2017

ANNUAL REPORT

Program Report

and

Summary of Institute Activities

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Manufacturing USA®

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About this Document

This annual report documents the progress of the Manufacturing USA program in meeting its goals as stated in its Strategic Plan.[1] It also describes the major accomplishments of the Manufacturing USA institutes in Fiscal Year 2017.

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[1] *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.

[2] Subject Matter of Copyright: United States Government Works, Pub. L. 94-553, 17 U.S.C. § 105, https://www.gpo.gov/fdsys/pkg/USCODE-2010-title17/pdf/USCODE-2010-title17-chap1-sec105.pdf.

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Manufacturing USA Annual Report, FY 2017

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August 2018

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology

TABLE OF CONTENTS

PROGRAM REPORT

SUMMARY OF INSTITUTE ACTIVITIES

Front Cover Photos: AIM Photonics, DMDII, IACMI, AIM Photonics, NextFlex.
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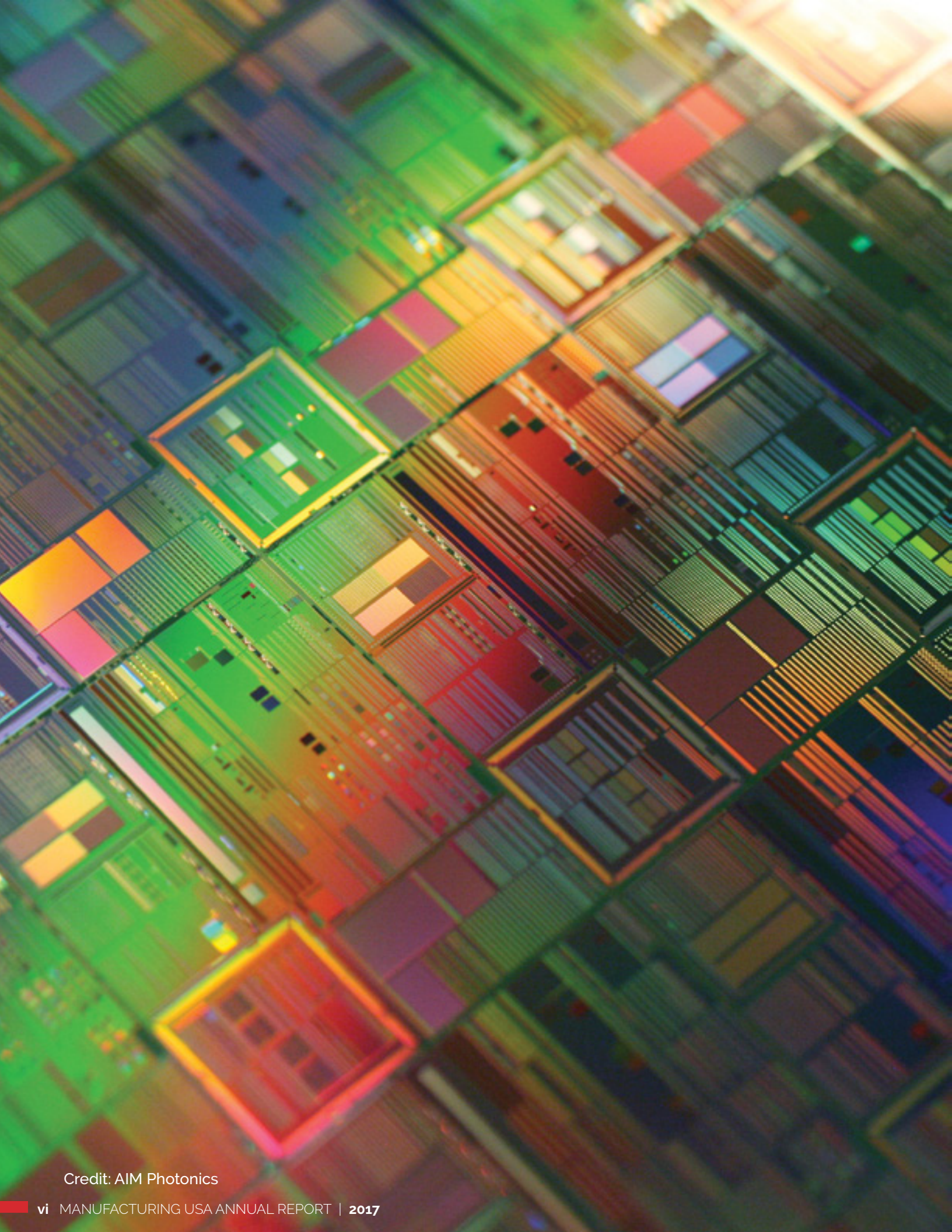
Manufacturing USA®

PROGRAM REPORT FY 2017



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MESSAGE FROM THE NIST DIRECTOR

Innovation has always been an American strength. While other nations have significantly increased their production of high-value, advanced products, the U.S. has, in recent years, often allowed its best early-stage inventions to languish in our laboratories only to see them developed and manufactured in other countries. Inventing here while other nations disproportionately benefit from new, technology-based, manufacturing jobs is untenable. Manufacturing catalyzes innovation, knowledge and economic value creation.

Manufacturing USA helps industry move discoveries from the Nation's universities and research laboratories into production in the U.S. The program's institutes develop world-changing manufacturing technology and equip the U.S. manufacturing workforce with the high-value skills needed to make tomorrow's products.

In fiscal year 2017, the fourteen Manufacturing USA institutes, sponsored by the Departments of Commerce, Defense, and Energy, conducted nearly 270 major applied research and development projects of high 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. Federal support for these institutes creates a framework that allows industry and academia to work together to develop the most promising new technologies into products to be manufactured in America.

The Manufacturing USA institutes act as manufacturing and innovation hubs, providing real value to U.S. industry. These hubs benefit the public by providing workforce development, improved job opportunities, and increased economic opportunity by advancing promising technologies into U.S. production, paying higher wages for U.S. workers, and delivering the products needed by the nation and the world.

Working with our agency partners, we at the National Institute of Standards and Technology are excited to lead this initiative and to support all the Manufacturing USA institutes to ensure a bright future for American manufacturing. Our commitment to a strong U.S. manufacturing sector is unwavering. Our vision is nothing less than U.S. global leadership in advanced manufacturing.

Walter G. Copan

Undersecretary of Commerce for Standards and Technology

Director, National institute of Standards and Technology (NIST)

Credit: America Makes

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.

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[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

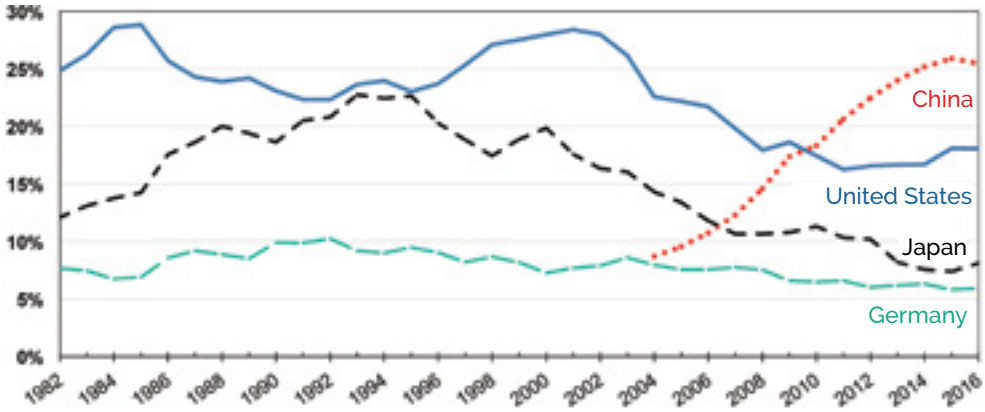


Figure 1. Manufacturing value-added by largest global manufacturers. Sources: United Nations and MAPI Foundation.

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.

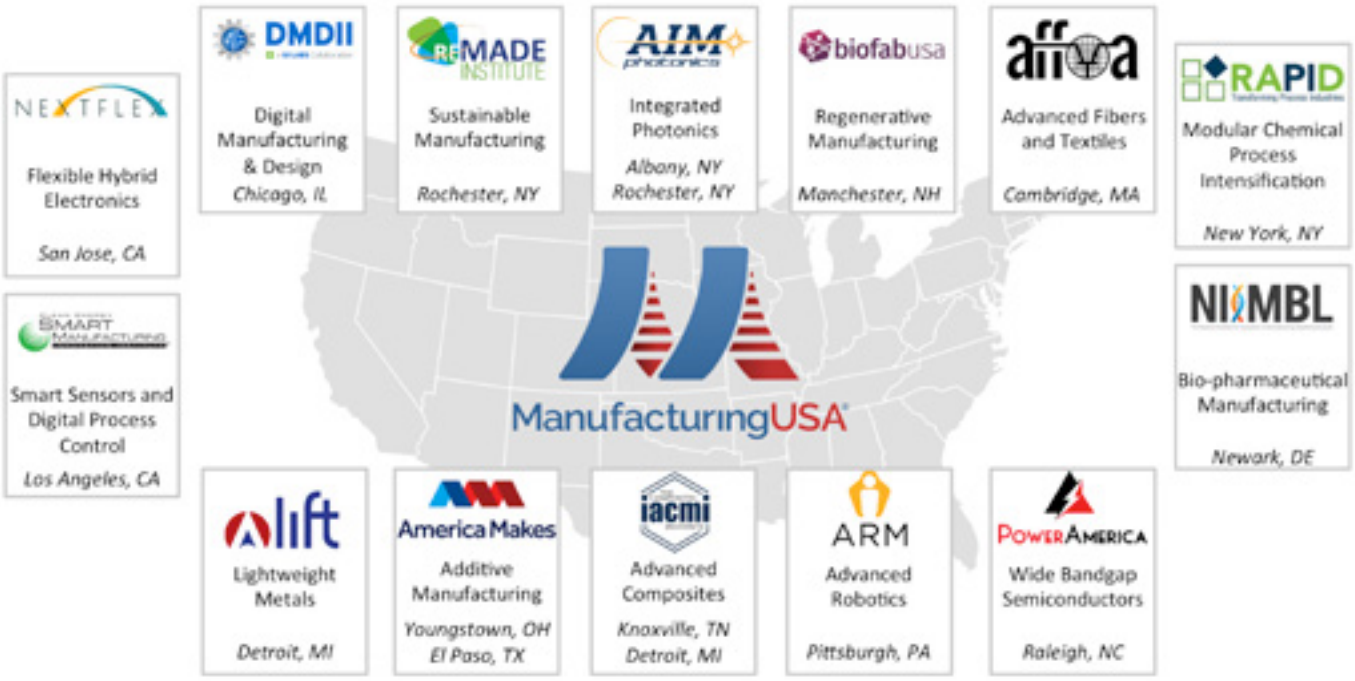


Figure 3. Six new institutes were established in FY 2017, bringing the total to 14 Manufacturing USA institutes.

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.

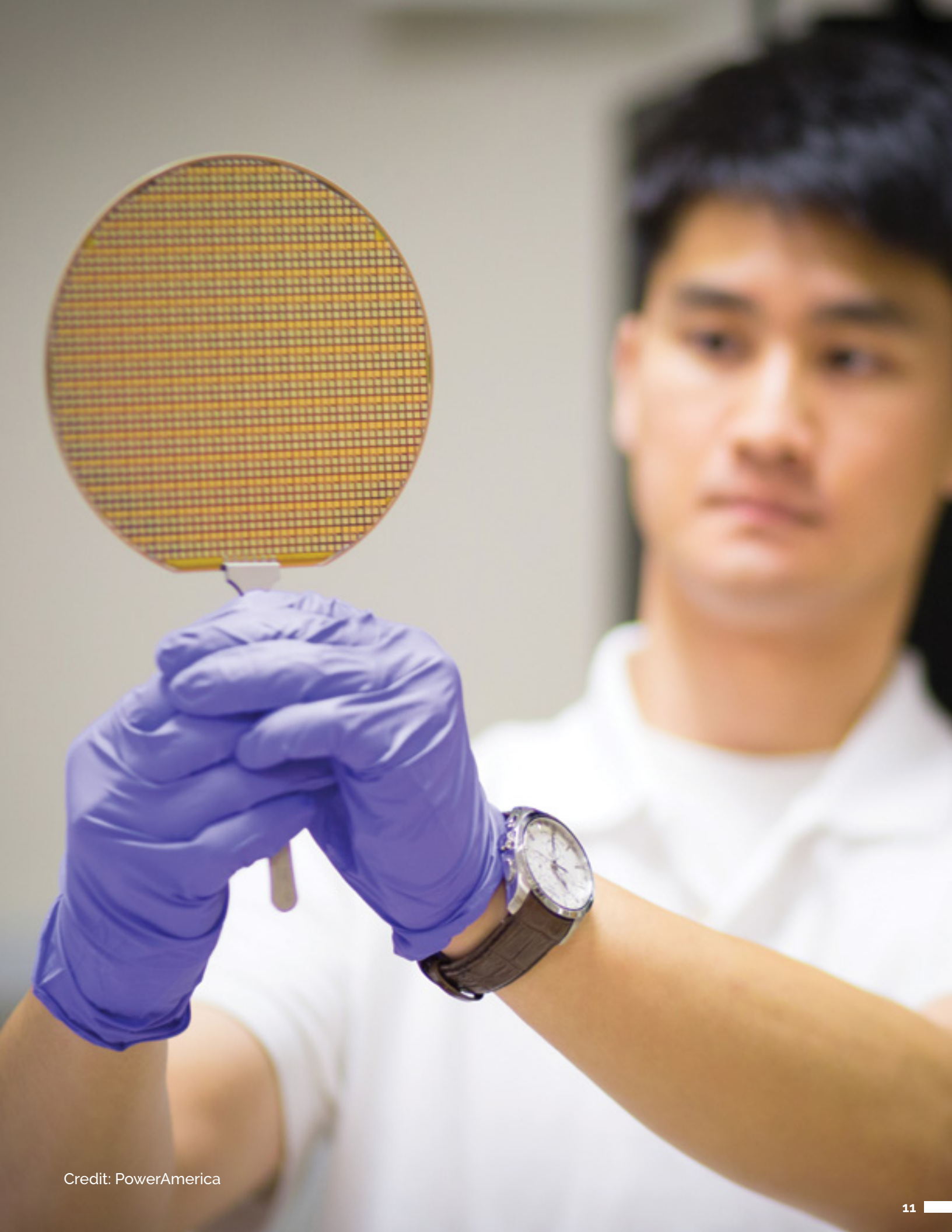
As Manufacturing USA grows and matures, metrics used for evaluation will evolve. While this evolution may introduce difficulties in comparing certain metrics over time, Manufacturing USA's leadership remains committed to continuous improvement to properly assess Manufacturing USA over the long term.

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.

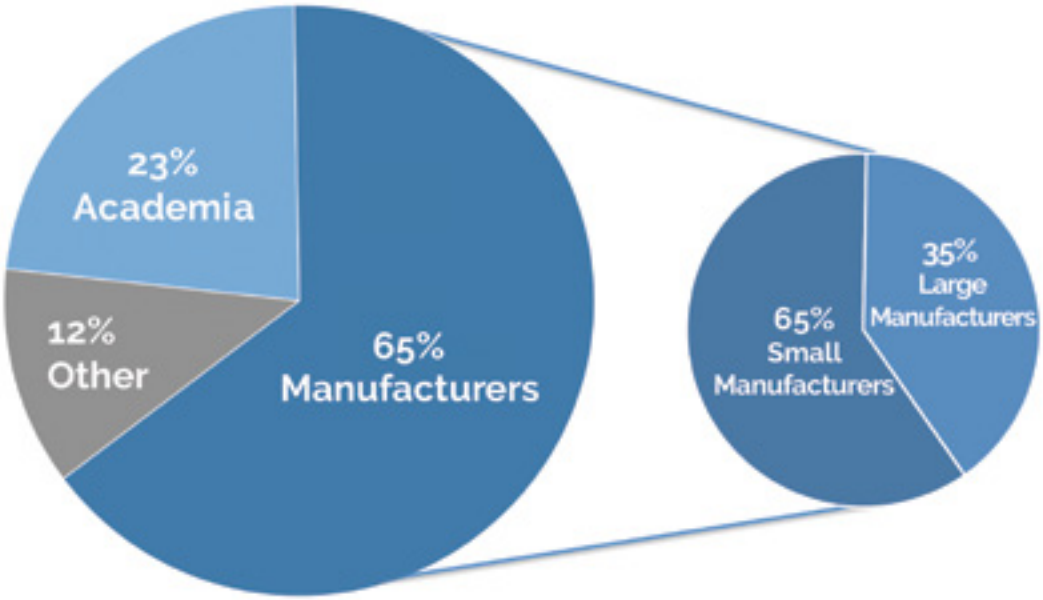


Figure 4. Manufacturing USA institute membership demographics.

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.

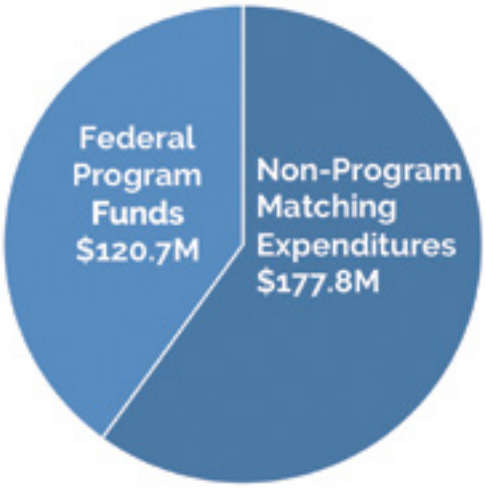


Figure 5. Financial Leverage.

- 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.

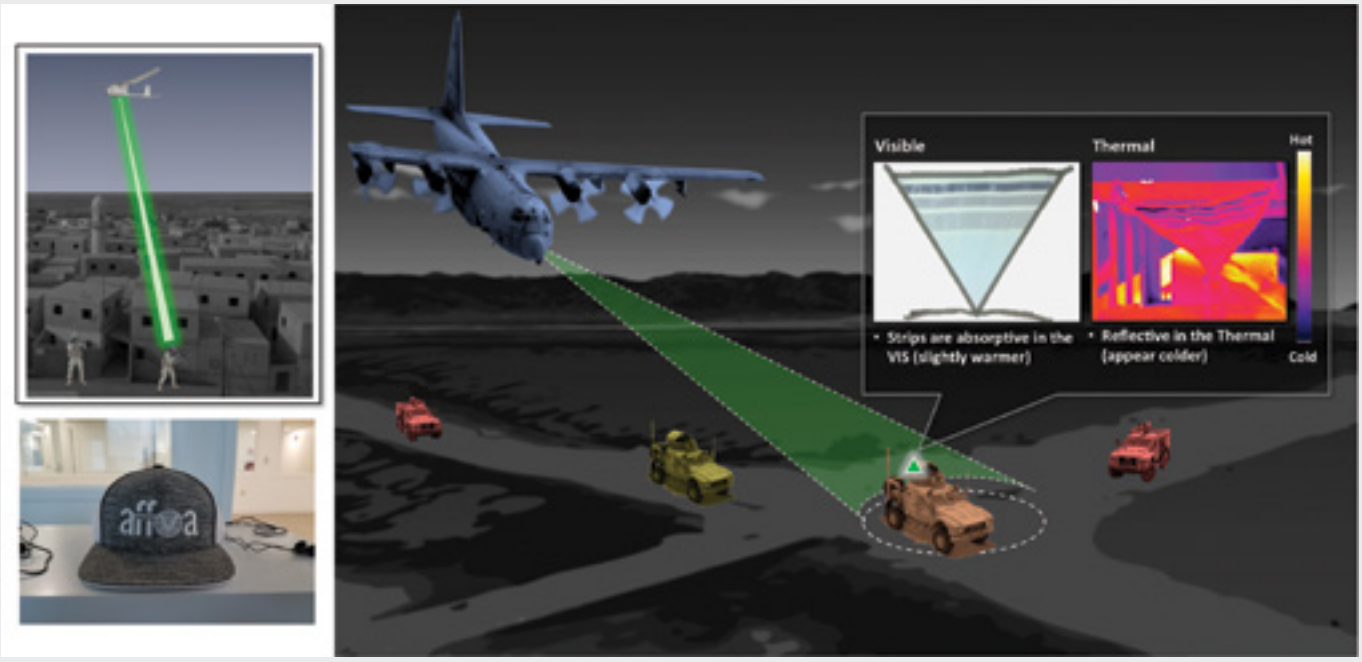


Figure 7. Free Space Optical Communications. Fabrics can be engineered with spectral features spanning ultraviolet through longwave infrared. Embedded sensors can enable fabric-based communications transmitters and receivers. Credit: AFFOA

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

2017 SUMMARY OF INSTITUTE ACTIVITIES

SUMMARY OF INSTITUTE ACTIVITIES

Department of Commerce

Credit: NIIMBL

NIIMBL

a Manufacturing USA institute

Photo courtesy of the University of Delaware/Evan Krape photographer

NIIMBL

Mission: To accelerate biopharmaceutical manufacturing innovation, to support the development of standards that enable more efficient and rapid manufacturing capabilities, and to educate and train a world-leading biopharmaceutical manufacturing workforce, fundamentally advancing U.S. competitiveness in this industry.

Location: Newark, DE

Established: March 2017

Consortium Organizer: University of Delaware

Funding: Federal, $70M; Non-federal, $129M (planned funding over five years)

Members (as of September 30, 2017): 69

NIIMBL

National Institute for Innovation in Manufacturing Biopharmaceuticals

niimbl.org

NIIMBL

NIIMBL is revolutionizing biopharmaceutical manufacturing in the United States through technology advancement, workforce training, and standards development. Biopharmaceuticals save, sustain, and improve lives by treating notoriously difficult-to-treat conditions. However, current biomanufacturing processes are too costly and inflexible to support efficient development of new types of products. By accelerating innovation in the manufacturing technologies and processes, supporting best-in-class workforce training and developing standards, NIIMBL helps industry to more quickly bring safe, efficacious treatments that lead to better patient outcomes.

Technology Description

"Continued innovation is critical for developing new biopharmaceutical therapies to address key medical needs. NIIMBL provides a unique opportunity to accelerate efforts to address manufacturing challenges so that novel approaches and treatments reach and benefit patients in the future "

– Dana Andersen, Genentech (San Francisco, CA)

Biopharmaceuticals are medicines produced or extracted from biological sources, such as living cells. They treat and prevent some of the most prevalent and debilitating diseases including cancer, diabetes and autoimmune disorders. NIIMBL provides a unique opportunity for large manufacturers, small companies, academic researchers and federal agencies to collaborate and to share the risk and benefits of transformative manufacturing technologies that will enhance patient access to these important medicines and secure the economic foundation of the U.S. biopharmaceutical industry.

Applications

The biopharmaceutical industry is a critical contributor to the Nation's economy, but the industry is facing challenges due to aging and inflexible infrastructure, and the risks associated with innovating in a highly-regulated manufacturing space. Development of innovative manufacturing technologies within the U.S. solidifies this country's competitiveness by enabling domestic growth of this sector and reducing the offshoring high-paying jobs. In addition, advances in relevant manufacturing technologies not only accelerate patient access to new types of therapies, but also provide more flexible manufacturing facilities to allow the U.S. to more quickly scale up production to respond to public health threats - whether manufactured or natural.

