowerAmerica, is dedicated to addressing technician education requirements to develop and grow U.S. wide bandgap manufacturing. The program has worked with the Surface Mount Technology Association student chapters in Texas and North Carolina and with Central Carolina Community College to provide equipment and establish curricula for technicians, and helped Fayetteville Technical Community College establish an electronic assembly education program for transitioning service people. In addition, NCMEP and GENEDGE are helping develop a custom training course for printed circuit board fabrication shops in Virginia to prepare workers to participate in the supply chain.

education and training materials to facilitate industry adoption and expansion of robotics practice areas throughout the MEP National Network.

Leveraging Other Government Investments

Collaboration is inherent to the work of the Manufacturing USA institutes. This extends to fully integrating and aligning the resources of key federal agencies to amplify results. Federal agencies support projects and facilities that provide resources and expertise to the institutes, and, in turn, the federal agencies also benefit from this investment. Such win-win collaborations spin-off promising discoveries and inventions from research laboratories to the institutes. Further, the high-tech products the government needs for its defense, energy, and other missions use advanced manufacturing methods transitioned from the institutes to industry. Agency programs also assist in educating the highly skilled craftsmen and women, technicians, designers, planners, researchers, engineers, and managers that U.S. industry needs to move from theory to practice.

National Science Foundation: Dear Colleague Outreach

The National Science Foundation (NSF) has fundamental research programs in advanced manufacturing that support the transformation of understanding of materials, processes, and systems into increased capabilities, reducing the costs, and expanding the product offerings of U.S. manufacturers. NSF research projects are performed at U.S. colleges and universities and small businesses and have the additional benefit of training the U.S. advanced technology workforce in research projects beyond the cutting edge of what is possible today. NSF projects provide an upstream pipeline of new ideas for the Manufacturing USA institutes and benefit from the knowledge, experience, and facilities of the institutes and their industry members. NSF published two "Dear Colleague Letters" in FY 2017 to encourage researchers to submit research proposals to collaborate with Manufacturing USA institutes:

- Dear Colleague Letter: Supporting Fundamental Research to Enable Innovation in Advanced Manufacturing at Manufacturing USA Institutes.[32] Two projects were funded in FY 2017: *In-Situ Collaborative Robotics in Confined Spaces*, Vanderbilt University and Carnegie Mellon Institute with Advanced Robotics in Manufacturing ($1.5 million), and *Determining the Role of Nanoscale Physics in the Microscale Selective Laser Sintering Process using a Multiscale Computational Modeling Approach,* University of Texas at Austin with the America Makes institute ($370,000).

- Dear Colleague Letter: Research on Integrated Photonics Using AIM Photonics Capabilities.[33] Six proposals were submitted to NSF 17-073 in FY 2017 and will be reviewed in Spring 2018.

These letters complement Dear Colleague Letter: Advanced Technological Education (ATE) Program Support for Manufacturing Innovation Institutes and Investing in Manufacturing Communities Partnerships (IMCPs),[34] issued in FY 2017. The ATE program focuses on the education of technicians for the high-technology fields that drive the U.S. economy, with an emphasis on the role of

[32] https://www.nsf.gov/pubs/2017/nsf17088/nsf17088.pdf

[33] https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf17073.

[34] https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf16007.

two-year community and technical colleges. The program creates partnerships between academic institutions and industry to promote improvements in the education of science and engineering technicians at undergraduate and secondary school levels. Three awards were made in FY 2017 for established ATE Centers to work with AFFOA, IACMI and CESMII.

NSF has a research portfolio that often is topically aligned with institutes but focuses on early-stage research. NSF research produces promising new directions for technology development, but once a technology has progressed, there is a need to transition the projects from institutes to manufacturers. To facilitate the continuation of research pipelines in additive manufacturing, the Manufacturing Machines and Equipment program hosted a workshop, "*Research in Additive Manufacturing toward Industrial Applications,*" held at the University of Pittsburgh. This workshop was co-located at a meeting of America Makes leadership and industry membership; the intent was to have NSF researchers present their research projects, so that they could be continued with other funding agencies or companies. The conference organizers identified three investigators who received follow-on funding through the DOE, and it was expected that the NSF researchers would participate with industry partners in future America Makes program calls. It is expected that this workshop will serve as a model for other institutes.

MForesight: The Alliance for Manufacturing Foresight

MForesight is a national consortium focused on identifying and assessing national needs and opportunities in manufacturing technology innovation, founded in 2015 with joint NIST and NSF sponsorship. The effectiveness of U.S. manufacturing depends in part on accurate information and analysis of future trends in technology and the advanced manufacturing technologies needed to produce innovative products of tomorrow. MForesight works to provide this analysis by bringing together experts from universities, companies, and other entities to forecast high potential manufacturing needs and opportunities. It evaluates emerging technologies that promise game-changing solutions and recommends specific actions to facilitate public-private initiatives. In FY 2017, MForesight issued four reports: A*merica's Next Manufacturing Workforce: Promising Practices in Education & Skills Building,*[35] *Ensuring America's Manufacturing Leadership Through Next-Generation Supply Chains,*[36] *Cybersecurity for Manufacturers: Securing the Digitized and Connected Factory,*[37] and *Democratizing Manufacturing: Bridging the Gap Between Invention and Manufacturing.*[38] The supply chain report was launched at an event at the U.S. Capitol Visitor Center and the cybersecurity report was jointly produced with the Computing Community Consortium and launched at an event in the Rayburn House Office Building, both hosted by the House Manufacturing Caucus.