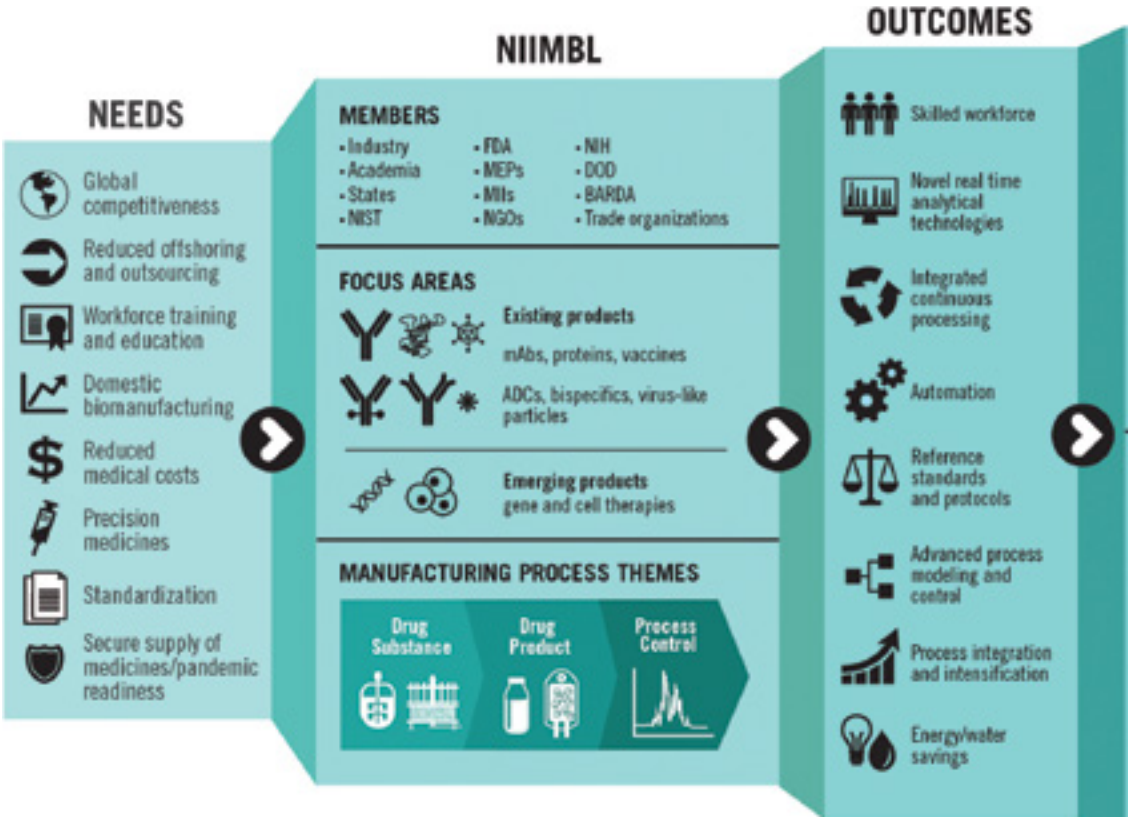


Figure 13. The NIIMBL innovation ecosystem is designed to meet the critical needs of the U.S. biopharmaceutical industry and U.S. taxpayer, providing broad-based national impacts. Credit: NIIMBL

Institute Structure

Governance

The initial work of NIIMBL was to fill in the governance and operational structure for the institute. Within the first quarter of operations, NIIMBL established its Governing Committee, Technical Activities Committee, and Workforce Activities Committee and began monthly committee meetings. Each of these committees play a crucial role in achieving the institute's mission of advancing biopharmaceutical manufacturing technology and workforce development. A key aspect of NIIMBL governance is a voting structure that gives weight to industry members to ensure that NIIMBL activities consistently reflect industry needs.

The Governing Committee develops the vision, mission, strategy, management processes and policies. The Technical Activities Committee is responsible for technical programs including project calls and roadmapping. The Workforce Activities Committee is responsible for education and workforce development projects and activities. Due to the highly-regulated nature of the NIIMBL technology space, NIIMBL leadership, key industry stakeholders, and representatives from the U.S. Food & Drug Administration (FDA) also have met to develop a consensus framework for engagement of the FDA within NIIMBL activities, including a Regulatory Considerations Committee which will facilitate the regulatory science awareness needed concurrently with the technology innovation anticipated from NIIMBL.

Early Actions

"NIIMBL represents a unique opportunity to collaborate on innovative manufacturing technologies that will advance the industry."

– Greg Russotti, Celgene (Summit, NJ)

Committee Activities

In May 2017, NIIMBL hosted its first National Meeting in Washington D.C. The event was attended by more than 250 stakeholders from nearly 100 organizations. The need for the NIIMBL partnership to strengthen the U.S. biopharmaceutical industry and accelerate patient access to life-saving therapies was highlighted in remarks from a bipartisan congressional delegation, as well as two Center Directors from the U.S. FDA. Industry panelists provided perspectives on precompetitive technology gaps, and the first NIIMBL small and medium enterprise (SME) showcase was held to increase visibility of innovative technology and promote partnerships. Following the public meeting, the initial member-only committee meetings of the four working committees (cited above) were convened to discuss strategy, articulate roles and responsibilities for members, and provide face-to-face opportunities to strengthen ties between stakeholder groups.

Technical Activities

In June 2017, NIIMBL issued its first Project Call. The purpose of this Quick Start Project Call was to initiate technical and workforce activities and promote rapid teaming. To offer the opportunity for all members to respond, proposals were solicited in any area of biopharmaceutical manufacturing, which met the NIIMBL mission. Projects will begin during FY 2018.

Additional Activities

In coordination with the project call, NIIMBL launched initiatives to support partnering and collaboration amongst its members. In July 2017, NIIMBL hosted two teaming meetings in Raleigh, NC and San Francisco, CA. Attendees at these events included representatives from 27 NIIMBL member organizations. Additionally, NIIMBL unveiled its Community Portal, an online resource for NIIMBL members to view research interests, areas of expertise, and facilities of other members.

Membership

NIIMBL opened its membership in April 2017, and has continued to attract new members from across the ecosystem including leading biomanufacturers, suppliers, SMEs, and academic institutions. As of September 30, 2017, NIIMBL had 69 members in 17 states.

NIIMBL offers a tiered membership structure. Industry tiers are designed to facilitate participation across the entire spectrum from mature, highly capitalized enterprises to contract manufacturers to SMEs and non-profits. Academic tiers aim to include major research-intensive universities to community colleges and non-profit organizations focused on economic and workforce development.

Figure 14. Over 250 stakeholders from nearly 100 organizations gathered at the inaugural NIIMBL National Meeting held at the National Academy of Sciences Building in May 2017. Credit: Kevin Quinlan/University of Delaware

Roadmapping

NIIMBL has engaged both members and non-members from biomanufacturers, suppliers, academic institutions, and federal agencies to begin its roadmapping process, which will continue next year. The initial NIIMBL roadmapping efforts are focused on addressing gaps in available technology roadmaps but will also begin to address needs around workforce development, regulatory science, and standards. NIIMBL has partnered with the BioPhorum Operations Group to facilitate a NIIMBL U.S. roadmap. This document will complement existing biomanufacturing-related roadmaps.

Workforce Development

"Through the partnership and collaborative opportunities fostered by NIIMBL, we are able to fully understand the skills and training needed for biopharmaceutical workforce now and in the future."

– John Balchunas, Biomanufacturing Training & Education Center, North Carolina State University (Raleigh, NC)

NIIMBL's workforce development and education efforts focus on cultivating the right skills for those who want to pursue careers in biomanufacturing and realize the benefits of high-wage jobs that are characteristic of this industry. NIIMBL began its workforce development efforts by engaging members in a comprehensive assessment of the most critical training needs of the biopharmaceutical industry, the most effective delivery methods, and the barriers and limitations to workforce training. Armed with this information, NIIMBL will create an asset map of its membership base to assess current workforce and training capacity and identify gaps that need to be addressed to provide skilled workers at all levels, from technicians to bioprocess engineers.

The Future

NIIMBL will reach full operational status in FY 2018 and will continue to expand its membership to develop a more extensive stakeholder ecosystem, as it builds and links regional networks for increased national impact. In addition to the Quick Start projects awarded in early FY 2018, NIIMBL will issue full project calls twice a year to accelerate its technical, workforce and regulatory science activities, prioritized by industry needs, and assisted by the developing NIIMBL roadmap. NIIMBL will continue to host events to facilitate networking and collaboration including its second National Meeting in May and several technical workshops in 2018. NIIMBL will structure future teaming meetings around priority technical and workforce topics. It will continue to develop activities that offer opportunities for SMEs to leverage resources within the NIIMBL network to strengthen these innovator companies. In addition, NIIMBL will continue preparations to move into its new national headquarters at the University of Delaware's Biopharmaceutical Innovation Building, scheduled to open in 2020.

Figure 15. NIIMBL headquarters will occupy two floors of the new University of Delaware Biopharmaceutical Innovation Building, scheduled to open in early 2020. Photo Credit: SmithGroupJJR

Photo courtesy of BTEC © North Carolina State University

SUMMARY OF INSTITUTE ACTIVITIES

Department of Defense

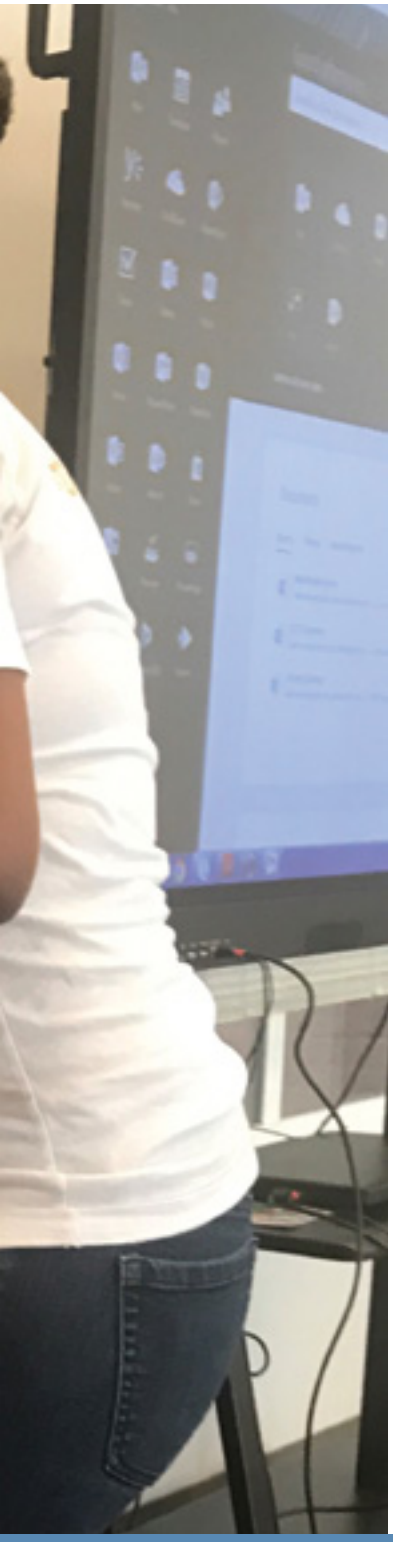
Credit: DMDII


Manufacturing
American Jobs

AMERICA MAKES

a Manufacturing USA institute

Credit: America Makes



America Makes

AMERICA MAKES

Mission: Develop and grow a comprehensive and globally competitive U.S. additive manufacturing (AM) and 3D printing (3DP)[42] infrastructure comprised of: world-class domestic sources of equipment and support; a robust domestic supply chain of high quality materials and services; and a highly-skilled workforce capable of executing and exploiting the capabilities and advantages of AM and 3DP.

Locations: Headquarters: Youngstown, OH;
Satellite location:
The University of Texas at El Paso, TX

Established: August 2012

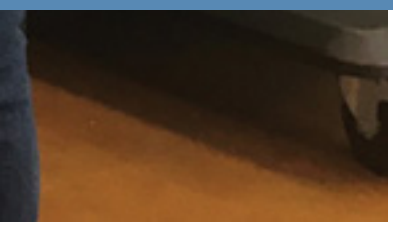
Consortium Organizer: National Center for Defense Manufacturing and Machining, Blairsville, PA

Funding: Federal, $65M, including support from DoD, DOE, NSF, and NASA; Non-Federal, $68M; Both planned over seven years;

Follow-on Five-Year Cooperative Agreement: $50M ceiling Federal funding and $25.8M non-Federal funding

Members (as of September 30, 2017): 189

The National Additive Manufacturing Innovation Institute



americamakes.us

[42] For non-technical documents, the terms "3D printing" and "Additive Manufacturing" are generally used interchangeably. For this report, the term Additive Manufacturing or AM will be taken as including 3D Printing.

AMERICA MAKES

Background

America Makes is the national accelerator for AM and is the Nation's leading driver for industrial collaborations in AM technology research, discovery, creation, innovation, and dissemination.

America Makes is an impartial convener of AM stakeholders, a coordinator of technical and workforce information and data, and an activation catalyst through the execution of high-value, high-difficulty, and high-impact projects. Three major focus areas of America Makes, necessary for establishing a competitive U.S.-based capability, are technology development, technology dissemination, and workforce and educational outreach.

Additive manufacturing allows for design and production of never-before-possible products, and for quicker and cheaper production of many existing products in applications that include automotive, medical, and aerospace. Use of AM for automotive products is reducing part counts from thousands to hundreds and includes an objective of having flexible-care design options, ultimately tailored for consumer needs. The aerospace industry is also benefiting from the impact of AM with improved product performance, reduced costs, and shortened manufacturing lead-times. Medical applications include patient-specific medications and drugs, patient-tailored joint and cranial implants, implanted tracheal support structures to treat birth defects, and custom-fitted hearing aids.

Technology Advancement

"America Makes Project - Economic Production of Next Generation Orthopedic Materials through Powder Reuse in AM, specifically developed the ability to reuse unfused powder in a selective laser sintering (SLS) build chamber. This is a significant, game-changing development — fundamentally changing the economics of this additive manufacturing process, making batch production viable, and broadening the application of the SLS process."

– Prof. Steven Schmid, Aerospace and Mechanical Engineering, The University of Notre Dame (Notre Dame, IN)

Projects Completed in FY 2017

In FY 2017, 18 projects were completed. Highlights addressing needs identified in the public-private-driven technology roadmap include:

- A new AM software tool has allowed organizations to streamline their production processes, enabling a 50 percent reduction in the design procedure of additive manufactured parts. The tool led to expedited orders to the customer, shorter design cycles, improved first-time builds, and reduction in cost measures. The software tool, available to all America Makes members, has improved additive

manufacturing printing design techniques and is currently being used by large aerospace companies. Project participants include: General Electric Global Research Center (Schenectady, NY); Autodesk Inc (San Rafael, CA); Altair (Troy, MI); ANSYS Inc (Canonsburg, PA); University of Wisconsin — Madison (Madison, WI); and the Raytheon-U. Mass Lowell Research Institute (Lowell, MA)

- The ability to reuse AM powder has reduced material costs by at least 15 percent for orthopedic designs. Powder materials typically cost between $75 and $100 per kilogram ($34 to $45 per pound) with high-performance materials costing twice this amount. A typical product uses only 5 percent to 20 percent of the powder to print the parts, with the remaining powder being discarded. The team studied titanium and stainless-steel powders and their reuse capabilities and found that even after four reuse cycles, the materials showed no signs of reduction in quality. This finding enables the parts to be built with significant cost savings. Project participants include: Johnson & Johnson (Bridgewater, NJ); University of Notre Dame (Notre Dame, IN); Case Western Reserve University (Cleveland, OH); SCM Metals Products (Research Triangle Park, NC); Zimmer (Warsaw, IN) and Johnson & Johnson, DePuy Synthes Companies (Bridgewater, NJ)

- The creation of the Multi3D system reduced cost and reduced space requirements by more than 50 percent. America Makes led a team to design and assemble the Multi3D system with a five-axis motion platform for additive manufacturing, subtractive manufacturing, and foil/wire embedding, demonstrating the capability to design and manufacture multifunctional components within a single enclosed unit. Project participants include: University of Texas — El Paso (El Paso, TX); Northrop Grumman (El Segundo, CA); Lockheed Martin (Bethesda, MD); Stranepresse (Kent, OH); AST2 (Youngstown, OH); and Draper Laboratory (Cambridge, MA)

New Projects Launched in FY 2017

In addition to ongoing projects, FY 2017 saw America Makes launch four new large projects addressing key additive manufacturing problems such as:

- Bell cranks, used in flight-control surface manipulation, are flight-critical parts with complex geometries that make conventional production both challenging and costly. The America Makes team will use additive manufacturing to reduce production steps and time, perform advanced statistics, develop qualification processes, and establish a supply chain to provide spare parts. The successful manufacturing of these bell cranks using additive manufacturing and the development of the path towards qualification and certification of this manufacturing technology will improve the ability of the Air Force Air Logistics Complexes to rapidly find replacement parts required for legacy aircraft, with an expected 30 percent reduction in lead times and a 20 percent reduction in cost. Project participants include: Youngstown State University (Youngstown, OH); Pennsylvania State University (State College, PA); Lockheed Martin (Bethesda, MD); Oerlikon (Westbury, NY); Boeing (St. Louis, MO); Youngstown Business Incubator (Youngstown, OH); and M-7 Technologies (Youngstown, OH).

- Aircraft oil coolers consist of very thin walls and are typically fabricated using brazing or welding to produce gas-tight sections, resulting in long production times and high costs. The America Makes team is using additive manufacturing

to allow end-to-end production of oil coolers that are lighter, with more intricate geometries for heat exchangers in turbine-based engines for the Air Force. A 30 percent reduction in lead times and improved productivity are expected, providing a straightforward process for companies like Honeywell (Phoenix, AZ), GE (Schenectady, NY), and other original equipment manufacturers to deliver these families of spare parts to the Air Force. Project participants include: University of Dayton Research Institute, General Electric Aviation (Evendale, OH); DRT Medical (Dayton, OH); Youngstown State University, Youngstown Business Incubator, and 3DSIM LLC (Park City, UT).

- Fairings, devices used for smooth flight surfaces with good aerodynamics, are often constructed of complex geometries using sheet metal fabrication or polymer layups requiring excessive manual labor, resulting in very high costs. Switching from traditional to additive manufacturing, Boeing (St. Louis, MO) will reduce production times by up to 50 percent and cost by 30 percent. The project will focus on a new weapons system being designed for a 1950's strategic Air Force aircraft platform, allowing a direct comparison of conventional manufacturing and the revolutionary hybrid additive manufacturing in terms of lead times, costs, repair options, and inventory requirements.

Workforce Development

"America Makes' continued role in the development of an AM workforce is essential for the nation to continue its momentum in the advanced manufacturing sector. By working with America Makes on its ACADEMI program we are able to help organizations to remain current as AM technologies emerge but also be well-rounded enough to remain grounded in AM technologies prevalent in the bulk of job demand."

– Tony Hughes, President, The Lanterman Group (Chagrin Falls, OH)

America Makes' workforce and educational outreach objective is to create and grow an agile workforce capable of meeting current and emerging needs in additive manufacturing that will increase overall domestic manufacturing competitiveness. To focus the workforce development actions, America Makes developed an Additive Manufacturing Workforce and Education Roadmap that identifies measurable and meaningful education and training challenges and opportunities across the AM industry. Key accomplishments in 2017 include:

- The Additive Manufacturing Body of Knowledge was updated. This critical update served as the basis for the 2017 nationwide launch of a Tooling U-SME (Cleveland, OH) / America Makes Additive Manufacturing Certification Program that establishes a stackable,

Figure 16. Chris Wentworth (California Manufacturing Technology Consulting/California Manufacturing Extension Partnership and U.S. Army Veteran), lead instructor for Los Angeles Boot Camp, providing individual 3D Printing instruction to Marine veteran Tim Astor. Credit: 3D Veterans, Inc.

America Makes Expands Life-Changing Additive Manufacturing Training Program for Veterans

With support from a Google.org Impact Challenge Grant, America Makes continued its work with the Veterans Administration and 3D Veterans (San Antonio, TX), introducing new hands-on, projects-based additive manufacturing technology training pilot programs for U.S. veterans in Pittsburgh and Los Angeles.

3D Printing Vocational Boot Camp — In Pittsburgh, 12 industry-leading experts provided one-on-one instruction to 14 veterans in critical additive manufacturing skills, including 3-D printing, computer-aided design drawing, 3-D scanning, traditional manufacturing, and additive manufacturing business creation. In addition to America Makes and 3D Veterans, Robert Morris University and General Electric's Center for Additive Technology Advancement also helped develop the program. As part of the boot camp, participants were trained at GE's center in Pittsburgh working through hands-on projects. The 4-week full-time training boot camp was designed to give the veterans the skills necessary for trainees to secure employment in advanced manufacturing within six months of program completion.

Year-Round Training Center for Homeless Veterans — In Los Angeles, a year-round 3D Printing Training Center for Veterans was established, serving temporarily homeless veterans living together in a permanent supportive housing facility. It is currently providing customized 3D printing training to the first cohort of ten veterans. The program includes residents of the Hollywood Veterans Center (Los Angeles, CA) and other area veterans. The program will scale to eventually reach over 60,000 veterans living in permanent supportive housing.

flexible, and modular pathway for mastering the principles and processes of additive manufacturing.

- The 2016 Google.org Impact Challenge Grant was scaled across the United States in 2017, with new pilot programs in Pittsburgh and Los Angeles. This collaboration with the Veterans Administration (Washington, DC) and 3D Veterans (Lexington, MD) focused on hands-on, projects-based additive manufacturing technology training for U.S. veterans.

Innovation Ecosystem

"America Makes has been central to the development of the Northeast Ohio Additive Manufacturing Cluster. Having a formal tie between the Cluster membership and America Makes has allowed [the Youngstown Business Incubator] to use their expertise, contacts and visibility to develop programs to support both the adoption and development of AM technologies throughout northeast Ohio. America Makes' interactions have greatly accelerated Ohio's technical supply chain participation."

– Barb Ewing, CEO, Youngstown Business Incubator (Youngstown, OH)

America Makes fosters a highly diverse, multi-disciplinary, innovation ecosystem spread across the U.S. As of September 2017, membership consisted of 49 large businesses, 67 small businesses, 41 academic organizations (universities, community colleges, and research institutions), 15 government organizations, 12 non-profit organizations, and 5 Manufacturing Extension Partnership centers.

The member businesses are a mix of additive manufacturing equipment companies, materials manufacturers and suppliers, design and analysis software suppliers, testing organizations, companies that design and produce additive manufactured end-item products, and component supplies at all levels in the supply chain. Participating industry sectors include aerospace and defense, electronics, automotive, petroleum, healthcare, and energy generation.

America Makes' public partners include the Departments of Defense, Energy, Commerce, and Education and the National Science Foundation, the National Institute of Standards and Technology, the National Aeronautics and Space Administration, the Federal Aviation Administration, and the Food and Drug Administration.

The extraordinary mix of America Makes partners and members share significant overlap in technical issues to be solved and a continued urgency for a skilled, multi-disciplinary additive manufacturing workforce. Under the America Makes infrastructure, a powerful, connected, and deeply collaborating innovation ecosystem is in place and producing benefits and value for all involved.

Key Innovation Ecosystem accomplishments in 2017 that addressed the need to "connect the dots" include:

- America Makes in partnership with Siemens (Milford, OH) and Deloitte (Arlington, VA) launched the America Makes Digital Storefront, enabling membership to access, search and discover, and consume intellectual capital assets from a broad and diverse set of public and private stakeholders. Hosting more than 400 requirements and thousands of project data and referenced artifacts, the America Makes Digital Storefront is more than just a data collection repository, rather it's the live connection of project and reference data to a Voice of Industry led Technology Roadmap and Workforce and Education Roadmap. This live connection allows for deliberate progress assessment of the U.S. AM capability.

- In partnership with the American National Standards Institute (New York, NY) and in collaboration with the over 150 partner organizations of the Additive Manufacturing Standards Collaborative (AMSC), published the Standardization Roadmap for Additive Manufacturing (Version 1.0). The roadmap publication represents over a year's work by the AMSC, a group specifically chartered as a cross-sector coordinating body whose objective is to accelerate the development of industry-wide additive manufacturing standards and specifications consistent with stakeholder needs.

- In partnership with Deloitte (Arlington, VA), led a collaboration with the Air Force, Army, Defense Logistics Agency, and Department of Navy on developing the first ever Department of Defense (DoD)-wide Additive Manufacturing Roadmap. The DoD Roadmap provides a foundation and framework for focusing collaboration and coordination of the DoD's activities in AM to systematically and efficiently mature the technology for multiple DoD applications. This is a major step forward in coordination that enables both the public and private additive manufacturing needs to be related in a single comprehensive roadmap.

- Established the America Makes @ program to serve as a new way of cultivating a diverse and robust membership community that more broadly represents the AM ecosystem in the U.S. The America Makes @ program established a critical mechanism in enabling the establishment of more relationships with more organizations working to advance the AM industry, critical in bringing increased visibility and positive impact to the current AM ecosystem. The @ Program offers cost share credits in lieu of the annual membership dues for activities that align to the mission objectives and roadmaps of America Makes.

- America Makes launched ACADEMI, Advanced Certification/Curriculum in Additive Design, Engineering, and Manufacturing Innovation, an innovative and multi-disciplinary training pro-gram focused on engineering and manufacturing innovation in additive manufacturing (AM) technologies, applications and processes. ACADEMI was successfully deployed within the Air Force and has recently been awarded funding from the Department of Defense to expand the program across the DoD. The foundation for the program has been shaped by input from over 100 companies and 30+ subject matter experts from across industry and academia, addressing current AM training offering gaps.

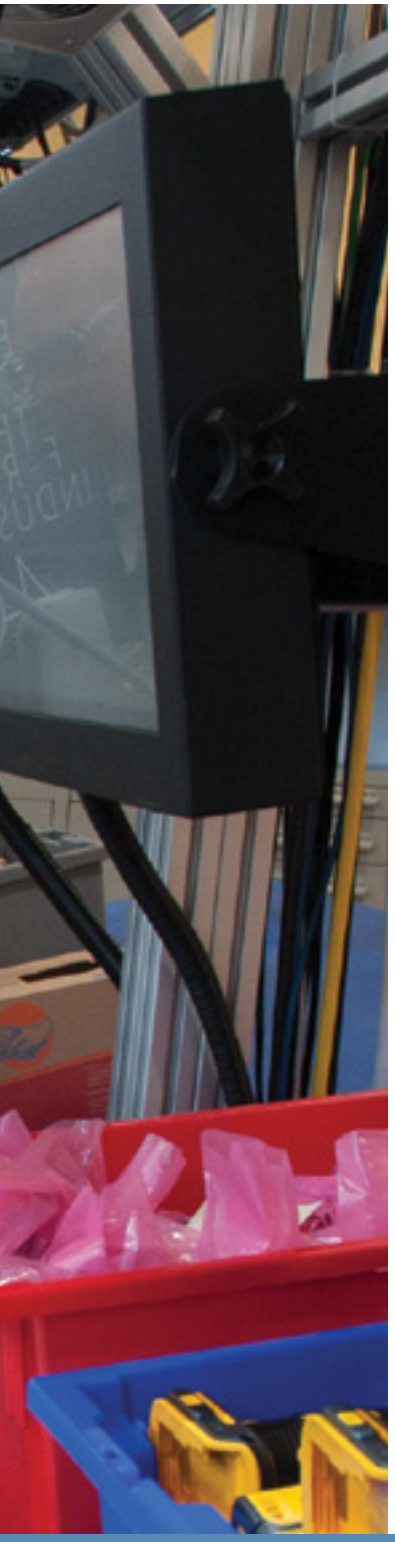
Credit: America Makes

Credit: America Makes

DMDII

a Manufacturing USA institute

Credit: DMDII



DMDII

a UI LABS Collaboration

Mission: The Digital Manufacturing and Design Innovation Institute provides the government and U.S. manufacturers with the digital tools needed to transform American manufacturing.

Location: Chicago, IL

Established: February 2014

Consortium Organizer: UI LABS

Funding: Federal, $83M; Non-Federal, $ 106M; both planned over five years

Members (as of September 30, 2017): 307

Digital Manufacturing and Design Innovation Institute

uilabs.org/innovation-platforms/manufacturing/

DMDII

Background

In partnership with UI LABS and the Department of Defense, the Digital Manufacturing and Design Innovation Institute (DMDII) provides factories with the digital tools and expertise they need to begin building every part better than the last. DMDII is where innovative manufacturers forge their futures. As a result, our more than 300 partners increase their productivity and win more business. Through us, the Department of Defense equips their contractors — who make everything from fighter jets to submarines — with the most advanced manufacturing technology in the world.

Technology Advancement

"We really like the ability to interact with university researchers and other industry partners to take on challenging questions about how we're going to implement digital manufacturing going forward. If you look across the entire country, there are very few other places that we can go where we can really have like-minded thinking in some of the new, emerging technologies that we see coming forward that are going to drive a competitive advantage."

– Craig Sutton, Manager, Advanced Manufacturing and Innovation Strategy, John Deere (Moline, IL)

DMDII managed a portfolio of 51 active research and development projects in FY 2017. These projects bring together partners from universities, industry, startups, and government to solve technology advancement challenges in digital manufacturing that are too big for any one organization to solve on its own.

Projects Completed in FY 2017

In FY 2017, 16 projects were completed. Highlights include:

- DMDII sponsored two projects to improve the cybersecurity resilience of the U.S. manufacturing base. These projects address a critical national security issue — 55 percent of small to mid-sized business have experienced a cyber-attack in the past 12 months.[43]
  - Assessing, Remediating, and Enhancing Defense Federal Acquisition Regulation Supplement (DFARS) Cybersecurity Compliance in Factory Infrastructure — A team led by Imprimis, Inc., released a guide to DFARS cybersecurity compliance, *What Manufacturing Executives Need to Know*, and an associated training module, *Cybersecurity Compliance: Threats, Standards, & Assessment*. The study assessed small to mid-sized manufacturers to determine how well DFARS (NIST SP 800-171) cybersecurity requirements 'fit' in the manufacturing environment and how difficult it is for manufacturers to comply with them. The team found it took an average of 52 hours to complete a cybersecurity assessment. Of the 109 DFARS requirements it found that average initial compliance is low, with 13 percent compliant, 61 percent partially compliant, and 34 percent non-

[43] 2016 State of Cybersecurity in Small & Medium-Sized Businesses, Phonemon Institute LLC, p. 29 (June 2016), https://keepersecurity.com/assets/pdf/The_2016_State_of_SMB_Cybersecurity_Research_by_Keeper_and_Ponemon.pdf

compliant. The Department of Defense can now use the findings from this project to inform modifications to the DFARS requirements being imposed on DoD suppliers. Team Participants included Imprimis, Inc., SPIRE, and the Rocky Mountain Technology Alliance (all in Colorado Springs, CO).

- Factory Operations and Industrial Control Systems — Cyber Security Assessment, Tools and Solutions - To help organizations understand the costs, capabilities, and effectiveness of DoD-required security measures for factory operations, the University of Illinois at Urbana-Champaign (Champaign, IL), Heartland Science and Technology Group (Champaign, IL), Lockheed Martin (multiple locations within the USA), HL Precision Manufacturing (Champaign, IL), and Integrity Technology Solutions (Bloomington, IL) formed a team to help develop the Cyber Secure Dashboard (https://www.cybersecuredashboard.com). The dashboard is designed to intuitively guide organizations, especially the small to mid-sized manufacturers that made up approximately 98 percent of U.S. manufacturers in 2015,[44] through the process of securing their information technology systems by providing detailed, step-by-step instructions, reference materials, industry best practices, and links to available templates and tools. It provides concrete implementation guidance for adhering to the nationally-accepted NIST cybersecurity framework, the DoD-mandated control requirements of the NIST SP 800-171 r1, and the NIST SP 800-53r4 cybersecurity control standard.

- Improving Supply Chains through Model-Based Engineering (MBE) — This Rolls-Royce led project team made recommendations to improve existing software capabilities and standards in order to reduce barriers to MBE integration within the supply chain. The project provides guidance for how organizations in supply chains can standardize MBE to communicate more efficiently and reduce product costs. The project outcomes are guiding additional research and development, generating playbooks for small to mid-size manufacturers about how to digitize their supply chains. Team Participants included Rolls-Royce (Indianapolis, IN), Lockheed Martin (multiple locations throughout the USA), ITI (Milford, OH), Anark Corp (Boulder, CO), Purdue University (West Lafayette, IN), and Microsoft (Redmond, WA).

New Projects Launched in FY 2017

In FY 2017, DMDII launched 14 new projects. The projects are addressing key problems in the digital manufacturing such as:

- Non-Invasive Computer Vision Toolkit for Legacy Machines — Manufacturers seeking to digitize their operations often need to incorporate data from expensive legacy manufacturing equipment in new, innovative processes without disrupting production, creating failure points, or voiding equipment warranties. This project, led by the University of Cincinnati, is developing an open source framework for computer vision-enabled cameras to recognize and read a variety of legacy digital displays and analog dials to produce information in the increasingly accepted MTConnect format. The final software and hardware toolkit is projected to cost less than $1,000 per machine, enabling even the smallest manufacturing company to update their processes without

[44] U.S. Census Bureau, Statistics of U.S. Businesses.

replacing costly legacy equipment. Other project participants include Raytheon (Andover, MA), Faurecia (Auburn Hills, MI), ITI (Milford, OH), and TechSolve (Cincinnati, OH).

- Achieving Smart Factory Through Predictive Dynamic Scheduling — Currently machine sensor systems monitoring the actual condition of equipment do not connect with manufacturing execution systems (MES) to schedule preventative maintenance. Forcam Inc. (Cincinnati, OH) and its project team are developing a solution that allows users to schedule maintenance within their existing MES, optimizing overall equipment effectiveness by decreasing machine downtime and ensuring that machines are only being serviced when necessary. The team is prototyping the integration of their software within Lockheed Martin's MES and anticipates decreasing Lockheed's machine downtime by 10 percent. Other project participants include Predictronics (Cincinnati, OH), Northeastern University (Boston, MA), and Lockheed Martin (multiple locations throughout the USA).

- Capturing Product Behavioral and Contextual Characteristics through a Model-Based Feature Information Network — Lockheed Martin (multiple locations throughout the USA), Purdue University (West Lafayette, IN), Rolls-Royce (Indianapolis, IN), Siemens (Plano, TX), MSC Software (Newport Beach, CA), Capvidia (New Ulm, MN), PTC (Needham, MA), and Materials Database Management (Indianapolis, IN) are collaborating on this DMDII project to develop a framework for collecting all part manufacturing and lifecycle data from disparate document formats into a single digital file that is transferable between suppliers and OEMs. Currently, build and design data are created by companies in supply chains in a range of incompatible formats, making information difficult to communicate. Manufacturers often need to re-enter design data, making manufacturing and maintenance error-prone and labor-intensive. The team estimates that suppliers that automate their processes using the new compiled data format can reduce the engineering resources needed for these tasks by as much as 95 percent.

Workforce Development

"The workforce analysis conducted by DMDII and ManpowerGroup offers insight into exciting new roles and skills needed to advance American manufacturing. The report envisions a future in which digital technologies like artificial intelligence and augmented reality are commonplace in factories across the United States."

– Gail Norris, Director of Customer Technical Learning Services, Siemens (Alpharetta, GA)

DMDII's Workforce Development programs bring together members from industry, academia, and key national stakeholders to solve workforce problems too large for any single organization to solve. Programs have been developed to build a strong foundation of understanding around the impact of Digital Manufacturing and Design technologies on the workforce while

Dow Chemical Company Leverages DMDII Digital Workforce Taxonomy

The Dow Chemical Company had a need to create forward-looking digital manufacturing role descriptions to staff its new Digital Operations Center. One of the biggest challenges faced was defining the roles needed to drive the future of digital manufacturing within the company.

The DMDII Digital Workforce Taxonomy was a key reference in helping to define the digital capabilities needed and for labeling the roles in terms of the emerging technology skills required for success. The DMDII Digital Workforce Success Profiles provided detailed lists of skills and experiences required in the specific areas targeted. The profiles were useful in building role descriptions that helped to find the right skills and expertise in Cyber Security and Digital Thread roles.

Dow Chemical Company has been a contributor to the DMDII Digital Workforce Development project and has leveraged the outcomes from this work into our needs for these innovative new roles.

enabling workers to start their own journey on a "digital" career pathway. In FY 2017, DMDII impacted our workforce as follows:

- The last of 10 Online Course Modules were developed in partnership with University at Buffalo, forming a Specialization on Coursera that introduces learners to key Digital Manufacturing and Design concepts and technologies. Over 580 learners have enrolled in the full Specialization — all 10 Course Modules. The "Digital Manufacturing & Design" Course Module that introduces learners to digital transformations occurring in industry had over 3,000 enrollees.
- The Digital Manufacturing and Design Job Roles Taxonomy identified over 165 job roles that support digital manufacturing and design technologies and business practices, with 20 roles highlighted in success profiles that provide detailed accounts of the roles' deliverables, interactions, skills, and business value. More than 60 experts from more than 30 industry and academic institutions contributed to the body of work. The report has been downloaded by representatives of industry and academia over 540 times.
- Digital Days: Through our Digital Days program, DMDII hosts middle and high school students for educational science, technology, engineering, and mathematics (STEM) programming including hands-on instruction, career coaching, and a digital manufacturing game. In FY 2017, more than 290 primary and secondary school students participated in Digital Days programming, tours, and technology demonstrations. Additionally, over 100 Chicago Public School teachers visited DMDII as part of Digital Days programming, tours, or lectures introducing them to digital manufacturing and design technologies.
- Throughout the year, 22 undergraduate interns and six high school interns worked with DMDII staff on various activities ranging from DMDII organizational support to research projects taking place on the manufacturing floor.

Innovation Ecosystem

"DMDII is a great center of excellence where companies can come to see the digital thread in action. They can get hands-on experience with the technology and learn about technologies that are delivering solutions today and not four or five years out into the future."

– Paul Ryznar, Founder, President & CEO, Light Guide Systems (Wixom, MI)

American manufacturing is experiencing a digital revolution. The technology is available to harness data and connect every stage of the manufacturing life cycle to drive efficiency, cut costs, and increase competitiveness. DMDII's Future Factory — a physical and digital manufacturing environment leverages data and cutting-edge manufacturing tools — is a strength of DMDII's innovation ecosystem. The Future Factory provides a physical manufacturing environment in which a variety of industrial partners and technology providers can come together to develop digital manufacturing solutions. This resource is a proving ground for new technologies as well as a learning center for teaching partner organizations about practical implementations of digital technologies in manufacturing.

As an example, in one collaborative partner innovation project, the participating DMDII members were able to reduce their investment costs by nearly 75 percent. Three global organizations, in non-competing industries, discovered they had similar interests in researching and developing a software prototype using big data for supply chain applications. DMDII worked with these organizations to define the scope, select partners, and negotiate and execute the contracting vehicle.

Working collaboratively through DMDII allowed each organization to invest nearly 75 percent less than required to achieve the same result independently. Through savings achieved by dividing R&D and administrative costs evenly across the organizations and through lower administrate rates achieved through DMDII project sponsorship, the organizations reduced their R&D investments drastically.

Figure 17. The North American Digital Capability Center's mock production line includes the high-performing, digitally driven production equipment of the future that incorporates advanced analytics, augmented reality, and digital assistance for the operators. Credit: DMDII

In June 2017, DMDII, in partnership with McKinsey & Company, launched the North American Digital Capability Center (DCC), a space for hands-on training in next-generation digital manufacturing technology. Based at DMDII's headquarters in Chicago, the center helps organizations, public and private, gain the capabilities to benefit from and produce new digital manufacturing innovations in operations, design, and productivity.

Company leaders can sign up for one-day workshops designed to build awareness of digital manufacturing, and managers and their teams can take advantage of multi-day workshops to equip them with necessary skills to undertake digital transformations within their organizations. Leaders from 50 UI LABS' partner organizations participated in trainings at the center in its first month of operation.

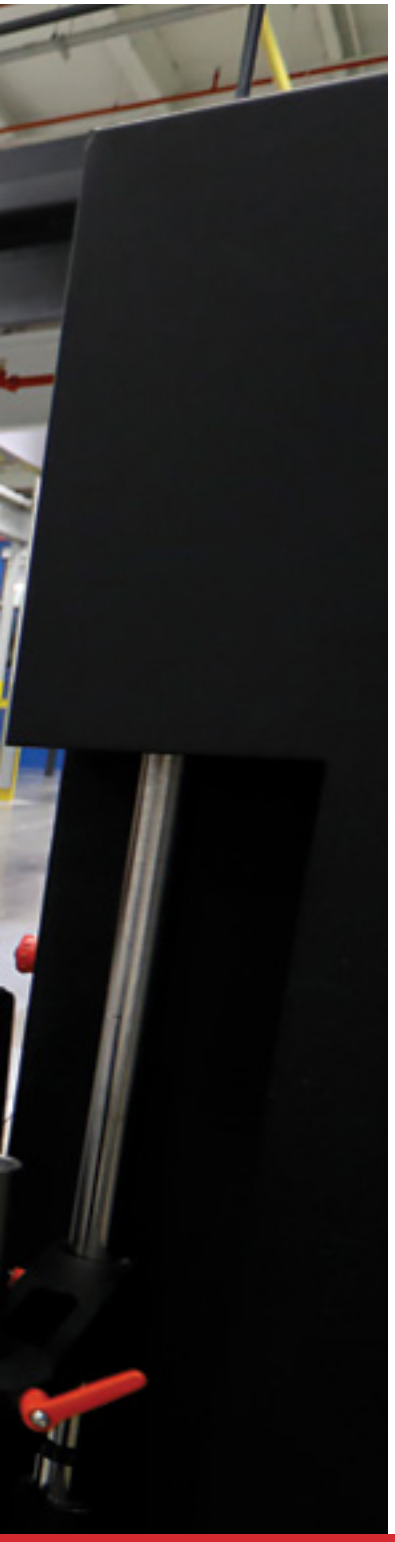
The North American Digital Capability Center's mock production line includes the high-performing, digitally driven production equipment of the future that incorporates advanced analytics, augmented reality and digital assistance for the operators. It is currently incorporating collaborative robots (cobots) and artificial intelligence.

The North American DCC is housed in DMDII's 94,000 square-foot collaboration studio and manufacturing floor. The North American DCC is digitally connected to four additional McKinsey DCC's in Singapore, Aachen (Germany), Beijing (China), and Venice (Italy).

LIFT

a Manufacturing USA institute

Credit: LIFT



Mission: To develop advanced lightweight materials manufacturing technologies and implement educational programs to train a workforce confident in deploying those technologies in defense and commercial applications.

Locations: Detroit, MI
Satellites:
Columbus, OH;
Ann Arbor, MI;
Worcester, MA;
Golden, CO;
Southfield, MI

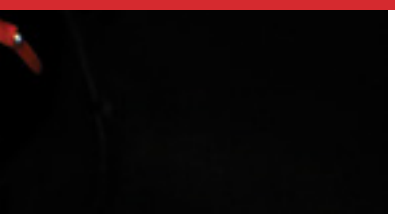
Established: February 2014

Consortium Organizer: American Lightweight Materials Manufacturing Innovation Institute (ALMMII)

Funding: Federal, $70M; Non-Federal, $78M (both planned over five years)

Members (as of September 30, 2017): 115

Lightweight Innovations for Tomorrow



lift.technology

LIFT

Background

LIFT develops and deploys new lightweight manufacturing technologies and processes for products using metals, including aluminum, magnesium, titanium, and advanced high-strength steel alloys, particularly for the transportation industry. These technologies are applied to vehicles in the air, land or sea, to enable the transportation of people or goods farther and more efficiently. Lightweight solutions save fuel and promote reductions in mass, thus reducing the cost of raw materials in the manufacturing process.

Technology Advancement

"Solving the (Humvee) rollover issue and saving lives is mission critical. We're pleased to be working as a team with LIFT, investigating opportunities for lightweighting while taking the system forward to production."

– Chet Gryczan, President, Ricardo Defense Systems (Van Buren Township, MI)

$50 Million LIFT Lightweighting Facility Nears Completion

LIFT and the Institute for Advanced Composites Manufacturing Innovation (IACMI), a DOE-sponsored Manufacturing USA institute headquartered in Knoxville, Tennessee, neared completion of their shared manufacturing facility in Detroit - a combined investment value of nearly $50 million. IACMI will house its Automotive Scale-Up Research Facility focused on lightweighting in vehicle structures, led by Michigan State University, in the LIFT headquarters in Detroit. To celebrate manufacturing the facility's progress, LIFT hosted a member preview event as part of its 2017 All-Member's Meeting.

The investment includes the acquisition and installation of new manufacturing equipment to increase LIFT's capabilities, as well as construction and infrastructure upgrades for the facility to support the new equipment. These investments will allow institute members, partners, and others in the industry to conduct research and development projects, in both lightweight metals and advanced composites, at the innovative facility. It will also provide education space for students and adult learners focused on the composites and lightweight materials industries.

The nearly $50 million investment is comprised of LIFT's $20.5 million and IACMI's $18 million towards equipment, with the rest supporting facility updates and upgrades. Some of the equipment slated for installation includes: hydroforming and extrusion presses; a flexible-robot joining cell; and a linear friction welder for LIFT, and, for IACMI, compression and injection molding presses; prepreg equipment; induction processing; and a resin transfer molding/liquid compression molding machine.

The ribbon cutting for the facility took place on Manufacturing Day in October 2017.

LIFT and Comau Open New Lightweighting Lab

In March 2017, Lightweight Innovations for Tomorrow, opened the doors to a new LIFT Lab inside the Comau Innovation Center in Southfield, Mich.

The 1,000-sq. ft. facility will provide additional collaborative space for LIFT members and partners to conduct lightweighting research along with access to Comau equipment and resources — including a fully equipped metallurgical lab, advanced laser welding lab and a machine shop. The facility will serve as an extension of LIFT's research center in the Corktown district of Detroit.

"Comau has been a proponent of LIFT's mission since the very beginning," said Martin Kinsella, Comau LLC and chairman of the LIFT Executive Advisory Council on Education and Workforce Development. "This new lab provides an ideal environment for idea-sharing and partnering among LIFT members and our staff to advance the world of lightweighting."

Program Progress in FY 2017

Overall, since LIFT's inception, the institute has launched 18 multi-year programs which include more than 30 individual projects. In FY 2017, several programs saw impactful results that address items in the institute's technology roadmap. Some highlights include:

- **Reducing Weight in Cast Iron Components** — LIFT completely redesigned and conducted initial tests on a cast-iron truck component in which the weight was reduced by 40 percent. While ductile cast iron is not a lightweight metal, it was required to meet required strength and durability standards. The team, including American Axle (Detroit, MI) Eaton (Cleveland, OH), and Michigan Technological University (Houghton, MI), revised the design, allowing the piece to be cast in its near final shape and used a new iron alloy to cast the piece with thinner walls, which reduced the weight and maintained its strength. Final testing by the customer and implementation is expected to be completed in early 2018.

- **Shipbuilders Learning from Auto-makers for Lightweighting** — LIFT continued work on another project to solve the issue of distortion, or buckling, when welding lightweight plates together to construct a ship. Ships often suffer from buckling during the welding process. This is especially true when using thinner, lighter-weight metals. The buckling leads to additional time and cost to repair, as well as added weight to the ship due to having to add additional structure to straighten and mitigate buckling. This project, led by Huntington Ingalls, employed lessons learned from the auto industry on techniques to mitigate distortion in sheet medal welds. The project team used a top deck of a Coast Guard Cutter to perfect their techniques. Testing of the marine structure with several automotive practices are yielding reduced cost and improved quality, and will lead to enhanced performance for ships. This project is expected to be completed in early 2018. Team Participants included Huntington Ingalls (Pascagoula, MS); Comau (Southfield, MI); Tenneco (Grass Lake, MI).

New Programs Launched in FY 2017

In FY 2017, eight new programs were awarded. These are addressing key problems in manufacturing such as:

- **Mitigating Risk to Armed Forces Personnel** — This project, led by Ricardo Defense, LLC (Van Buren Twp., MI), employs technology that can significantly reduce rollovers — by 74 percent, based on National Highway Traffic Safety Administration (NHTSA) data from similar vehicle classes — thus reducing fatalities of our military service men and women by further developing and scaling to production an Anti-Lock Braking System/Electronic Stability Control (ABS/ESC) system from Ricardo Defense Systems. The project will also provide validation of quality retrofit installation on the Humvee fleet, including training soldiers on the installation process and further demonstrating the systems' value in the field.
- **Development of Technologies for Joining Titanium to Steel** — Led by Tenneco (Grass Lake, MI), this project is exploring dissimilar metal joining, which has gained considerable attention to design lightweight structural components. This program, exploring the joining of titanium to steel is using an automotive exhaust system as the development article, will further advance the technology for joining dissimilar materials and will enable achieving higher performance goals and efficiency in automotive, aviation, aerospace, military vehicles, and oil and petrochemical applications.
- ***In-Situ* Manufacturing of Nanoparticle Reinforced Aluminum Matrix Composites** — This program will explore the process of strengthening aluminum alloys by incorporating aluminum-based nanometer-scale particles into them. Although some aluminum alloys already have very high strength and are light, further strength improvements can be achieved by reinforcing them with nanoparticles. By providing additional strength and improving the strength-to-weight ratio, the reinforced aluminum alloys can be used more widely in aerospace structures and other military applications. The program team includes North American Die Casting Association (Arlington Heights, IL) and Eaton (Menomonee Falls, WI).

Workforce Development

"By working with a national institute like LIFT to connect its research to educational and training strategies, we are driving toward our goals, while helping transform an industry."