[35] America's Next Manufacturing Workforce: Promising Practices in Education & Skills Building, MForesight: Alliance for Manufacturing Foresight p. 54 (2017), http://mforesight.org/download-reports/.

[36] Ensuring America's Manufacturing Leadership Through Next-Generation Supply Chains, T. Mahoney, S. Helper, MForesight: Alliance for Manufacturing Foresight p. 41 (2017), http://mforesight.org/download-reports/.

[37] Cybersecurity for Manufacturers: Securing the Digitized and Connected Factory, MForesight: Alliance for Manufacturing Foresight p. 49 (September 2017), https://cra.org/ccc/wp-content/uploads/sites/2/2017/10/MForesight-Cybersecurity-Report.pdf, http://mforesight.org/download-reports/.

[38] Democratizing Manufacturing: Bridging the Gap Between Invention and Manufacturing, MForesight: Alliance for Manufacturing Foresight p. 30 (2016), http://mforesight.org/download-reports/.

America Makes Hybrid Manufacturing Working Group

The America Makes Hybrid Manufacturing Working Group began operating in 2017. The mission of this group is to accelerate the adoption of hybrid manufacturing of metal functional products with a focus on integrating additive manufacturing with other more traditional production processes including subtractive machining and grinding, heat treatments, metrology, and more.

The objectives are to:

- **Create an ecosystem of people and organizations fostering hybrid manufacturing;**
- **Integrate the Consortium of Advanced Hybrid Manufacturing — Integrating Technology roadmap into the America Makes Roadmap;**
- **Expand the development focus of hybrid manufacturing to include secondary and tertiary processes such as machining, chemical processes, heat treatment, and multi-functionality;**
- **Propose, evaluate, and endorse hybrid manufacturing topics (critical technology elements) and sub-topics; and,**
- **Foster the identification of common technical and industrial challenges overarching many or all constituents and establishing appropriate technology investment goals.**

NIST Laboratories and the Advanced Manufacturing Technology Consortium Program

NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. The work of the various institutes developing new manufacturing innovations is enhanced through collaborations with the NIST laboratories, especially in the areas of measurement science and standards. The strong technical expertise of the NIST staff has led to productive engagement with each of the institutes, and NIST has identified a senior scientist to act as technical lead to coordinate NIST laboratory resources to support each institute.

NIST staff have active technical collaborations and advisory roles within the institutes, ranging from project collaborations and leadership roles in institute road-mapping to serving on institute technical advisory councils and executive committees. NIST also provides subject matter experts to help other agencies develop topics for new institutes.

The NIST AMTech program develops industrial consortia to address precompetitive challenges to advance manufacturing processes needed across an industry sector. In general, the consortia develop technology roadmaps that guide research for members and non-members. The roadmaps accelerate research in promising directions while preparing U.S.-based supply chains for likely new technologies. The AMTech roadmaps have directly contributed to the initiation of four institutes, and institutes are using ten other AMTech roadmaps to shape the direction of their technical research.

External Assessments

Two external assessments of Manufacturing USA were discussed in the FY 2016 Annual Report. The first, Manufacturing USA: A Third-Party Evaluation of Program Design and Progress, produced by Deloitte, included recommendations which Manufacturing USA implemented in FY 2017.[39]

The second assessment, was undertaken by the Comptroller General of the Government Accountability Office (GAO), as required in the RAMI Act.[40] The GAO's report recommended that DOC encourage participation of the Department of Labor. This recommendation was implemented in FY 2017, with the Department of Labor becoming an active participant in the program. The report also recommended that Manufacturing USA expand its governance document to detail the roles of agencies that have not sponsored institutes. In FY 2017, discussions began with the involved agencies to detail their roles and responsibilities.

While no formal assessment was conducted in FY 2017, Manufacturing USA was the subject of several congressional briefings and a workshop held by the National Academy of Engineering.[41]

[39] *Manufacturing USA: A Third-Party Evaluation of Program Design and Progress,* Deloitte LLP, p. 65 (January 2017) https://www2.deloitte.com/us/en/pages/manufacturing/articles/manufacturing-usa-program-assessment.html.

[40] Revitalize American Manufacturing and Innovation Act of 2014 (Pub. L. 113-235, codified in relevant part at 15 USC 278s(g)(3)).

[41] NAE Workshop NAE Workshop Securing Advanced Manufacturing in the United States, The Role of Manufacturing USA: Proceedings of a Workshop, The National Academy of Sciences, p. 128 (2017), https://www.nap.edu/catalog/24875/securing-advanced-manufacturing-in-the-united-states-the-role-of.

Credit: IACMI

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