– Jim Woodell, Vice President for Economic Development and Community Engagement, Association of Public and Land-grant Universities

In addition to its 115 members, in FY 2017, LIFT had 101 education and workforce development affiliates. Through the design and implementation of demand-driven, results-oriented, replicable, and scalable solutions, we are working with our affiliates to

Figure 18. A Ricardo Defense Systems pilot project retrofitted 10 Michigan National Guard vehicles with antilock braking systems and electronic stability controls to reduce high mobility multipurpose wheeled vehicle fatal rollovers. Credit: Department of Defense

develop a workforce that is educated, skilled, and confident in using new lightweighting technologies and processes.

In FY 2017, LIFT launched or supported 10 initiatives, including:

- **"Operation Next" for Separating Military: Building the World-class Manufacturing Workforce** — "Operation Next", created by LIFT and being piloted at Ft. Campbell, KY, is designed to provide military service members the opportunity to pursue industry-driven education and skills development during their transition period prior to separation, earning nationally recognized industry credentials in some of the most in-demand advanced manufacturing metalworking related jobs in the country. Their training includes precision machining and industrial technology, where more than a half million jobs are currently available. The pilot program has an initial goal of enrolling, graduating, and securing employment for 101 soldiers. The first graduates of the program are expected in early 2018.
- **MakerMinded Expands to More States** — LIFT launched MakerMinded in Ohio, the third state in which LIFT rolled out the program following Kentucky and Tennessee. MakerMinded is an online STEM learning and competition platform

designed to inspire students about advanced manufacturing and provide them with transformational STEM learning experiences that set them on track towards 21st century manufacturing careers. MakerMinded's digital platform connects students to leading-edge STEM and advanced manufacturing education experiences, while galvanizing participating students and schools around a student-driven, pro-manufacturing campaign and competition. The platform's goal is to provide students access to the right programs that will encourage and prepare them for further education and careers in advanced manufacturing. In its launch year in Tennessee, 1,124 students in 132 schools completed activities.

- **Kentucky Teacher Externships Expand Statewide** — Following the successful 2015 pilot externship program for teachers, in which LIFT partnered with the Northern Kentucky Industry Council and the Kentucky Federation for Advanced Manufacturing Education (KYFAME), LIFT announced the rollout of a statewide externship program. Once again partnering with KYFAME, the program will help up to 135 teachers and instructors connect classroom learning to authentic manufacturing-related activities These externships equip teachers to translate their learnings into their classroom instruction, and increase their students' understanding of emerging technologies in advanced manufacturing careers. Through FY 2017, due to the number of teachers taking their learnings back to the classroom, nearly 1,500 students have been impacted through this initiative.

Innovation Ecosystem

"(Participating in this webinar) allowed us an opportunity to communicate how our unique rivet weld process for joining dissimilar materials could offer a solution for lightweighting structures in transportation products. We were contacted by a number of people who participated in the webinar including a potential customer, a strategic partner, and an editor from Assembly Magazine who eventually wrote a feature article on our technology a few months later. We would recommend that other LIFT members, especially small business and start-up members use this platform to provide exposure for their unique technologies."

– Dan Radomski, Chief Operating Officer, Optimal Process Technologies LLC (Plymouth, MI)

Expert Educator Team Releases Recommendations

LIFT, the Association of Public and Land-grant Universities, and the National Center for Manufacturing Sciences convened an Expert Educator Team to identify the knowledge, skills, and abilities workers at all levels will need to deploy new technologies, materials, and processes in manufacturing.

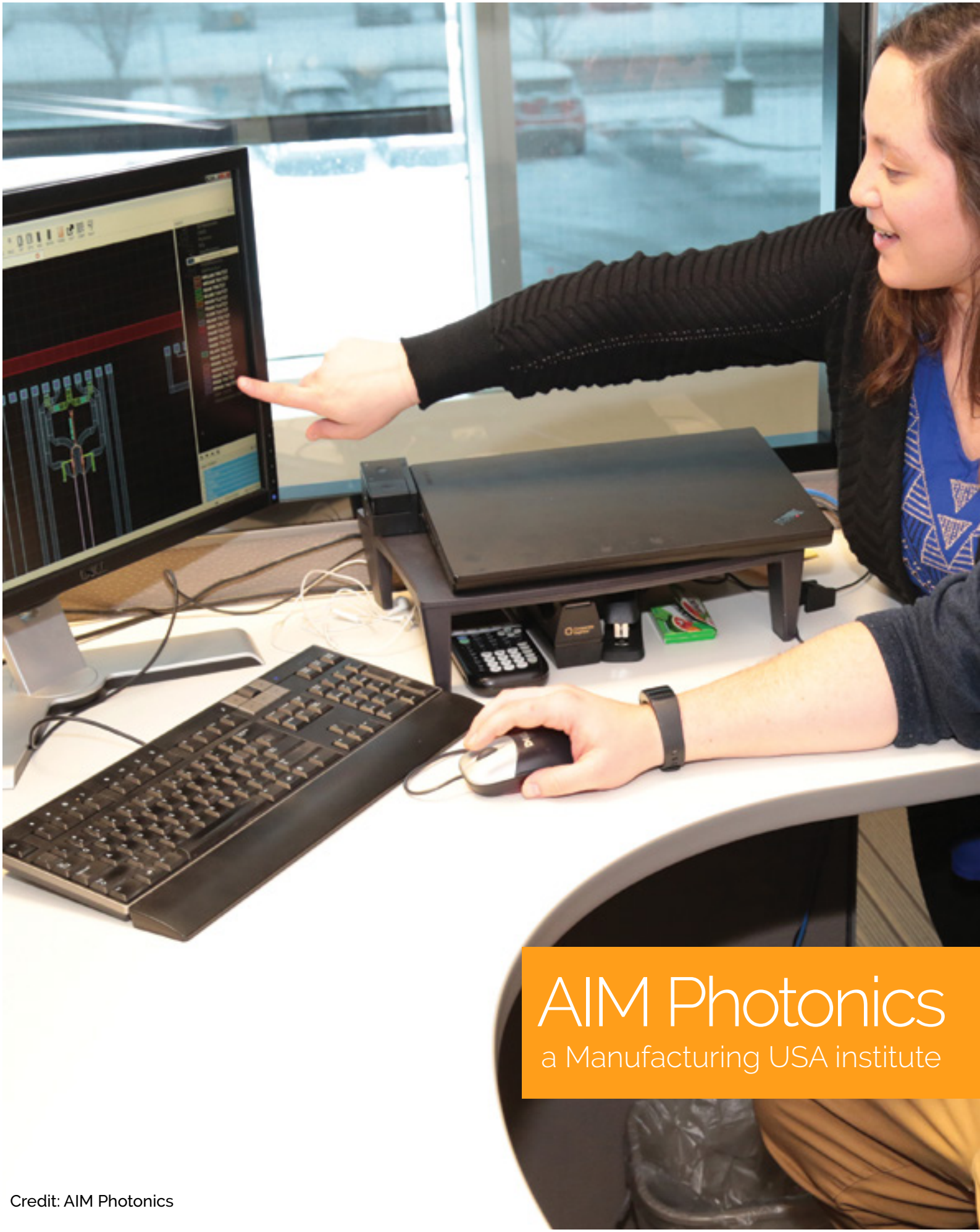
The team also released its first report, which included recommendations about college-level competencies required for emerging technologies and lightweight metal solutions across several industries. The report urges programs at both the technical/production (two-year, associate's degree) and design/engineering (four-year, bachelor's degree) levels to review curricula and integrate materials and approaches that address competencies in four different manufacturing areas, including integrated computational materials engineering, metamorphic manufacturing, distortion control, and thin-wall aluminum die casting.

"These recommendations represent an important step in closing skills gaps in emerging technology areas," said Jim Woodell, vice president for economic development and community engagement at Association of Public and Land-grant Universities. "There is tremendous research going on around the country and it is important that we bring the conversation about education and workforce needs closer to the development of emerging technologies. If we wait until technologies are deployed, it's too late."

"The recommendations do an excellent job of identifying skills that must be addressed by college curriculum so that our students develop the skills, knowledge and abilities needed to be successful in advanced manufacturing careers," said Rebecca Taylor, senior vice president, National Center for Manufacturing Sciences. "Work and learn opportunities are an important strategy included in the recommendations—the closer we can connect students at our colleges and universities to real-world, hands-on experiences, the better prepared they will be for the workforce upon graduation."

During FY 2017, LIFT and the Michigan Manufacturing Technology Center launched the "LIFT Off" webinar series in support of small and mid-sized enterprises (SME) and start-up manufacturers by providing them a platform to showcase the lightweighting innovations they are developing. The monthly webinar series supports the combined missions of LIFT and the Center to support SME manufacturers and to help their innovations flourish and find a foothold in the marketplace. These webinars, while just starting late in the year, have offered small and mid-sized companies the opportunity to grow their businesses and help build relationships between them and larger manufacturing companies.

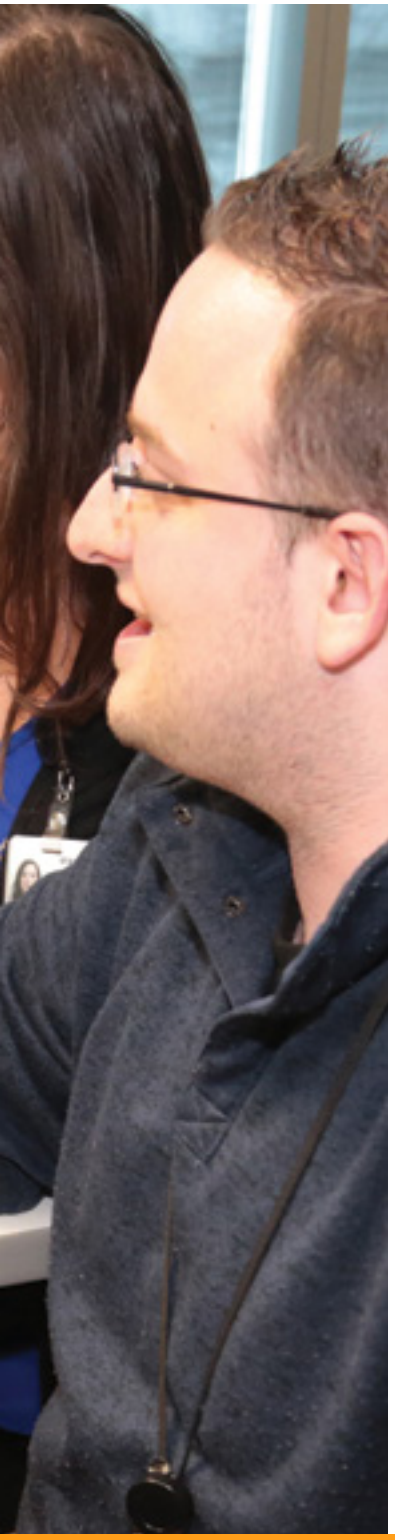
More information on the LIFT Off webinar series can be found at www.lift.technology/liftoff.



AIM Photonics

a Manufacturing USA institute

Credit: AIM Photonics



Mission: AIM Photonics seeks to advance integrated photonic circuit manufacturing technology development while simultaneously providing access to state-of-the-art fabrication, packaging, and testing capabilities for small-to-medium enterprises, academia, and the government; create an adaptive integrated photonic circuit workforce capable of meeting industry needs and thus further increasing domestic competitiveness; and meet participating commercial, defense, and civilian agency needs in this burgeoning technology area.

Locations: Main hubs: Albany, NY and Rochester, NY
Satellite hubs:
Cambridge, MA;
Santa Barbara, CA;
Tucson, AZ

Established: July 2015

Consortium Organizer: Research Foundation for the State University of New York

Funding: Federal, $110M; Non-Federal, $502M (planned funding over five years)

Members (as of September 30, 2017): 68

American Institute for Manufacturing Integrated Photonics

aimphotonics.com

AIM PHOTONICS

Background

Photonics, the use of light for applications traditionally addressed through electronics, is finding use in a wide range of areas including: telecommunications, laser-based radar, data communications, sensing, and many others. Integrated photonics dramatically improves the performance and reliability of electronic integrated circuits while significantly reducing size, weight, and power consumption.

Developing a widely-accepted set of processes and protocols for the design, manufacture, and integration of photonics systems will not only advance this technology, but also present the United States with a tremendous economic opportunity, with the overall global market estimated to grow to more than $795 billion by 2022. Integrated photonics will advance established industries and enable new ones in the 21st century in the same way that semiconductors fostered the revolution in computing, telecommunications, and other fields over the past 40 years.

Technology Advancement

"At Ortho Clinical Diagnostics, our purpose is to save and improve lives through diagnostics. Every technology we have on our systems and every test uses optics for its measurements. The future, obviously, is about the AIM Photonics Test, Assembly, and Packaging (TAP) facility"

– Raymond Jakubowicz, Innovation Fellow, Ortho Clinical Diagnostics (Raritan, NJ)

Projects Completed in FY 2017

Fourteen projects funded by AIM Photonics were completed in FY 2017. These projects addressed the needs identified in the Integrated Photonics Systems Roadmap, including the following highlights:

- **Inline Test Development** — The project, undertaken by SUNY Polytechnic Institute (SUNY Poly) in Albany, NY, completed the installation of inline controls and test equipment to permit optical and electrical testing of photonic components. Such testing is a key to the improving photonics manufacturing processes. Inline testing significantly improves yield and reduces scrap loss. This will advance the development of photonic integrated circuit (PIC) technology in the data communications area for AIM Photonics members such as Hewlett Packard Enterprise (Palo Alto, CA) and Cisco Systems (San Jose, CA) and other organizations by reducing cycles of learning and product development costs.

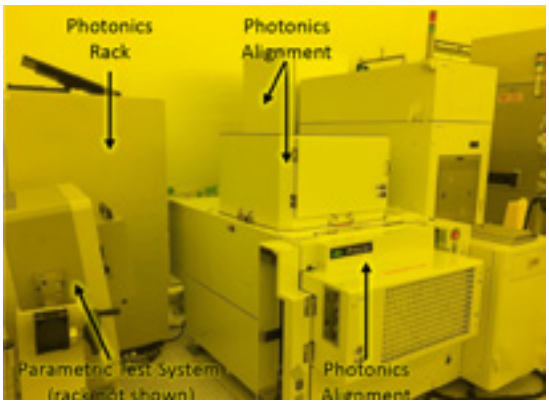


Figure 19. Newly installed electrical optical test equipment in the SUNY Poly cleanroom. The tools, part of the Inline Test Development project, will reduce the time to detect a misprocessed wafer from 4 months to a few days.
Credit: AIM Photonics

- **Photonics Process Design Kit Component Library** — Analog Photonics, LLC (Boston, MA) and SUNY Poly expanded the comprehensive set of publicly available silicon PIC components in the integrated photonics process design kit (PDK). Continued development of the PDK is an essential enabler for both the baseline technology and the efficient design of the products that will ultimately be manufactured. Work in in 2017 provided new capabilities in optical integration, enabling reductions in the time to market, product development risk, and investment.

  This work was enabled through a unique partnership with leading design companies working jointly to improve the design methodologies for future integrated photonics technology development. Other team members include: Cadence Design Systems (San Jose, CA), Lumerical (Vancouver, BC), Mentor Graphics (Wilsonville, OR), Mosis (Marina del Rey, CA), PhoeniX B.V. (Netherlands), and Synopsys (Mountain View, CA).

Figure 20. A group of leading industry partners is developing the photonics process design kit (PDK) for integrated photonics manufacturing. Credit: AIM Photonics

- **Development of Universal Transducer Components and Microfluidic Systems** — Led by the University of Rochester, this project, which also includes University of California, Santa Barbara (Santa Barbara, CA), Analog Photonics, LLC (Boston, MA), University of Tulsa (Tulsa, OK), PhoeniX B.V. (Netherlands), Ortho-Clinical Diagnostics (Rochester, NY), and OndaVia (Hayward, CA), demonstrated photonics manufacturing processes for common detection elements of chemical and biological sensors and completed testing of photonics based components

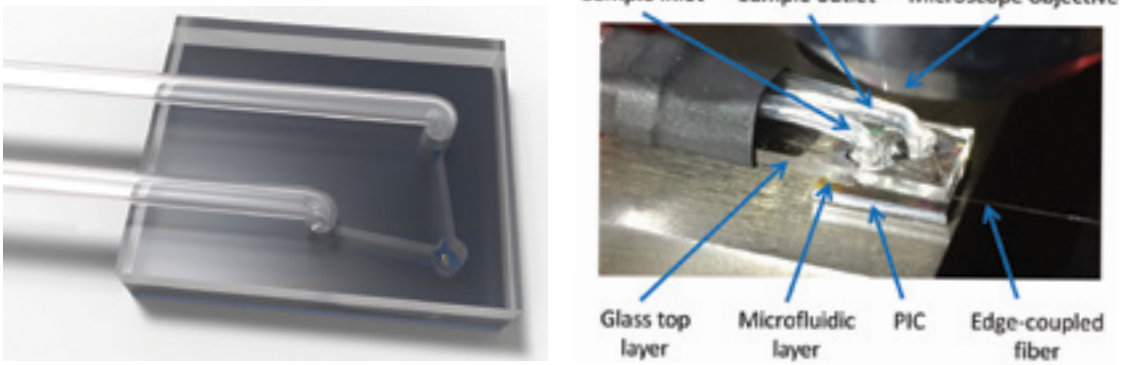


Figure 21. Schematic (left) and fabricated device (right) for microfluidic-enabled PIC for SERS. Credit: Carl Meinhart, University of Rochester.

that detected simulants of the chemical warfare agent Sarin within tolerances approaching Department of Defense (DoD) requirements. This is the first time a sensor of this type has been manufactured using a process that can be scaled for commercial production.

- **High Capacity Photonic Interconnected Systems** — University of California at Santa Barbara, along with Columbia University (New York, NY), Keysight Technologies (Santa Clara, CA), and Lockheed Martin (Bethesda, MD), completed a set of key design deliverables, which were implemented with the assistance of products from member companies working in the AIM Photonics Data Communications Key Technology Manufacturing Area, in developing very high speed photonics-based digital and data communication links. By replacing electronic switches, which have been a major communication bottleneck and power sink in data centers, this technology will increase capacity tenfold and reduce energy consump-tion-per-bit transmitted by a factor of 10.

New Programs Launched in FY 2017

The AIM Photonics Executive Team, working closely with DoD and industry representatives, developed a more directed, top down approach to its call for proposals for 2018 projects to improve the overall quality of proposals. The new approach was codified in a strategic investment plan that places additional emphasis on soliciting projects with technical vitality, continuity, industry participation, and high potential for generating demand for the institute's services.

Based on this approach, the AIM Photonics Leadership Council approved in-depth project planning for 16 new projects (13 in research and technology development and 3 in education and workforce development) for 2018. These projects are expected to address key challenges such as:

- **High Density Fiber-Chip Input/Output (I/O) Packaging** — Columbia University (New York, NY) and Cisco Systems (San Jose, CA) are developing the critical fiber-to-photonic chip coupling technology that will become the mainstay manufacturing solution at the TAP Facility in Rochester, New York. Widespread commercial adoption of integrated photonics has been impeded by the challenges of realizing low cost scalable optical I/O packaging solutions. The fiber and fiber array connector envisioned in this PIC attach process would open a path to high volume manufacturing, with unprecedented coupling alignment tolerances for scalable, cost effective assembly. The significant reduction in the size of components, as depicted in Figure 22, will result in cost reductions for those components.

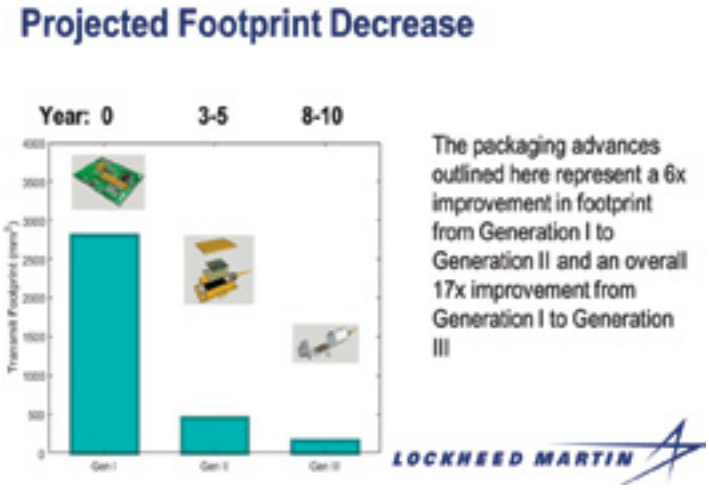


Figure 22. Timeline for reduction in packaging footprint. Credit: Lockheed Martin.

- **TAP Facility Process Development** — Led by the University of Rochester, this project, which also includes Rochester Institute of Technology (Rochester, NY), Columbia University (New York, NY), and Precision Optical Transceivers (Rochester, NY), complements the planning, construction, and implementation of the TAP Facility by coordinating process development with equipment installation and qualification. Validation and testing of products for the facility are performed in advance with the help of industrial partners and their design teams. The TAP Facility, which represents an investment of $194 million by New York State for facility upgrades, equipment, installation, and lease costs, will open in the second half of 2018.

Additional Projects Supporting the Department of Defense

The fabrication and packaging capabilities enabled by AIM Photonics are also being leveraged to advance priority projects pursued by DoD. The use of photonic integrated circuits in military applications will provide improvements in cost, size, weight, and power as compared to discrete photonic components. The first of these DoD projects include:

- **Photonics-Based Transducers that Identify A Wide Range Of Chemical Or Biological Threats** — In March 2017, AIM Photonics awarded $900,000 to a consortium led by the University of Rochester to develop PIC-based transducers — the part of a sensor that interacts with what is being detected — that will expand the capability and broaden the availability of "lab-on-a-chip" devices. These transducers will allow researchers and clinicians to simultaneously detect several different proteins in a single blood sample and will enable municipalities to continuously monitor drinking water for dangerous toxins.
- **Integrating PICs with Focal Plane Arrays (FPA) to Advance Imaging Capabilities for National Defense Applications** — In August 2017, AIM Photonics awarded $1.2 million to a consortium led by the University of Arizona to develop FPAs that use of integrated photonics in advanced imaging systems to overcome the limitations of conventional electronic FPA readout components, which are both a communications bottleneck and an undesired heat source. The PIC-based FPAs will accommodate the growth in the FPA size and the associated increases in data rates. This technology will eventually be transitioned into advanced imaging systems to support U.S. warfighters.

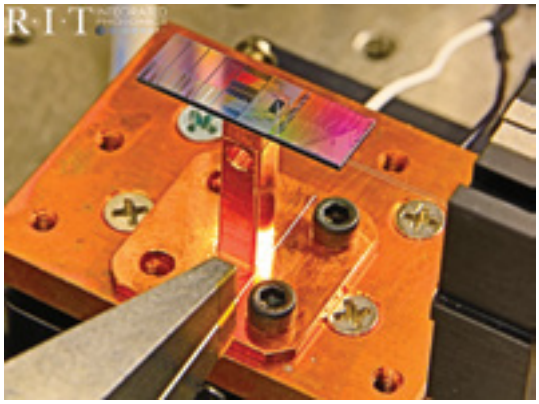


Figure 23. Optical testing of an AIM Photonic Imposer Chip designed by the RIT Integrated Photonics Group. Credit: Rochester Institute of Technology and AIM Photonics.

Workforce Development

"Lockheed Martin continues to partner with AIM Photonics and AIM Academy. This partnership is critical for accelerating the adoption of Photonic Integrated Chip (PIC) technology across our enterprise. As an industry member, our involvement in AIM Academy roadmap meetings and application interest groups help shape future investments and educate our technical community. Lockheed Martin has been committed to sending engineers and managers to AIM's Summer/Winter Academy and supporting the Internship Matching Program. Feedback for both initiatives has been very positive and the Lockheed Martin team looks forward to leveraging opportunities offered by AIM Academy in the future."

- Nick Rhenwrick, AIM Photonics Program Manager, Lockheed Martin Corporation (Bethesda, MD)

AIM Photonics Academy (AIM Academy) is the unified education knowledge, technology, and workforce program for the institute. AIM Academy is creating an adaptive portfolio of integrated photonics education and workforce development offerings capable of meeting industry needs to further increase domestic and international competitiveness. AIM Academy activities in FY 2017 include:

- **AIM Summer Academy** — The one-week intensive curriculum was offered July 24-28 at MIT. Seventy participants, largely from industry, participated in nine newly-developed lecture sessions on integrated photonics design, chip processing, and manufacturing constraints taught by expert faculty and industry specialists. Two lab demonstrations were also presented, one taking place at the MIT's new Education and Practice factory.

Figure 24. Attendees during a short course at AIM Summer Academy 2017. Credit: Frank Tolic, AIM Photonics

Figure 25. College students participating in research internships as part of AIM Academy's FLIP program. Courtesy: University of California, Santa Barbara.

- **Future Leaders in Integrated Photonics (FLIP)** — 11 rising seniors from across the country participated in hands-on research internships at MIT, SUNY Poly, the University of California Santa Barbara, and the University of Arizona. The internships gave the students practical experience and exposed them to professional opportunities available in the field of integrated photonics.

Innovation Ecosystem

"The TAP facility is going to offer equipment that allows people to build products. Because of that, it's going to just move the Optics industry forward."

– Bryce Tennant, Chief Technology Officer, Precision Optical Transceivers (Rochester, NY)

Prior to the establishment of AIM Photonics, the growth of the integrated photonics industry was impeded by an immature manufacturing and design ecosystem that lacked an open and easy-to-use design library and common, accessible manufacturing platforms. This situation produced a proliferation of exotic materials and assembly processes, as well as proprietary and expensive optical packaging solutions. The ecosystem being created by AIM Photonics harnesses the combination of the nation's leading industrial and academic experts in indium phosphide and silicon photonics integration. SUNY Poly's fully-functional, best-of-class, U.S.-based facilities are designed for continuous upgrade to support the photonics-manufacturing infrastructure of the future. Driven by industry needs, AIM Photonics in FY 2017 continued to focus on capacity building to address a broad range of challenges that drive up the cost of integrated photonics, including processing, packaging, assembly, and testing. In 2018, capacity building will accelerate with the opening of the TAP Facility in Rochester, New York.

Figure 26. TAP Facility Headquarters, Rochester, NY. Credit: Eastman Business Park

A Bright Line to the Future of Integrated Photonics Manufacturing

As envisioned in its original proposal, AIM Photonics has focused on bringing the type of common core manufacturing and design platforms that transformed the semiconductor industry to manufacturers of integrated photonics and companies without access to high-cost cleanrooms. This approach will enable small, medium, and large companies to prototype, develop, assemble, test, package, and demonstrate devices at the manufacturing scale and commercialize quickly. The two key building blocks of this effort are the AIM Photonics' PDK and multi project wafer and assembly services (MPWA). During its first two full years, AIM Photonics created and rolled out two improved versions of its PDK, including an expanding component library, providing companies of all sizes, government agencies, and others a common starting point for manufacturing processes, thereby lowering costs and accelerating commercialization. By design, the PDK is closely linked to the MPWA process. Together, they afford access to state-of-the-art integrated photonics capabilities for photonics, and for wafer-level optical packaging and assembly. FY 2017 saw enhancements in MPWA capability and capacity, including 25 percent reductions in target times for full wafer runs and improvements in a variety of manufactured devices. Practical, immediate access to this newly created, integrated photonics manufacturing infrastructure is providing technology on-ramps for U.S. industry, government, and academic institutions.

Credit: AIM Photonics

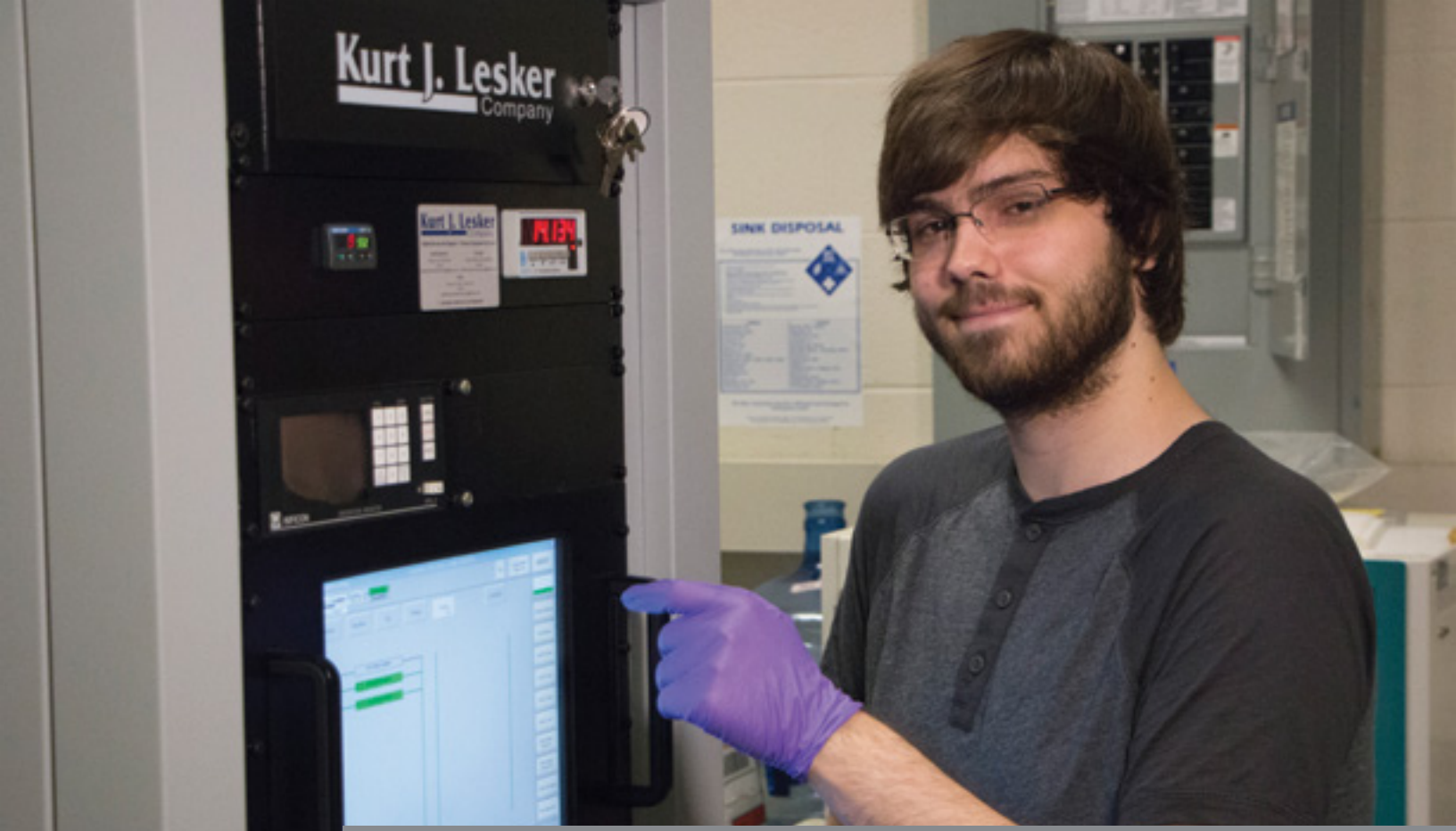


Figure 27. Ryan Kosciolek, a Rutgers University physics major, interned with Dr. Anu Agarwal and Prof. Lionel Kimerling at MIT as part of the AIM Future Leaders Program. Credit: Denis Paiste, MIT.

Lighting the Path to a Career in Photonics

Under the AIM Future Leaders Program, faculty members from with AIM member universities develop research projects for undergraduates that align with the institute's key technology manufacturing areas. Eleven undergraduate interns were recruited in FY 2017 into the AIM Future Leaders Program for internships at the University of California Santa Barbara, the Massachusetts Institute of Technology, the University of Arizona, and SUNY Poly. These interns were provided with 8-10 weeks of training in integrated photonics research, professional skills, and career orientation. During the program, the interns produced technical talks, posters, and abstracts related to their research.

According to Ryan Kosciolek, a physics major at Rutgers University who interned with Dr. Anu Agarwal and Prof. Lionel Kimerling at MIT during the summer of 2017, his experience was transformative:

"A substantial portion of my work over the summer was hands on. I repaired and modified equipment, created samples and preformed tests on them. This was largely new to me, but by the end of the program, I enjoyed the work so much that I extended my stay to continue working under my mentors for the month of August. I'm eager to learn more about integrated photonics and am very interested in pursuing a Ph.D. in the field, something I would never have considered had I not participated in the AIM Photonics Academy Future Leaders program."

NextFlex

a Manufacturing USA institute

Credit: NextFlex

NEXTFLEX

Mission: To pioneer Flexible Hybrid Electronics (FHE) manufacturing to serve our nation's warfighters and the U.S. economy.

Location: San Jose, CA

Established: August 2015

Consortium Organizer: FlexTech Alliance

Funding: Federal, $75M; Non-federal, $96M+ (planned funding over five years)

Members (as of September 30, 2017): 80

NEXTFLEX

America's Flexible Hybrid Electronics Manufacturing Institute

nextflex.com

NEXTFLEX

Background

NextFlex facilitates development of flexible hybrid electronics (FHE) technology, which integrates low-cost printed electronics with the processing power of thin semiconductors to create a new category of stretchable, bendable, conformable, and flexible electronic devices. The low cost, small size, and reduced weight of FHE devices will create versatile shapes to deliver the long-promised "Internet of Everything." Early beneficiaries of this technology include the healthcare system, national infrastructure, and agricultural technology industries.

NextFlex is focusing on four areas for FHE-enabled technologies: human health and performance monitoring, structural (bridges, buildings, aircraft wings, etc.), health monitoring, soft robotics, and integrated antenna arrays. These focus areas guide the FHE manufacturing roadmap, and the project calls. NextFlex brings institute members together to collaboratively overcome manufacturing challenges in commercializing novel FHE products.

Technology Advancement

"Early technology roadmapping on human health and performance monitoring systems laid the groundwork for three successive NextFlex project calls, each one building on the previous one for exponential value to the member participants. GE benefits from participating in NextFlex projects because they advance technology in a collaborative, low-risk way, helping us to realize our vision of healthcare in the future."

–Azar Alizadeh, Senior Materials Scientist, GE Global Research (Niskayuna, NY)

NextFlex has completed two revisions to the FHE roadmap in its second full year. The roadmap guides 24 current projects and seven recently launched projects this fiscal year. Such critical success factors as member engagement, participation, and hours of education and collaboration across member organizations increased in NextFlex's second national call for support of the roadmap. Highlights from the Project Call 2.0 process include:

- More than doubling of full project proposals submitted (33), resulting in twice the number of projects awarded (16);
- Education and collaboration hours increased to 11,500 hours over 44 events held over the course of the year;

- 84 member organizations contributed the equivalent of 253 months (21+ years!) of NextFlex-led FHE research and development.

The NextFlex Technology Hub includes capabilities for electronic printing and additive manufacturing processes and curing systems; component integration and assembly; and test and measurement—all installed in state-of-the-art clean rooms made accessible to members and prospective customers. FHE devices and manufacturing processes can be prototyped, materials can be tested, and pilot-scale manufacturing can be proven at the NextFlex Technology Hub.

Projects Ongoing in FY 2017

In FY 2017, 24 projects were underway at NextFlex. Examples of these projects that address major items in the FHE roadmap include:

- **FHE Manufacturing Processes for Medical Devices** — Project partners Binghamton University (Binghamton, NY), GE Global Research (Niskayuna, NY), Analog Devices (Wilmington, MA), i3 Electronics (Endicott, NY), and Rochester Institute of Technology (Rochester, NY) are collaborating to lower costs for patients and improve comfort by replacing bulky, wire-laden EKG monitors with slim, wireless versions. The team met their FY 2017 milestone by producing a functional flexible, wireless EKG that allow patients leave the hospital and be remotely monitored at home.
- **Oral Biosensing for Athletes and Warfighters** — The Technical Working Group on Human Health and Performance Monitoring Systems that includes PARC (Palo Alto, CA) and University of California at San Diego are developing a sensing device to detect the threat of human physical exhaustion and dehydration through a continuous-sensing system embedded in a mouth guard. Printed sensors detect bioanalytes in saliva and give early warning of imminent injury or casualty among athletes and warfighters; thereby, replacing the current generation of devices that are limited to physical signs, such as heart rate and motion. The partners successfully met their milestone in FY 2017 by printing and testing a working sensing device.
- **Smart Bandage Heals Wounds Faster** — Non-healing wounds impact over 6.5 million Americans each year. Purdue University (West Lafayette, IN), Indiana University (Indianapolis, IN), Integra Life Sciences (Plainsboro, NJ), and Western Michigan University (Kalamazoo, MI) are developing a flexible and conformable smart wound dressing that senses and controls oxygen levels to speed healing at a low cost. In FY 2017 the team succeeded in manufacturing a functional demonstrator.

New Programs Launched in FY 2017

Projects under development led by NextFlex and its members will accelerate development of novel and innovative devices. Seven new projects initiated in FY 2017 lay the foundation for the next generation of innovative devices. Examples include:

- **Superhuman Powers for American Heroes** — The Soft Robotics Technical Working Group identified the need for responsive and adaptable physical augmentation devices. Human-assistive devices are needed in healthcare for rehabilitation, and in the field to provide strength support for marines carrying up to 120 pounds (54 kg) of gear, and firefighters carrying at least 45 pounds (20 kg). Extra weight adds stress to joints, especially knees; therefore, engineers at Lockheed Martin (Bethesda, MD) and Georgia Tech (Atlanta, GA) are developing and testing sensors for an FHE soft robotic exoskeleton to reduce the stress associated with carrying heavy loads.

- **Changing Healthcare Forever with Multi-Sensor Monitoring Systems** — Following the path defined by the NextFlex FHE Roadmap for Human Health and Performance Monitoring, GE Global Research (Niskayuna, NY) and Binghamton University (Binghamton, NY) are developing a cost-effective clinical-grade, non-invasive and vital sign-monitoring device. This low-cost device is the world's first product that combines printed, stretchable substrates with the power of a multi-sensor chip. It is literally a lab-on-a-system that frees athletes and patients from trips to the clinic.
- **One Platform, Infinite Possibilities** — The Structural Health Monitoring Technical Working Group consisting of a cross-disciplinary team comprised of Boeing (Huntsville, AL), Western Michigan University (Kalamazoo, MI), Imprint Energy (Alameda, CA), American Semiconductor (Boise, ID), Chromera (Poway, CA), and DuPont (Wilmington, DE) is paving the way for creation of a flexible substrate-based wireless system. This system will host a variety of sensors for the measurement of temperature, strain, humidity, and pressure. This system can be used in automobiles and airplanes, or attached to bridges and roads, or used for tracking inventory and monitoring condition of food products when shipped around the world.

Workforce Development

"FlexFactor prepares every student for success in college and for careers after high school that support the advanced manufacturing sector. It brings real-world experience to students through an engaging project-based learning approach that teaches critical thinking, creativity, communication, and collaboration. The challenge in developing the workforce of the future is that most educators have never experienced the careers that we need to prepare our students for in the twenty first century, and FlexFactor overcomes this problem."

– Vito Chiala, Principal, Overfelt High School, San Jose, CA

NextFlex's workforce development activity moved rapidly in FY 2017, from an idea to a fully operational program, called FlexFactor. This program exposes students to the vast range of opportunities in advanced manufacturing careers. A total of 19 FlexFactor program iterations were completed across six school districts throughout Silicon Valley, reaching 650 students who generated 88 FHE-enabled product ideas ranging from an advanced athletic product that treats shin splints to a blood alcohol-content detecting steering wheel cover.

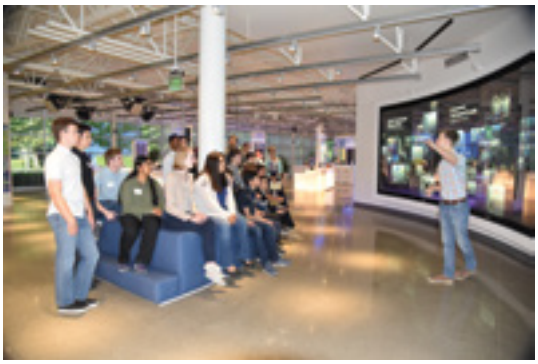


Figure 28. FlexFactor students from Branham High School being briefed on a tour of the Jabil Blue Sky Manufacturing Center in San Jose, CA. Source: NextFlex

Planting a Seed and Letting It Grow

- **Learn-and-Earn Pilot Program Expands to 36 Partner Companies:** NextFlex continued to work with Lorain County Community College in Northeast Ohio to develop a fantastic learn-and-earn program. During the first year of this initiative, the program grew from seven to 36 employer partners and included 12 work-based learning commitments and 22 high school and career center connections.
- **Going National:** The FlexFactor multi-week high school program was piloted with eight students in Silicon Valley, In FY 2017, the program made strides as NextFlex prepared to expand it to communities across the country in a franchise model, complete with a user guide and mentoring by NextFlex staff.
- **Proliferating Internship Opportunities:** NextFlex collaborated with the Silicon Valley Organization to host an event for local manufacturers to learn about the Silicon Valley Organization summer internship program. By engaging 100 local companies and more than 200 interns in finance, manufacturing, marketing, and facilities management, the program served the community while giving young people an introduction to a range of manufacturing careers through paid summer internships.

Innovation Ecosystem

"NextFlex has become the focal point of the FHE ecosystem by facilitating much of the discussion around this evolving technology and drawing together a diverse community of subject matter experts that are driving advancements at a rapid pace."

– Joseph Kunze, Ph.D., Founder, President and CEO, SI2 Technologies, Inc. (North Billerica, MA)

NextFlex continues to draw together academia, non-profits, and government agencies to improve manufacturing processes for scalable manufacturing and commercialization of FHE devices. This is accomplished through strategic funding for innovation projects that engage all supply chain sectors from printed electronics to semiconductors to electronics manufacturing services. The following are a few examples:

- Boeing (Huntsville, AL) connected with Chromera (Poway, CA), a small business that joined NextFlex at the Observer level, via attendance at several of NextFlex's technical events. A partnership was formed based on these interactions, that resulted in a successful project funding to develop a condition monitoring sensor array. Chromera has now upgraded their membership to a Tier 3 level.
- Soft, flexible microfluidics are largely unexplored, and their supply chain is underdeveloped. Project support from NextFlex is allowing Epicore Biosystems (Evanston, IL) to establish a low-cost manufacturing route for a performance-monitoring wearable, known as Always-on Imperceptible Monitoring. This

manufacturing module depends on new and strengthened partnerships among at least eight organizations.

- With funding from the Commonwealth of Massachusetts, AFFOA and NextFlex partnered to launch the Fabric Discovery Center. This is an excellent opportunity for the functional fabrics supply chain to interact with the flexible hybrid electronics supply chain with the goal of developing revolutionary fiber and textile manufacturing processes. Projects are already underway, engaging entities throughout New England, including NextFlex members Raytheon (Waltham, MA), small business SI2 (Billerica, MA), and University of Massachusetts at Lowell.

Building Upon Success

A key focus for NextFlex has been on wearable and human-interfacing medical sensors and diagnostic devices. In the first project call, NextFlex requested development of a variety of individual sensor technologies, each incorporating FHE in their design. The primary goal was to achieve four distinct advantages for improving data collection from patients: new sensors, increased data accuracy, improved compliance, and continuous monitoring.

NextFlex has progressed from single-sensor solutions in early project calls to launching three projects to manufacture multi-sensor platforms. These are: the Epicore Biosystems-led sweat chemistry patch, the Boeing-led RF, low-power flexible substrate-based system to track factors affecting flight, and a GE Global Research and Binghamton University project to combine several clinical-grade medical sensors into a single system. This progression will bring us closer to the vision of the future of healthcare.

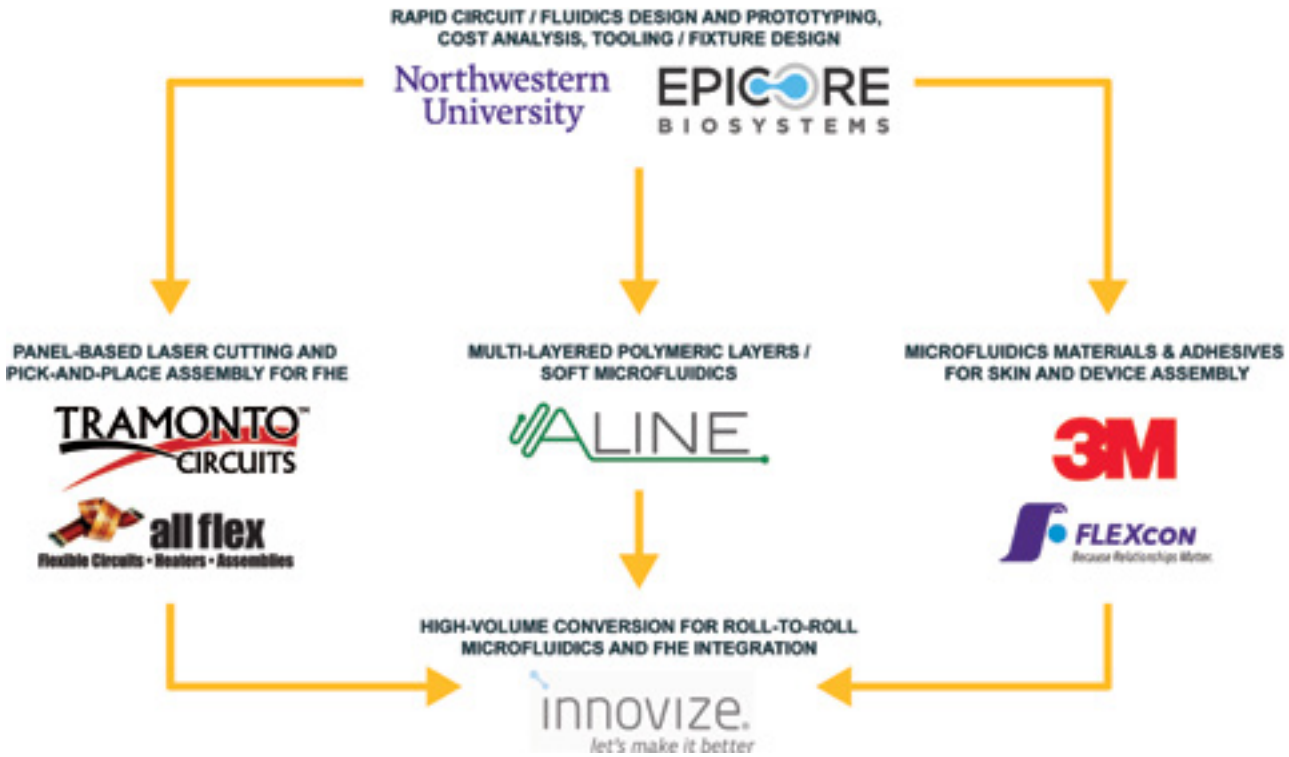


Figure 29. Epicore Biosystems is establishing a supply chain comprised of suppliers and contractors necessary to manufacture soft microf uidics. Credit: NextFlex

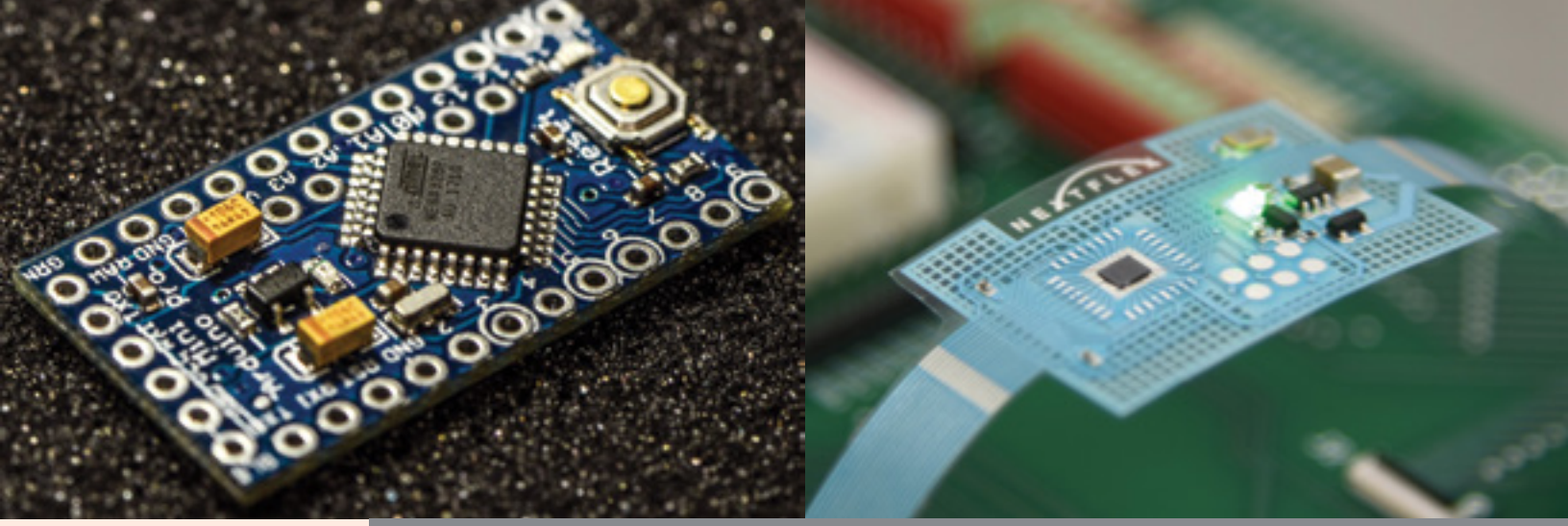


Figure 30. NextFlex has developed a flexible Arduino (right) that is smaller, lighter, and less expensive to manufacture than a traditional rigid board Arduino (left). Credit: NextFlex

Success in Numbers: Serving the DoD Catapults FHE Success

NextFlex has experienced a rapid increase in the projected demand for agency-driven projects in both the short and longer term. In FY 2017, NextFlex successfully secured 11 government funded projects from several agencies and armed services labs from across the country to solve critical technical problems. This was made possible by our access to broad institutional know-how and a deep and diverse network of connections from across the FHE community.

One such project was the flexible Arduino microcontroller board, an open-source, microcontroller-based electronics prototyping platform based on versatile and easy-to-use hardware and software. Popular with developers ranging from novices to seasoned experts, Arduino controllers have publicly available design files and bills of materials (BOMs) that are low-cost and ideal for a host of Internet of Things (IOT) and basic automation projects.

In developing the process flow for manufacturing the flexible Arduino, NextFlex reduced the number of traditional process steps by more than 60 percent compared to that of a rigid board, resulting in a faster and less expensive manufacturing process, resulting in a smaller, flexible form factor compared with a traditional rigid board, including the reduction of weight by two-thirds.

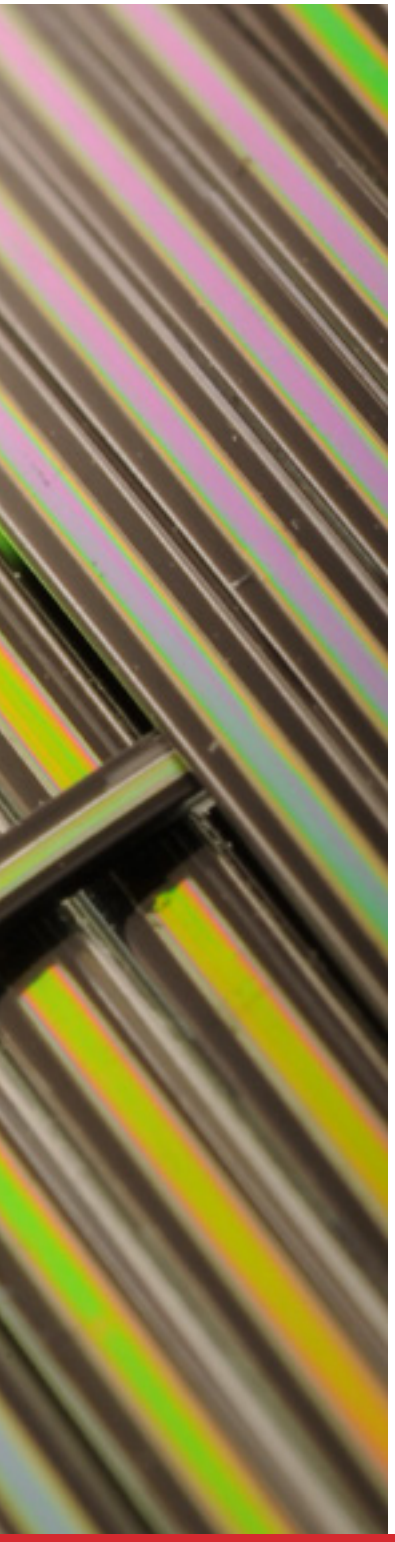
At the project's conclusion, NextFlex proved the robustness of the FHE manufacturing process by producing multiple functional samples of a flexible Arduino system while integrating the degree of complexity required for IoT and sensor applications. Most importantly, the project's success is serving as a springboard for other FHE innovations.

Clearly, NextFlex is proving the strategic value and significance of its project management capability for our government partners. That capability will be further bolstered by a state-of-the-art manufacturing facility that upon completion, will equip us with the most diverse set of printing capabilities anywhere in the world, further accelerating the pace of innovation of U.S.-based advanced manufacturing.

AFFOA

a Manufacturing USA institute

Credit: AFFOA



Mission: To enable a domestic manufacturing-based revolution by transforming traditional fibers, yarns, and fabrics into highly sophisticated, integrated and networked devices and systems.

Location: Cambridge, MA

Established: April 2016

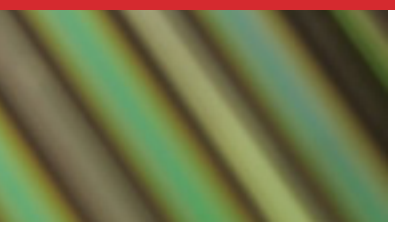
Consortium Organizer: Massachusetts Institute of Technology

Funding: Federal, $75M; Non-federal, $272M (both planned over five years)

Members (as of September 30, 2017): 110

AFFOA

Advanced Functional Fabrics of America



affoa.org

AFFOA

Institute Overview

Our clothes help define us, yet the fabrics we wear remain functionally unchanged after thousands of years. Recent breakthroughs in fiber materials and manufacturing processes allow us to design and produce fabrics that see, hear, sense, communicate, store, and convert energy, regulate temperature, monitor health, and change color—heralding the dawn of a "fabric revolution." Over the past few decades, the U.S. has lost many of its capabilities in fiber and textile development. These capabilities included extensive and rich laboratory facilities, pilot lines both in industry and academia, fiber and textile programs at universities that were traditionally strong in textile education, and workforce training either through continuing education or technical institutes. AFFOA is catalyzing a domestic manufacturing-based revolution, transforming traditional fibers, yarns, and textiles into highly sophisticated integrated and networked devices and systems and facilitating the conversion of the textile industry into a value-added, high-tech industry. Since its establishment in April 2016, AFFOA sought to deliver compelling product prototypes to excite industry and DoD customers to invest in the institute. The projects and prototypes served to illustrate two pillars AFFOA fundamental to the revolution ahead:

Moore's Law for Fibers

AFFOA leads the convergence of advanced technology into fiber and textile production to commercialize fabric products that will benefit both the warfighter and consumer. At the heart of AFFOA's approach, is the merger of semiconductor technology into fiber to deliver advanced fiber capabilities such as energy storage, light emission, optical receivers, and color change, to list a few. The functionality of fibers will dramatically increase over the next years creating a "Moore's Law for Fibers" leading to dramatic increases in fabric capabilities. These fibers are then incorporated into fabrics using conventional weaving and knitting equipment to enable advanced fabric products. Along with commercial applications, advanced fabric technology offers unique solutions to critical national security challenges, including soldier communication systems; functional composite materials for ground and air vehicles; and distinctive undersea and space capabilities.

Fabrics as Service

A key element of AFFOA's strategy is to accelerate exciting, advanced, internet-connected textile products that offer consumers "fabrics as a service." These products will lead to new business models that create value to the U.S. textile industry — moving it from producing low-margin commodity goods to producing high margin products with recurring revenue models based on the rapid innovation cycles characteristic of technology sectors.

Product Platform Advancements

"A backpack is a place to put something to eat, something to drink and something to wear —that's what's most important. Now, it becomes potentially an avenue for social interaction."

– Steve Munn, President of JanSport – Americas (Alameda, CA)

AFFOA bases its roadmap projects on IP-protected technology as a mechanism to ensure domestic manufacturing of resulting innovations. The roadmap projects are designed to encourage follow-on industry investment, through proprietary projects funded by industry members and executed through the Fabric Innovation Network, described below. These projects materialize revolutionary fibers and textile products to meet market needs and demands and will help grow the domestic supply chain for these products.

Product Platforms

In FY 2017, three core demonstrator platforms were completed:

- **LOOks** — One of a kind, unique, yet mass-produced coded fabrics, that are associated with their owner and share "user-curated" information through a smart phone app. Unlike other social media, the LOOks app allows sharing of information through a fabric with people you just met and have not connected with until now. AFFOA launched its "programmable fabric" platform through website and university activities in collaboration with JanSport, the world's largest backpack maker, with fabric produced in South Carolina. To date about 10,000 "programmable" backpacks have been manufactured. Project partners included Inman Mills (Spartanburg, SC), JanSport (Seattle, WA), and International Textile Group (Carlisle, SC).

- The project partners developed a new product platform to create fabrics with unique spectral features that can be used for search and rescue missions by increasing the fabric's visibility in easy-to-detect wavelengths of light. Partners included Ideo (Cambridge, MA), Boston Engineering (Waltham, MA), David Bono and Associates (Cambridge, MA), and Analog Devices (Wilmington, MA)

- **Gen 1 & 2 Fabric Communications** — In collaboration with members, AFFOA launched a first generation "Fabric LiFi" (Light Fidelity refers to the transmission of data via light) product platform. An advanced fabric-based hat receives data from overhead light sources for long distance, directional, and high-bandwidth communications. This system can be used to provide indoor navigation, to stream audio to select groups without using their phone, to locate and communicate in radio-frequency and GPS-denied environments, and to transfer highly secure information.

- **Electrophoretic Color Change** — Low-power, electrophoretic-based color-changing fibers and fabrics were created to test conceptual product designs for implementation in 2018. These fabrics provide on-demand color and pattern changes that adapt to changing environments for adaptable clothing, as color changing camouflage for military applications, and for communications. The transduction mechanism they employ is inherently low power to enable mobile solutions with long operational lives. Partners included E-ink (Billerca, MA), and Rhode Island School of Design (Providence, RI).

Project Call 1.0

AFFOA launched a Project Call in FY 2017 and held a member event to communicate project criteria, process and expectations, as well as to facilitate partnering among member organizations. Subsequently, thirty-four groups submitted white papers, and six teams were invited to submit full proposals, with five selected for award and one under evaluation. Contracting activity is underway with projects expected to begin in the first half of FY 2018. The following projects have been selected for award:

- **"Capacitive Touch Sensor & Interface"** — Drexel University and Apex Mills. The Knit Capacitive Touch Sensor is a gesture sensitive functional textile touchpad interface for physical devices. This project will transition the existing prototype to larger scale manufacturing in a knitting mill.
- **"Sensing Textiles for Civil Infrastructure Monitoring"** — St. Gobain and University of Massachusetts at Lowell. This project is developing a civil infrastructure monitoring system that will actively monitor stress and strain in civil infrastructure, enabling damage to be detected in its early stages, thereby minimizing maintenance costs and environmental impacts, while preventing disruptions due to unexpected infrastructure failures.
- **"Electrically Controlled Color-Changing Fabric"** — University of Central Florida, Inman Mills, Hills, Chameleon International, and WETESO. The team has developed electrically-controlled color-changing fabrics using thermochromic pigments. They are now working to scale the manufacturing processes to create garments with the ability to change color, appearance, and pattern on demand.
- **"Controlled Active Ingredient Delivery via Textiles"** — Manufacturing Solutions Center and Textile-Based Delivery, Inc. (TexDel). Yarns capable of delivering pain-relieving medications topically and through the skin are being scaled for production now.
- **"Shape-Shifting Climate-Adaptive Garments"** — Massachusetts Institute of Technology (MIT), Ministry of Supply, Hills, and Iowa State University. Today's smart and high-performance clothing relies on device-heavy solutions that require electronic components and complex mechanisms for sensing and actuation. Using specially-designed bi-component fibers and full-garment knitting, the team will produce climate-adaptive garments with true material-based intelligence. Using this powerful technology, smart garments will adapt to the user's body temperature and tune fabric compression and porosity to increase performance and breathability.

Workforce Development

"We see the needs of the industry and how the AFFOA initiative can fundamentally change everything for the good."

– Dan St. Louis, Executive Director, Manufacturing Solutions Center (Conover, NC)

Leveraging its understanding of the current and future needs of industry, AFFOA invests in Education and Workforce Development (EWD) that aligns with its technology programs. By creating a skilled workforce that can create new, functional fabrics, AFFOA is ensuring the success and longevity its impact on the fibers and textiles industry. AFFOA also advises states on regional economic development investments in revolutionary fibers and textiles. Key EWD Highlights from 2017 include:

- **EWD Integration** — Each funded AFFOA project has defined education and workforce development deliverables to create tools to train the future workforce in advanced textiles.

- **Online Learning** — AFFOA made North Carolina State University's online course, "Textile Fundamentals," available to its member-ship.
- **Advanced Fabric Hackathon** — In collaboration with MD5 and MIT, AFFOA hosted its first Advanced Fabrics Hackathon to build functional fabric product prototypes to address the needs of emergency responders in challenging environments in challenging environments. One-hundred and twenty participants attended, with three winners chosen, two of which were from AFFOA member institutions.
- **AFFOA Member Portal** — AFFOA established and expanded its Member Portal to include project, product, and learning content, incorporating the continuous integration and deployment methodology first developed for agile software development.

Innovation Ecosystem

"We are thrilled to celebrate this first of its kind Fabric Discovery Center and the advances and jobs it will unlock in revolutionary fabrics and textiles. Our investments and the commitment of partners from the federal government, academia, and the private sector in harnessing these emerging technologies are critical to the Commonwealth's competitiveness in advanced manufacturing and creating job opportunities for Massachusetts' residents."

– Charlie Baker, Governor of Massachusetts

Figure 31. Ribbon cutting at the first Fabric Discovery Center in Lexington, MA. From left: Rep. Joe Kennedy (MA), Rep. Nikki Tsongas (MA), Gov. Charlie Baker (MA), MIT President Rafael Reif, Sen. Elizabeth Warren (MA), Deputy Assistant Secretary of Defense for. Tactical Warfare Systems James A. MacStravic, New Balance CEO Rob DeMartini. Credit: AFFOA

AFFOA's core strength is the Fabric Innovation Network, a collaborative infrastructure of industrial and academic partners with significant, yet previously isolated, expertise. The Fabric Innovation Network offers a collaborative prototyping and pilot manufacturing engine for the nation. AFFOA therefore has a strategic position in helping industry define exciting new high-margin products that will help drive investments in advanced manufacturing processes and in high value-added manufacturing, establishing a high-margin innovation cycle.

Fabric Discovery Centers of Excellence and Opportunity

On June 19, 2017, AFFOA opened its national headquarters and first of its kind Fabric Discovery Center (FDC). With cost-share funded by MIT and the Commonwealth of Massachusetts, the FDC hosts end-to-end prototyping, start-up incubation space, and education and workforce development activities. AFFOA is also establishing a national network of regional FDCs aimed at creating jobs and facilitating innovation in local communities. The FDCs enhance the DoD's effort to secure U.S. leadership in revolutionary fibers and textiles manufacturing and are part of the national landscape of Manufacturing USA, promoting global competitiveness in manufacturing across a spectrum of economic sectors.

AFFOA conducted a call for regional fabric discovery centers across the nation. The first was awarded on May 25, 2017 with Massachusetts Lieutenant Governor Karyn Polito visiting MIT Lincoln Laboratory to announce a $2.2 million state cost-share grant to support the first FDC focused on defense technologies. The Defense Fabric Discovery Center was formed through a partnership of MIT Lincoln Laboratory, the U.S. Army Natick Soldier Systems Center, the Commonwealth of Massachusetts, and AFFOA. The Defense Fabric Discovery Center works closely with its partner organizations, participating government agencies, and local companies to develop and transition advanced fabric technologies to serve the warfighter.

Figure 32. On June 19th, 2017 AFFOA launched the LOOks platform and distributed 300 unique yet mass produced LOOksPacks to guests attending the Grand Opening of the Fabric Discovery Center. Credit: AFFOA

LOOks Is the World's First Programmable Backpack

In June, AFFOA unveiled LOOks, the world's first programmable backpack that is mass produced yet is completely unique. LOOksPacks are made of an advanced fabric that is manufactured at Inman Mills in South Carolina. The LOOks fabric enables the wearer to program their backpack through a smartphone app called LOOks. Users with the LOOks app can retrieve information from the LOOks fabric by just pointing their phone at it ("LOOking") from distances up to 30 feet away. Like other social media, the LOOks app allows the user to control the content they share. Throughout 2017, AFFOA distributed LOOksPacks to test "fabric as a service" technologies, collect data on usage, and gather feedback from users at various events. These activities educated the future workforce, while enabling students and professionals to better connect on campuses and at conferences.

The innovations in fabric development needed for LOOks advanced U.S. manufacturing processes in South Carolina. Rather than manual system entry into each loom, automated weft and warp codes enabled mass production of unique fabric.

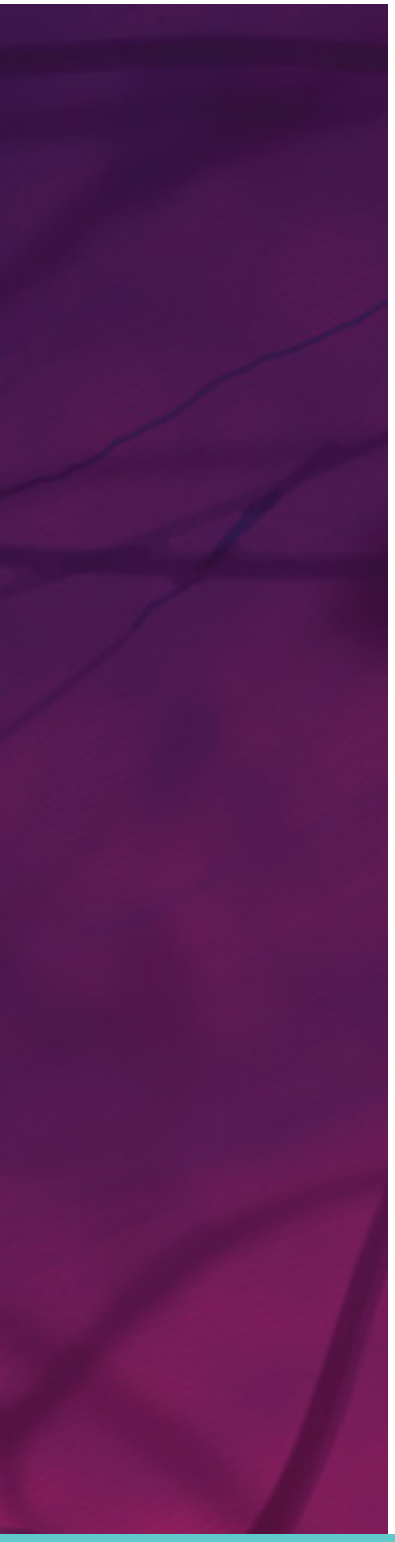
This pack exemplifies the founding premises of AFFOA — advancing the role of U.S. product and manufacturing innovation in "advanced fabrics."

Figure 33. Through LOOksPacks, AFFOA introduced over 3,000 Drexel University students and 1,200 MIT students to the advanced fabrics industry. Credit: AFFOA

BIOFABUSA

a Manufacturing USA institute

Credit: BioFabUSA



biofabusa

BIOFABUSA

Mission: BioFabUSA seeks to make the large-scale manufacturing of engineered tissues and tissue-related technologies practical and prepare the required workforce to meet the needs of the wounded warfighter and others in need of this technology across the U.S.

Location: Manchester, NH

Established: December 2016

Consortium Organizer: Advanced Regenerative Manufacturing Institute (ARMI)

Funding: Federal, $80M; Non-federal, $214M (planned funding over five years)

Members (as of September 30, 2017):[45] 2

biofabusa.org

[45] BioFabUSA welcomed its first members on September 20, 2017. As of December 2017, the institute had 30 members.

BIOFABUSA

Institute Overview

"I am astounded by the 21st century science fiction done by scientists in the field of regenerative medicine. I am equally astounded by the science fiction in their labs, where the manual labor conducted by technicians is reminiscent of Louis Pasteur's laboratory. It is amazing that these miracles can be performed without modern process controls, robotics, and sensors, but this field will need 21st century engineering and manufacturing to mature into an industry capable of manufacturing FDA-approved tissues at the scale they are needed."

"BioFabUSA will build the coalition of industry, academia, and government that I hope will make that happen and enable the next big advance out there."

– Dean Kamen, Chairman, ARMI (Manchester, NH)

Significant breakthroughs in cell biology and materials science in the last decade have laid the foundation for large-scale manufacturing and commercialization of engineered tissues and tissue-related technologies, but the tissue engineering field is fragmented and lacks a mechanism with which to turn laboratory breakthroughs into manufactured products. The BioFabUSA program is designed to attract and develop an ecosystem of both large and small industrial/commercial entities, educational and medical non-profit institutions, and government organizations. Together, this ecosystem seeks to address the grand challenges hindering the transformation of tissue engineering and regenerative medicine research into an industry that can realize the potential of these breakthroughs to deliver therapies to patients in need.

Technology Description

"This is literally a life-changing approach and adds a new chapter to medicine. To apply technology across multiple disciplines to help people live longer, healthier lives — there's going to be nothing but more interest in that as the population ages and the technology becomes more capable."

– Blake Moret, CEO of Rockwell Automation (Milwaukee, WI)

Figure 34. Ribbon-cutting at BioFabUSA launch event (ARMI).

"Innovation is a team sport. We have to partner collectively to be able to accomplish this."

– Michael Hill, VP of Corporate Science, Technology, and Clinical Affairs, Medtronic (Minneapolis, MN)

BioFabUSA's mission is to develop and enable the technologies, predecessor products, standards, regulatory-consistent development practices and strategies, appropriately trained workforce and commercial ecosystem necessary for large-scale manufacture of these products. This approach does not focus on the development of any particular tissue or tissue-related product. BioFabUSA seeks to achieve its mission by:

- Removing existing hurdles to reproducible tissue biomanufacturing;
- Producing modular and scalable good manufacturing practice compliant processes and integrated technologies;
- Developing and standardizing commercial-scale manufacturing practices across the field; and
- Disseminating knowledge and technologies to enable continued innovation across the ecosystem.

Figure 35. Advanced Solutions Life Sciences CTO Jay Hoying demonstrates the BioAssembly Bot at BioFabUSA launch (courtesy of Advanced Solutions Life Sciences).

Applications

"There are often three stages of dealing with disease. In the first stage, we identify the disease, but we can't do anything for people other than understand what kills them. In the second stage, we learn how to treat disease. This is an improvement, but chronic treatments are often a daily torture of injections, infusions, or worse. These treatments avoid death but frequently provide poor health — and at incredible cost! In the third stage, we can prevent or completely cure the disease. Vaccines have historically been the gold standard in this third stage, but regenerative medicine will provide another high-quality solution – building new organs from our own cells."

– Dean Kamen, Chairman, ARMI (Manchester, NH)

Eventually, BioFabUSA hopes to develop next-generation manufacturing techniques for fabricating tissues and tissue-related constructs. The goals are to manufacture new skin for soldiers scarred from combat, produce blood products on demand, or generate replacement organs[46] from a patient's own cells. These efforts will help save the lives of the more than 7,000 people who die each year waiting for organs and some of the more than 750,000 Americans who die each year due to failure of their heart, kidney, liver, or pancreas.[47] Moreover, 86 percent of all U.S. health care costs are related to chronic disease[48], and regenerative tissue products provide a path toward dramatically better health outcomes and significantly lower costs. For example, according to recent reports, patients with chronic kidney disease account for 20 percent of Center for Medicare and Medicaid Services expenditures.[49]

Early Actions

Established on December 19, 2016, BioFabUSA spent much of FY 2017 laying the groundwork for long-term success.

- **Organizational Infrastructure** — BioFabUSA opened its offices in newly renovated space in Manchester, NH. Start-up personnel are in place, and organizational infrastructure (IT, finance, etc.) has been established. The Stakeholder Council, Leadership Advisory Committee, and Technical Advisory Sub-Committee all had their first meetings.

[46] https://www.organdonor.gov/statistics-stories/statistics.html
[47] National Center for Health Statistics, Centers for Disease Control and Prevention, https://www.cdc.gov/nchs/fastats/deaths.htm
[48] Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, https://www.cdc.gov/chronicdisease/overview/index.htm
[49] 2017 Annual Data Report Highlights, United States Renal Data System, https://www.usrds.org/adrhighlights.aspx

- **Membership and Outreach** — BioFabUSA hosted an energizing launch event on July 28, 2017 that was attended by 400 people, including U.S. Senators Shaheen and Hassan, former U.S. Senator Ayotte, and New Hampshire Governor Sununu. Membership sign-up started September 20, 2017 and prospective members have already begun to sign membership agreements.
- **Roadmapping** — A provisional tech-nical roadmap was established, and BioFabUSA used both web-based tools and in-person meetings to begin work on the first full BioFabUSA roadmap.
- **Education and Workforce Development (EWD)** — The focus of BioFabUSA's EWD program is to ensure that we have the appropriately trained workforce necessary for large-scale manufacture of engineered tissues. This can be accomplished by closing the skills gap in tissue and organ manufacturing and engaging students in the field of regenerative manufacturing. Given the nascent state of this industry, EWD development was an immediate focus. In addition to the EWD projects, BioFabUSA has started foundational work for its EWD roadmap and conducted a wide variety of outreach initiatives.
- **Regulatory Pathways/Standards** — BioFabUSA recognized the importance of clarifying regulatory pathways and developing standards to increase the velocity of bringing engineered tissues and tissue-related products to patients. Towards that end, one of the first key hires of the institute was Chief Regulatory Officer Richard McFarland, PhD, MD, who joined BioFabUSA after 17 years at the United States Food and Drug Administration, most recently as Associate Director for Policy, Office of Cellular, Tissue, and Gene Therapies, Center for Biologics Evaluation and Research. Additionally, BioFabUSA has been instrumental in the establishment of the Standards Coordinating Body, whose mission, in support of both BioFabUSA and NIIMBL, is to optimize development and utilization of standards in the cell therapy, gene therapy, regenerative medicine, and cell-based drug discovery.

Figure 36. BioFabUSA Chief Regulatory Officer Richard McFarland (ARMI).

- **Projects** — BioFabUSA approved seven technical and six EWD quick-start projects. Technical projects are developing viability sensors, sterility sensors, fluid management, and tissue transport, among others. EWD projects address topics such as a workforce needs assessment, online curriculum development, flexible degree pathways, and retraining veterans.

"With BioFabUSA's emphasis on research and strong interest in quickly developing products, having the local connection to UNH Manchester is essential. Through internships and class projects, students can gain hands-on experience and be prepared to fill some of the jobs that will be created because of the work spearheaded by BioFabUSA."

– Matt Cookson, Executive Director, New Hampshire High Tech Council (Manchester, NH)

The Future

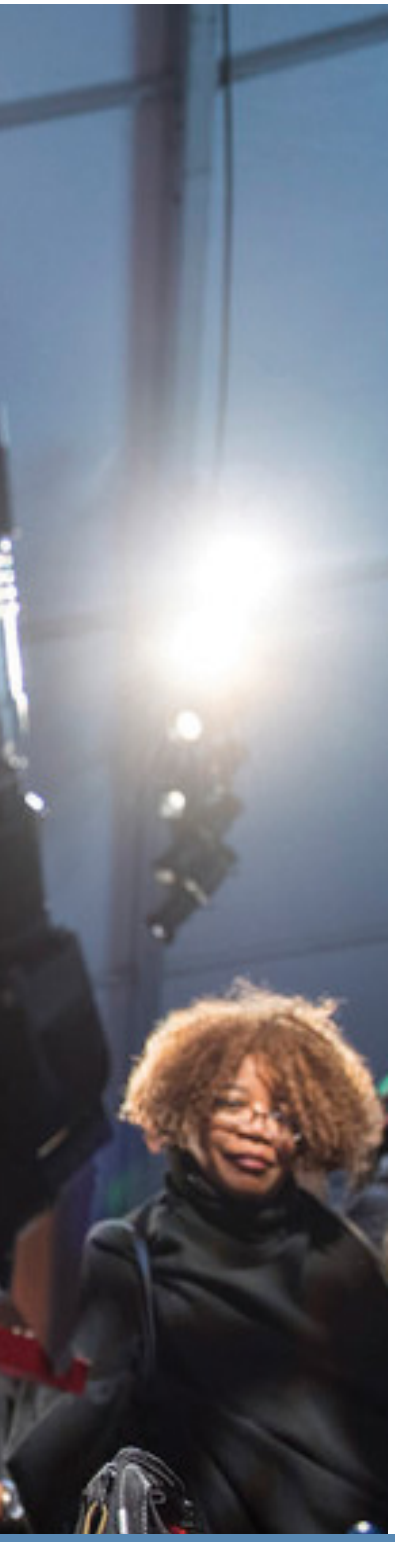
2018 will be an exciting year for BioFabUSA. Prospective members will become official members. The tissue engineering field will convene at the first BioFabUSA Summits. The full technology roadmap will be completed and shared with membership. Technology and EDW projects approved this year will report their first results. Both technical and EWD project calls will be announced and BioFabUSA anticipates funding a number of additional technical and EWD projects in 2018.

Credit: BioFabUSA

ARM

a Manufacturing USA institute

Credit: Carnegie Mellon University



ARM
ADVANCED ROBOTICS
FOR MANUFACTURING

Mission: ARM accelerates robotics innovation to drive U.S.-based growth in manufacturing while developing domestic robotics expertise to create high-value careers. By lowering economic, technical, and operational barriers, ARM ensures that enterprises of all sizes can adopt robotic solutions, while preparing the American workforce to work collaboratively with robots.

Location: Pittsburgh, PA

Established: January 2017

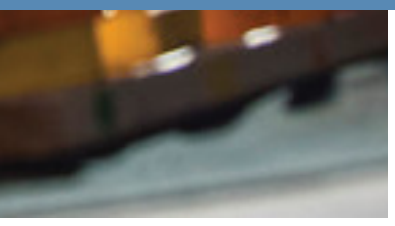
Consortium Organizer: Carnegie Mellon University

Funding: Federal, $80M; Non-federal, $173M (planned funding over five years)

Members (as of September 30, 2017): 73

ARM

Advanced Robotics for Manufacturing Institute



arminstitute.org

ARM

Institute Overview

"ARM connects our company with leading manufacturers that need automation, and with top research facilities that are creating new tools and technologies for industrial robots."

– Roger Christian, Yaskawa America Inc., Motoman Robotics Division (Dayton, OH)

Institute Overview

Established in FY 2017, the ARM Institute will accelerate research, development, and implementation of collaborative robotic technologies for use in manufacturing. In collaborative robotic technology, robots physically interact with humans in a shared workspace. Smart, perceptive, collaborative robots are needed that can efficiently perform multiple tasks with great precision and be repurposed for other tasks quickly. To foster a robust, innovative manufacturing sector, these robots also need to be accessible for implementation by small and mid-sized manufacturers.

ARM consists of a national network of Regional Robotics Innovation Collaboratives with members spanning industry, academia, and government organizations. ARM is working to integrate the diverse industry best practices and institutional knowledge across many disciplines to realize the promise of a robust manufacturing innovation ecosystem. These include new sensor technologies; novel devices and tools, called end-effectors, that are devices connected to the ends of robot arms; artificial intelligence software; human and machine behavior modeling; and advances in quality assurance.

To achieve these goals, ARM established four manufacturing operational aims:

- Versatility — robots that can perform a variety of tasks;
- Flexibility — robots that can be deployed and re-deployed rapidly and easily;
- Lower cost — reducing the overall cost of robot systems; and
- Collaboration — robots that safely work alongside and with people.

These manufacturing operational aims are guided by seven technical thrust areas: human-robot interaction; scheduling, learning and control; dexterous manipulation; mobility and navigation; perception and sensing; testing, verification and validation; and mechanism design.

Technology Description

"We are going to see automation and robotics move from a caged and isolated environment to the aisle-ways and even traveling to different locations, with a continued high emphasis on collaboration with humans."

– Joel Reed, Vice President, IAM Robotics (Sewickley, PA)

ARM advances new robotic technologies to ensure that the U.S. retains its global leadership in manufacturing. The institute is creating a highly collaborative network of members that includes best-in-the-world technologists; industry thought leaders; and education and workforce development experts.

Applications

To execute on the goal of accelerating collaborative robotic technologies in manufacturing, the ARM Institute issued a Project Call for "Quick Start" proposals for applied research projects addressing the following topics:

1. Smart Companion Robot for Automotive Assembly
2. Perception-aided Collaborative Robotic Wire Harness Assembly
3. Robot Assistance for Composites Manufacturing
4. Robotic Sanding and Finishing

Early Actions

To ensure the sustainability and expand the national impact of the institute, ARM has formed eight Regional Robotics Innovation Collaboratives representing all states across the country and co-hosted three regional events to share insights and resources, including facilities and equipment. ARM is also developing sustainable education and training resources for the robotics and automation industry (e.g., apprenticeships, curricula, virtual, and augmented reality simulations). A marketing campaign is underway to promote advanced manufacturing careers in robotics and automation. ARM plans to build a robust training system to support new jobs in robotics and automation.

Membership

ARM continues to enlist members from across the country representing industry, academia, and government organizations. Members range from high-tech start-ups to some of the largest robotics companies to global Fortune 500 manufacturers.

Roadmapping

ARM, in partnership with the Boston Consulting Group, conducted extensive, industry-led research culminating in working drafts of roadmaps for fostering a robust and innovative national manufacturing ecosystem for technology development and education and workforce development. These plans chart a clear path to achieving near-term, high-impact, and high-feasibility success and will be available to the institute members by the end of FY 2018.

Workforce Development

"As a New York City-based manufacturer of underwater drones, Duro UAS requires highly specialized talent to stay competitive. ARM's workforce development leadership and support have been essential to successfully navigating this challenge. By helping U.S. companies to compete and lead in advanced manufacturing, and developing workforce programs that create the manufacturing talent of the future, ARM is making a tangible difference in our business and in the industry."

– Brian Wilson, President, Duro UAS (New York, NY)

Increased productivity gained by collaborative robotic automation will help create new high-paying jobs to build, manage, and maintain the robots; promote on-shoring by manufacturers, and replace dangerous jobs with safer jobs.

The ARM Institute's Education and Workforce Development primary initial strategies are to:

1. Establish ARM's educational partner network to develop messaging around robotics and automation careers and the sustainability of manufacturing careers, develop and promote broad participation in ARM certification and education programs, and encourage a robotics/ automation industry-recognized stackable credential;
2. Inform, educate and support small and mid-sized manufacturers;
3. Train, certify and offer internships, apprenticeships and externships to students and educators; and
4. Address diversity through research-based STEM and industry-recognized ARM certifications.

The Future

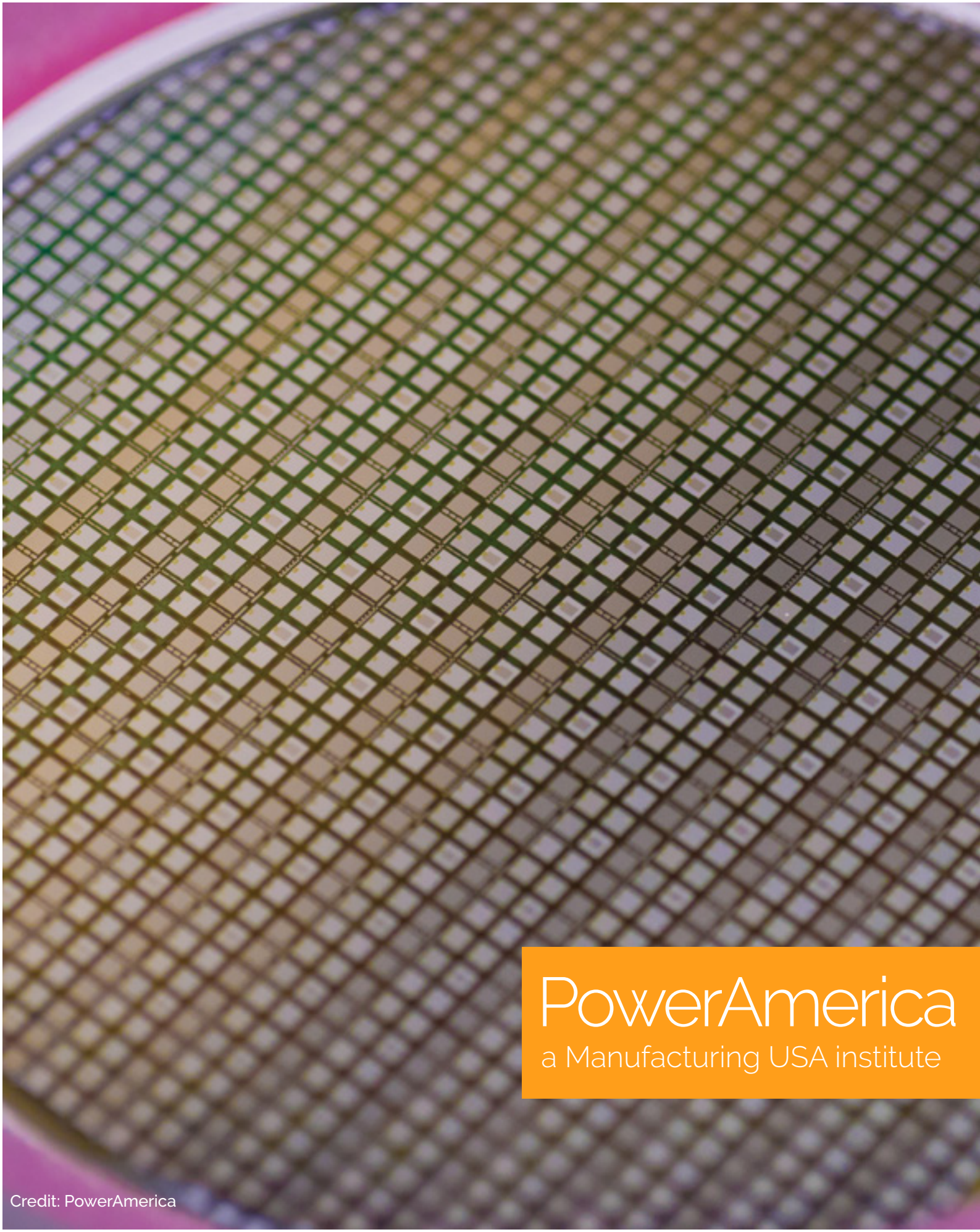
ARM is in the midst of issuing its first project call with the intention to fund eight to ten technology projects and six to eight education and workforce development projects. ARM will hold its first membership meeting in the coming fiscal year and hold a groundbreaking ceremony for its new headquarters, which will also house Carnegie Mellon's Manufacturing Futures Initiative.

Credit: Girls of Steel Robotics Team

SUMMARY OF INSTITUTE ACTIVITIES

Department of Energy

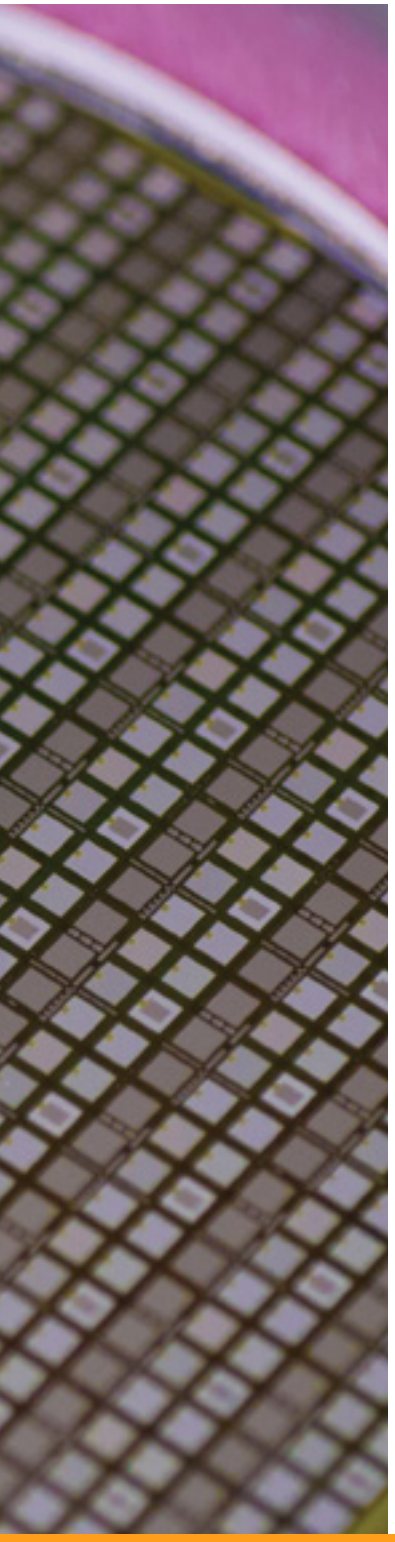
Credit: Power America



PowerAmerica

a Manufacturing USA institute

Credit: PowerAmerica



PowerAmerica

Mission: The PowerAmerica institute at North Carolina State University seeks to save energy and create U.S. manufacturing jobs by accelerating the development and large-scale adoption of wide bandgap semiconductor technology in power electronic systems.

Location: Raleigh, NC

Established: January 2015

Consortium Organizer: North Carolina State University

Funding: Federal, $70M; Non-Federal, $70M; both planned over five years

Members (as of September 30, 2017): 41

POWERAMERICA

poweramericainstitute.org

POWERAMERICA

Background

PowerAmerica is working to accelerate the development and adoption of advanced semiconductor components made with silicon carbide (SiC) and gallium nitride into a wide range of products and systems. These "wide bandgap" (WBG) semiconductors operate at much higher voltages, frequencies, and temperatures than conventional semiconductors. They are also smaller and more energy efficient than the high-power electronics widely available today. WBG semiconductors have applications in electric power distribution, data centers, industrial motors, and in the efficient, robust power components needed for trains and electric vehicles.

Technology Advancement

"The funding from Power America was critical to establish key equipment at X-FAB Texas needed to support our vision of bringing SiC manufacturing to 150 mm wafers. PowerAmerica has played a key role in accelerating the commercialization of our SiC Schottky diodes."

– Kiran Chatty, Vice President of Product Development, Monolith Semiconductor (Round Rock, TX)

To advance this new technology, PowerAmerica funds innovative projects and brings together a range of companies from startups to major corporations, as well as universities, that accelerate every facet of the supply chain, from development to manufacturing.

Projects Completed in FY 2017

In FY 2017, 36 projects were completed. Some highlights that address items in the technology roadmap are:

- **Manufacturing SiC Devices at the First U.S. Open Foundry** — The lack of cost-effective silicon carbide devices is limiting their widespread adoption in commercial power electronic applications. Monolith Semiconductor, a Round Rock, TX startup and PowerAmerica member, has perfected a process to manufacture silicon carbide power electronic metal–oxide–semiconductor field-effect transistors (MOSFETS) and diodes at the X-FAB Texas SiC foundry. In 2017, the company successfully released both products to market through its majority investor, Littelfuse, Inc. (Chicago, IL). The project is an example of two PowerAmerica partners (X-FAB and Monolith) working together to bring SiC products to market in a mass capacity.

- **Better Packaging for Wide Bandgap Devices** — Traditional packaging modules made for silicon-based power electronics do not allow the end user to fully exploit the potential of silicon carbide power devices. Silicon carbide power devices require packaging that can handle higher temperatures, deliver power more reliably, and offer increased power density. Led by Wolfspeed (Fayetteville, AR), this PowerAmerica project fills a market gap by making high performance SiC power

modules commercially available. The company is readying their product for commercialization by qualifying it to industry standards and creating manufacturing capability that will lead to full production.

- **More Efficient Uninterruptible Power Supplies** — Uninterruptible power supplies (UPS) are key to providing clean and reliable power to operations such as data centers, telecom, military equipment, and more. PowerAmerica member and global company ABB (Raleigh, NC) undertook a project to improve the efficiency of a 100 kW UPS unit. Peak double conversion efficiency of 98 percent has been obtained by upgrading their existing product to use silicon carbide solid-state switches. A 35 percent to 45 percent reduction in measured power loss has been shown over the entire load range. The overall operation of the UPS system has been improved, demonstrating that silicon carbide can help operators successfully meet their sustainability and reliability goals.

New Programs Launched in FY 2017

In FY 2017, 26 new projects were launched. These are addressing key problems in wide bandgap power electronics manufacturing such as:

- **Expanding Manufacturing and Accelerating Adoption of SiC Devices** — Microsemi (Aliso Viejo, CA), a new addition to PowerAmerica headquartered in California with offices worldwide, is a key supplier of SiC power devices and has the capability to produce them in-house. To further expand its manufacturing capability, the company is transferring its design and process to the X-FAB Texas SiC foundry. The devices manufactured there would also be subjected to the AEC-Q 101 qualification (Stress Test Qualifications for Automotive Grade Discrete Semiconductors) to ensure that they meet the industry standard. Microsemi's global marketing, sales and distribution network will lead to swift adoption of these SiC devices in power electronics applications.

- **Benchmarking Reliability and Enhancing Adoption of Wide Bandgap Devices** — Reliability is critical for the adoption and commercialization of wide bandgap power devices. To make the switch from traditional silicon semiconductors over to these efficient technologies, companies must have confidence that the devices will perform well in commercial applications. A team of researchers at Texas Tech University (Lubbock, TX) is helping boost confidence in SiC by establishing a third-party testing center to evaluate and benchmark the reliability metrics for SiC power devices' lifetime transient performance and long term switching reliability.

- **Expanding the Market of SiC Devices in High Power Applications (UTRC)** — A large power electronics manufacturer can play an essential role in breaking the market barrier for wide bandgap power devices in high power applications. United Technologies Research Center, a Hartford, Conn. division of United Technologies with extensive experience in critical commercial and defense applications, is utilizing PowerAmerica funding to develop an active harmonic filter — a component that filters out electrical interference, making electronic devices operate more reliably. This

filter, made with SiC, is 50 percent smaller and 20 percent cheaper than those commercially available today. The active harmonic filter has applications for heating, ventilation, and air conditioning, among other areas, providing a significant market opportunity for the insertion of wide bandgap devices.

Workforce Development

"I especially appreciated the opportunity PowerAmerica' s short course provided to interact with some key players in the silicon carbide realm, in a much more intimate setting that allowed interactive exchanges."

– Samantha Reese, National Renewable Energy Laboratory

PowerAmerica's Education and Workforce Development effort is directed at preparing the workforce to meet the industry's growing needs for engineers and other technical professionals that are well versed in WBG technology. The program has evolved over the years and is focused on the key target audiences that provide the greatest near-term value to the industry: upper level undergraduates, graduate students, and working professionals.

- PowerAmerica offered its first wide bandgap short course geared to working professionals in fall 2017. Demand was high — the course was filled to capacity, with 30 attendees representing a range of industry, as well as graduate students. The 2 ½ day course provided an opportunity for deep, focused training on various aspects of wide bandgap technology. PowerAmerica will offer another short course in 2018.
- PowerAmerica holds a monthly technical webinar series featuring a university researcher working on an institute project. Each of these free monthly webinars, open to the public, has attracted 50 to 120 attendees interested in learning more about wide bandgap research and applications.
- Each of PowerAmerica's academic members are required to involve at least two undergraduate students in each project, providing the opportunity for hands-on, applied technical training across the supply chain. In FY 2017, there were more than 110 students directly involved in PowerAmerica projects with hands-on applications.
- In 2016, N.C. State initiated a new type of "technology transition" project that focused on a Power-America funded technology, an electric vehicle fast charger built with silicon carbide. This work brought together engineering and business school students to study the market and identify steps necessary to commercialize wide bandgap technology.

Innovation Ecosystem

"PowerAmerica has really accelerated our move into the silicon carbide business by two years, and our association with the institute lends significant credibility to the X-FAB-Texas operation."

– Jon Ransom, Technology Director, X-FAB Texas (Lubbock, TX)

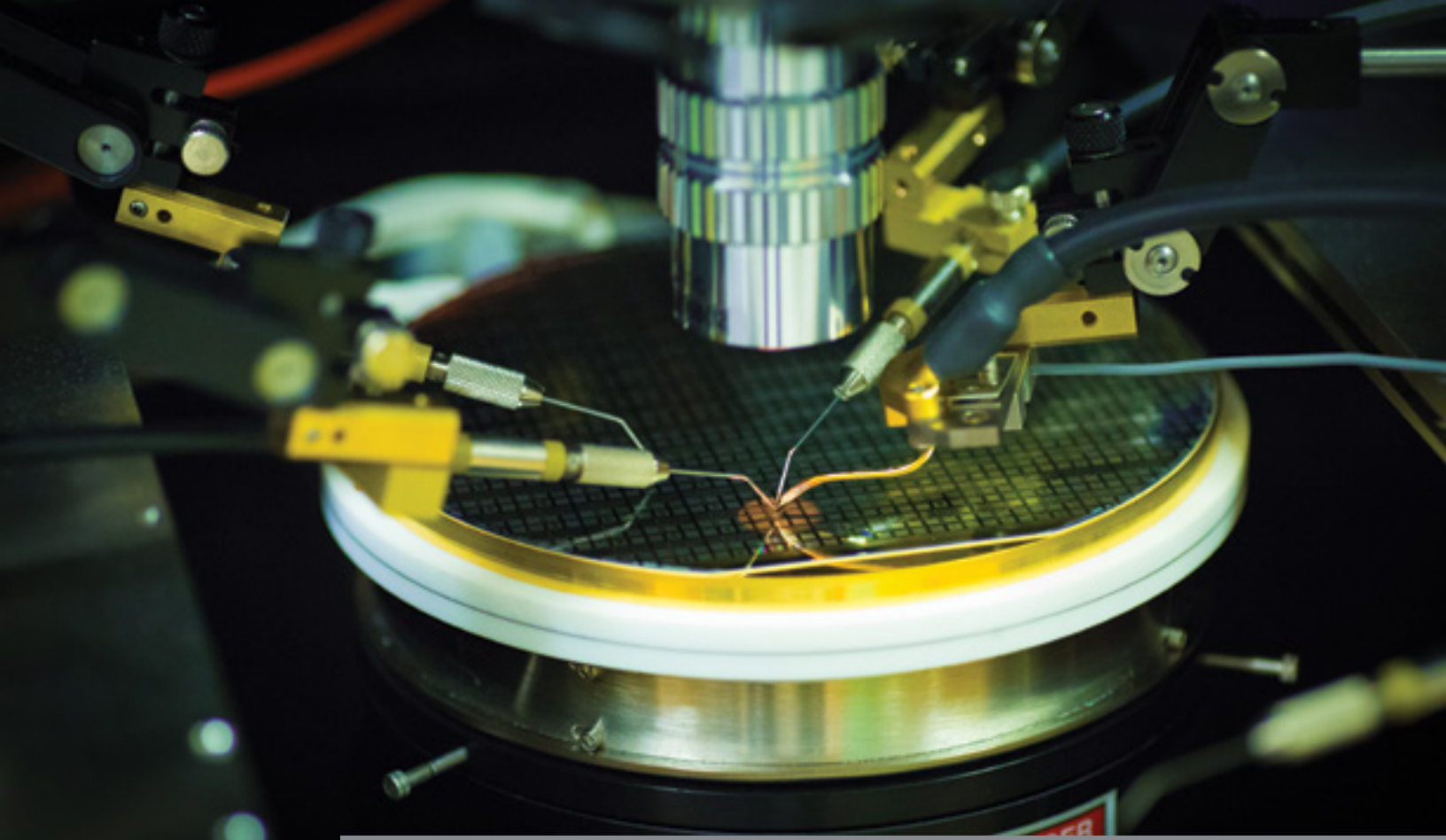


Figure 37. Electrical probing of a silicon carbide device wafer. Credit: PowerAmerica

PowerAmerica is driving the growth of a globally competitive wide bandgap semiconductor industry in the U.S. by funding projects that fill technology and knowledge gaps to enable wide bandgap manufacturing. Projects span from device design through module development and manufacturing to commercialization applications. These projects create supply chains that include a wide array of industry members, from startups of a few people innovating with emerging technologies to huge multinational corporations with large research departments, marketing teams and factories, as well as top U.S. universities.

The X-FAB silicon carbide foundry in Lubbock, Tex., is a key example of PowerAmerica's innovation ecosystem in action. In 2016, PowerAmerica funding enabled X-FAB to renovate an existing foundry to accommodate the production of silicon carbide wafers (previously, the factory produced silicon wafers). Today, multiple companies, including five members of PowerAmerica, produce silicon carbide devices at the facility. Monolith, cited in an example above, was purchased earlier this year by global circuit protection company Littelfuse, and today produces two of its SiC product offerings at X-FAB. N.C. State University professor Dr. Jay Baliga patented PRESiCE™, which relies on a manufacturing process developed at X-FAB, which also lowers the barrier for SiC market entry for U.S. companies, as described above.

To continue supporting wide bandgap research and development, PowerAmerica opened a device bank in FY 2017 available to its members. The device bank offers engineering samples, thus cutting down on long lead times and high expenses, as well as providing device makers with timely and reliable feedback on the performance of engineering samples for potential customers.

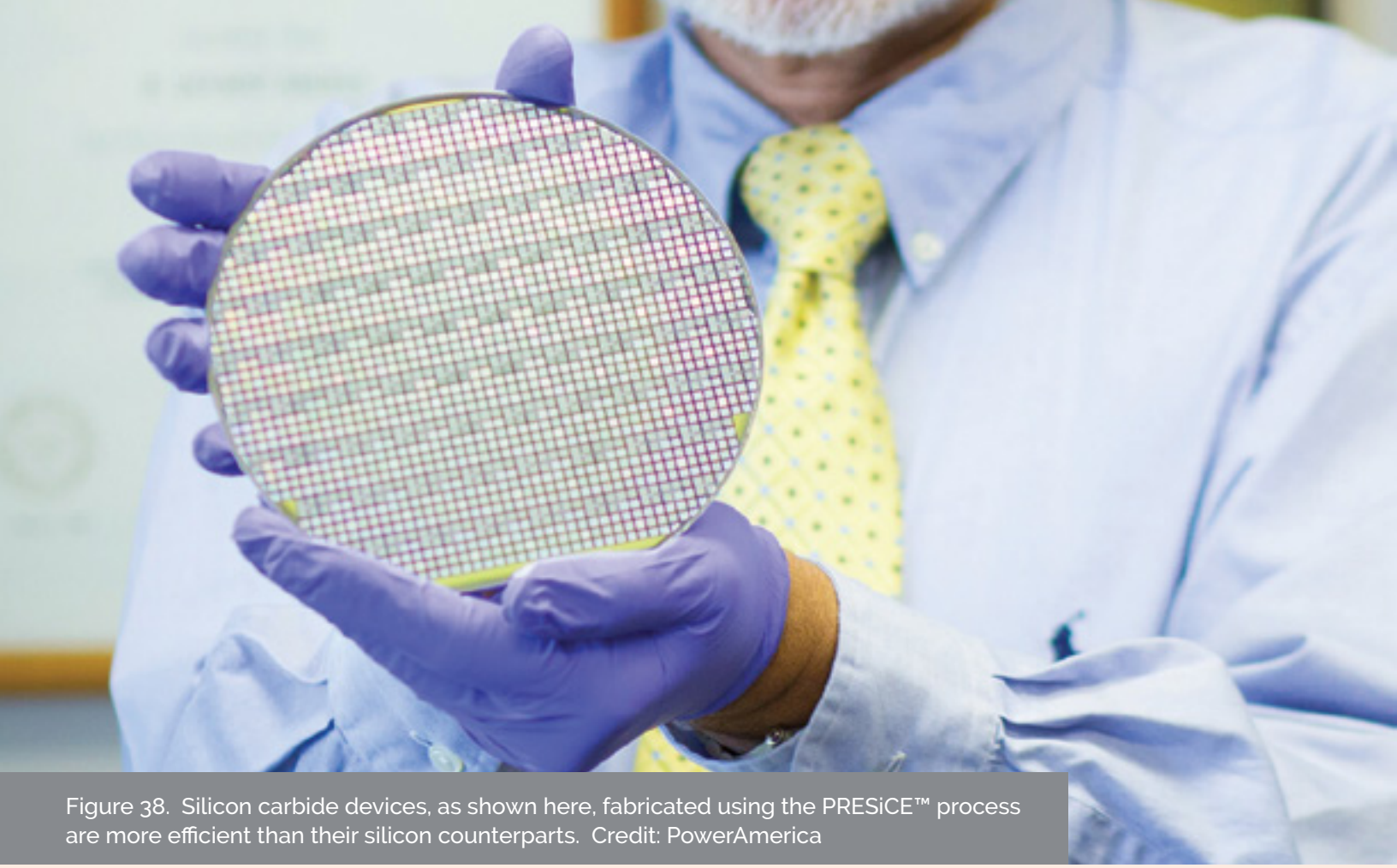


Figure 38. Silicon carbide devices, as shown here, fabricated using the PRESiCE™ process are more efficient than their silicon counterparts. Credit: PowerAmerica

Lowering the Barrier to Market Entry: N.C. State

A major goal of the PowerAmerica institute is to facilitate the industry's switch from silicon-based power electronics to silicon carbide power electronics, which are more efficient. SiC power devices can be used to more efficiently regulate electrical power — losing 30 percent less power than traditional silicon devices. However, the cost of developing a manufacturing technology for SiC devices presents a significant barrier to companies, particularly small ones.

Distinguished University Professor Jay Baliga and his team at N.C. State University have developed a manufacturing process, known as PRESiCE, which companies can use to create their own SiC devices. According to Baliga, the team's goal is to drive the price of silicon carbide devices from five times that of silicon devices down to 1.5 times.

The process is exclusively available at the X-FAB Texas SiC foundry, a former silicon foundry that was upgraded to a silicon carbide foundry with the help of PowerAmerica funding. By helping companies avoid the steep price of developing their own manufacturing process, PRESiCE aims to enable more silicon carbide manufacturing, thus driving down the overall cost of silicon carbide as more companies produce SiC products.

Credit: PowerAmerica

IACMI

a Manufacturing USA institute

Credit: IACMI

THE COMPOSITES INSTITUTE

Mission: To accelerate innovative research and development in the advanced composites field.

Locations: Headquarters: Knoxville, TN;
Satellite hubs:
IACMI Scale-Up Research Facility (SURF), Detroit, MI;
Michigan State University Composites Lab: Lansing, MI;
University of Dayton Research Institute's Composites Laboratory: Dayton, OH;
The Composites Manufacturing Education and Technology Facility (CoMET) at the National Renewable Energy Laboratory's National Wind Technology Center: Boulder, CO;
The Indiana Manufacturing Institute at Purdue University: West Lafayette, IN

Established: June 2015

Consortium Organizer: Collaborative Composite Solutions Corporation, a not-for-profit corporation under the University of Tennessee Research Foundation

Funding: $70 M federal over five years; $178+ non-federal support ($58 M+ from states and $120 M+ from industry over five years)

Members (as of September 30, 2017): 145

IACMI

Institute for Advanced Composites Manufacturing Innovation

iacmi.org

IACMI

Background

The Institute for Advanced Composites Manufacturing Innovation (IACMI) is committed to increasing domestic production capacity and manufacturing jobs across the U.S. composites industry. IACMI partners private industry with academic researchers and workforce development leaders to validate composites manufacturing materials and processes in vehicle, wind turbine, and compressed gas storage production that enables private industry to advance manufacturing techniques. Validation of these techniques and materials allow U.S.-based businesses to integrate the techniques into production, allowing the U.S. manufacturing industry to lead global competitiveness now and in the future.

Technology Advancement

"The partnership with IACMI—The Composites Institute and its vast group of partners provides access to unique research and development capabilities, ultimately resulting in a more efficient manufacture process for our organization."

– Gregory Haye, Local Motors General Manager

Projects Completed in 2017

Big Area Additive Manufacturing Materials Development and Reinforcement with Advanced Composites

Local Motors (Knoxville, TN), a technology company that designs and builds vehicles using local micro-manufacturing, leads this project, which developed composite materials, including reinforcements with advanced composites, for vehicle applications using large-scale additive manufacturing. The complementary impact across a broad range of manufacturing sectors from this project can lead to a 50 percent reduction in design-to-manufacturing cycle time. Other project partners include the University of Tennessee (Knoxville) and Oak Ridge National Laboratory (Oak Ridge, TN).

Composite Parts are Enabling Lower Cost, Lighter Weight, and Higher Volume Materials

IACMI's project to develop carbon fiber composite manufacturing process creates an ultra-fast way of producing lower cost continuous fiber reinforced polymer materials that conform well during molding with tremendous physical properties. This use of emerging materials and new approaches for fabric formation will potentially lower costs of high volume composites production by 20 percent. The project was led by DuPont Performance Materials (White Lake, DE) and supported by Fibrtec (Atlanta, TX) and Purdue University (West Lafayette, IN).

Development of Standard Evaluation Tools for High Volume, High Speed Inspection of Composite Components in Automotive

This IACMI project is creating low cost, rapid, automated techniques and standard evaluation criteria to determine part quality for large-scale manufacturing of composite components for vehicles. The criteria being developed for non-destructive evaluation and testing systems can be used to aid in selection of systems for other applications and will lower overall cost of production. This project was led by American Chemistry Council (Troy, MI) and supported by Vanderbilt University (Nashville, TN) and Plasan Composites (Wixom, MI).

New Projects in 2017

In FY 2017, IACMI launched 12 new projects. These projects addressing key challenges in the composites manufacturing, such as:

- **Novel Composite Products and Processes Enabling High Volume, Lightweight Automotive Parts** — Project partners including an OEM, material supplier, tier 1 supplier, academia and national laboratory work together to optimize carbon fiber production enabling high volume manufacturing of lightweight automotive components. The invention of unique chemistry and development of novel products and processes led to achievement of OEM specifications and demonstrated viability. Ford Motor Company, the project lead, is currently reviewing opportunities for broad implementation. Other project partners include Dow Chemical Company (Midland, MI), DowAksa (Farmington Hills, MI), Oak Ridge National Laboratory (Oak Ridge, TN), The University of Tennessee, Knoxville, Purdue University (West Lafayette, IN), and Michigan State University (East Lansing, MI).
- **Automated Preform Manufacturing Equipment for Recycling Scrap Pre-Preg** — The Composite Recycling Technology Center (Port Angeles, WA) leads a team pioneering ways to automate processing of carbon fiber scrap and remanufacture it into new consumer products. This automation is essential so that the 50 million pounds of carbon fiber scrap produced annually can be processed in high volumes, fulfilling the enormous potential for energy savings and carbon reduction and creating a global composites recycling industry. At the Automotive Lightweight Materials Summit in Detroit in August 2017, the team demonstrated the manufacture of an automotive seatback made from recycled carbon fiber composite using tooling supplied in partnership with IACMI. Other project partners include: The University of Tennessee, Knoxville and Oak Ridge National Laboratory (Oak Ridge, TN).
- **Project to Optimize Resins and Sizing for Vinyl Ester/Carbon Fiber Composites** — This project, led by Ashland Performance Materials (Columbus, OH), focuses on optimizing vinyl ester resins and fiber sizings for the fabrication of carbon fiber composites. The effort will identify styrene-free prepreg formulations with longer room temperature shelf life, shorter cycle times, and reduced cost. Advancements in these areas will increase productivity, decrease scrap and material costs, and enable adoption into the automotive industry. Other project partners include: Zoltek (Bridgeton, MO); Michelman (Cincinnati, OH); University of Dayton Research Institute (Dayton, Ohio); JobsOhio (Columbus, OH); and Michigan State University (East Lansing, MI)

Workforce Development

"After attending an outstanding event at last year's IACMI training workshop at the National Wind Technology Center, our team at Siemens Wind Power sent sixteen new employees to the 2017 workshop to gain experience and insight as part of their on-boarding program."

- Jacques Nader, Head of Boulder R&D Center, Siemens Gamesa Renewable Energy

In FY 2017, IACMI hosted more than 500 attendees at training workshops, organized 21 summer internship appointments at 7 academic and private industry locations. The institute also trained 120 current industry technicians and workers through an online training program partnership with Tooling-U SME.

Highlights from FY 2017 include:

- Hosted more than 480 kindergarten through high school students at STEM activities in Knoxville, TN and Detroit, MI for Manufacturing Day 2016.
- Placed 21 interns at academic labs and private industry for summer and long-term internships. The interns presented the research done during their internships to over 300 professionals and IACMI Members at the IACMI Summer 2017 Members Meeting in Dayton, OH.
- Held four Closed Mold Alliance training workshops, through a partnership with Composites One. During these workshops, composites technicians learned from composites researchers about new composite processing techniques, participated in live demonstrations of creating composites, and saw presentations given by members of private industry about their experiences integrating composites into their fields.

Innovation Ecosystem

"The diverse capabilities of IACMI-The Composites Institute and its partners, Oak Ridge National Laboratory and the University of Tennessee, Knoxville, allowed us to work full circle by utilizing reclaimed carbon fiber in the tooling and preforms to produce a lightweight automotive part. Combining reclaimed carbon fiber with 3D printing processes will greatly reduce the manufacturing time and cost demonstrating the viability of composite parts in vehicle light weighting."

– Jim Stike, President and CEO, Materials Innovation Technologies (Fletcher, NC)

Figure 39. Eleven industry partners collaborated on an IACMI project to create a nine-meter prototype wind turbine blade that validates speeded production times, reduced manufacture cost, and provides stronger, more energy efficient blades. Credit: IACMI

IACMI Team Combines Technologies to Create Prototype Nine-Meter Wind Turbine Blade

IACMI unveiled an innovative nine-meter wind turbine blade prototype. The turbine blade was fabricated at IACMI's Wind Technology Area in the Denver, Colorado area. Commercialization of the wind blade prototype created could speed production times, reduce manufacture cost, and provide stronger, more energy-efficient blades for the United States.

The new blade, molded on tooling supplied by TPI Composites, Inc., features innovations such as impact resistant components and continuous fiber reinforced thermoplastic parts. The blade was produced via pultrusion with the first textile PAN fiber made at Oak Ridge National Laboratory's Carbon Fiber Technology Facility.

This prototype was nominated for the Combined Strength Award at CAMX 2017, the nation's leading composites conference with more than 250 education sessions and more than 8,000 attendees.

This project was a partnership of 11 industry partners, including Arkema, Inc. (King of Prussia, PA); Johns Manville (Denver, CO); TPI Composites Inc. (Warren, RI); Huntsman Polyurethanes (Auburn Hills, MI); Strongwell (Bristol, VA); DowAksa USA (Farmington Hills, MI); Chomarat North America (Anderson, SC); Composites One (Arlington Heights, IL); SikaAxson (Madison Heights, MI); Creative Foam (Fenton, MI); and Chem-Trend (Howell, MI). Additionally, the project was supported by Oak Ridge National Laboratory (Oak Ridge, TN); the Colorado Office of Economic Trade and Development; and others.

Figure 40. The 4,000-ton Schuler press, located at IACMI's Detroit Scale-Up Research Facility (SURF) provides unique capabilities for manufacturing research and validation purposes. Credit: IACMI

Schuler Press Installed at IACMI's Scale-Up Research Facility

IACMI's Scale-Up Research Facility (SURF) in the Corktown neighborhood of Detroit installed a 4,000-ton Schuler hydraulic press in 2017. IACMI members have access to this state-of-the-art composite manufacturing equipment, where technology can be demonstrated on full-scale prototypes. The press can manufacture thin parts within limited tolerances for lightweight construction, for example, significantly below 0.01 inches. The press "brings a key composite manufacturing capability to the United States and being able to utilize the press is a significant opportunity for IACMI members working with compression molding projects," said Ray Boeman, Director of the IACMI Vehicle Scale Up Facility.

In FY 2017, IACMI worked closely with Lightweight Innovations for Tomorrow (LIFT), a DoD-sponsored Manufacturing USA institute headquartered in Detroit, MI, to complete an new IACMI/LIFT manufacturing innovation facility in Detroit, scheduled to open early in FY 2018.

The planned facility will house the IACMI Vehicles Scale-Up Facility, the research and development hub for the IACMI Vehicles Technology Area, which will include several large pieces of composites manufacturing equipment that will be made available for development of materials and processes for automobile composites production. The centerpiece is a 4,000-ton press, designed for high-pressure resin transfer molding, sheet molding compound and thermoplastic compression molding. Facility users will also have access to an injection molding machine

Figure 41. IACMI hosted more than 500 attendees at Closed Mold Alliance training workshops throughout the United States in 2017. Credit: IACMI

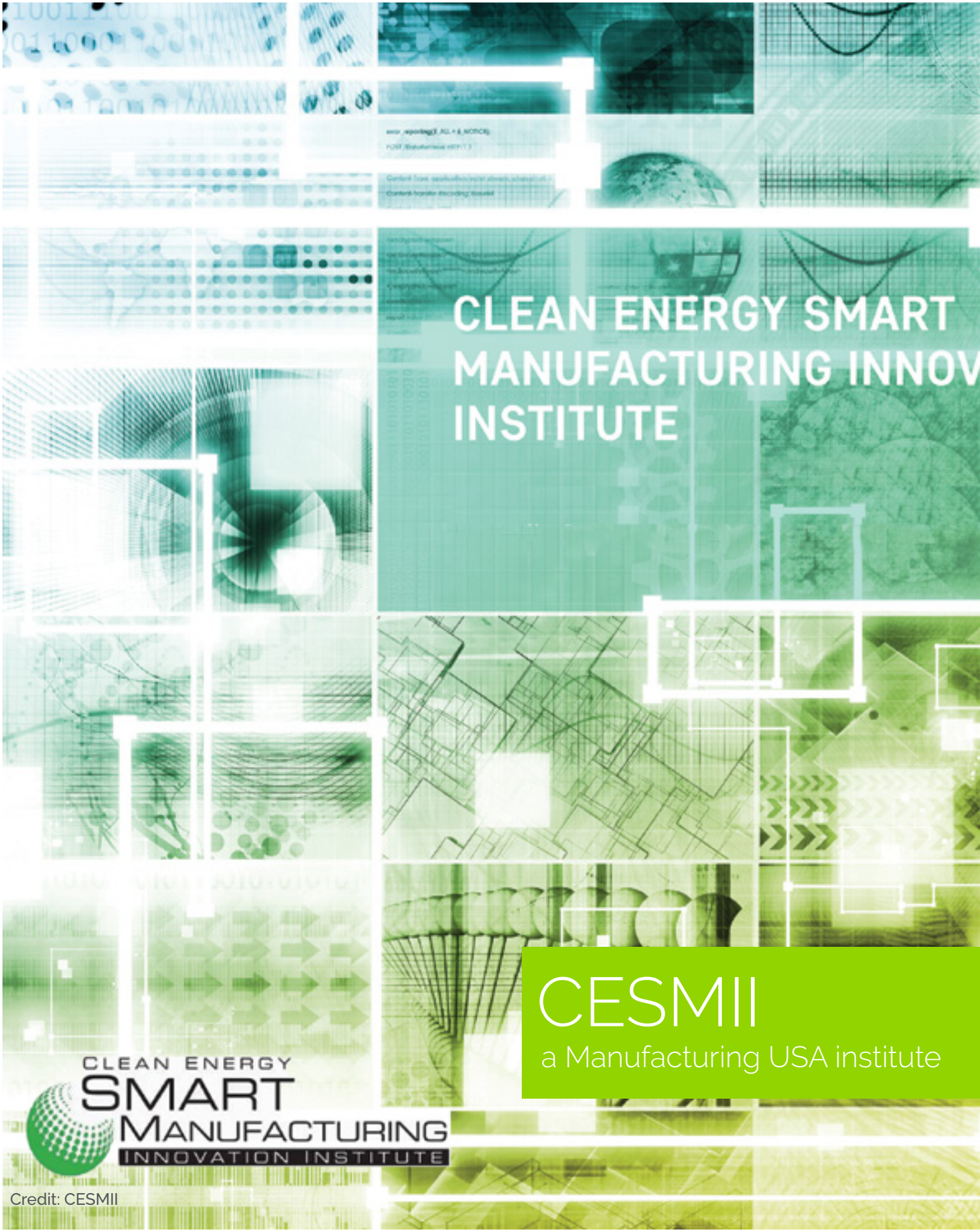
Closed Mold Alliance Training Workshops

In 2017, IACMI hosted more than 500 attendees at the Closed Mold Alliance training workshops. The Closed Mold Alliance is a partnership of IACMI, Composites One (Arlington Heights, IL), and Magnum Venus Products (Knoxville, TN), and serves to train technicians and those who work, or are transitioning to work, in the composites industry.

Closed Mold Alliance Workshops specialize in each of IACMI's technology areas and are held in various locations throughout the United States to better serve a range of communities. Closed Mold Alliance Workshops in 2017 were held at University of Dayton Research Institute, Vanderbilt University (Nashville, TN), the National Renewable Energy Laboratory (Lakewood, CO), and Michigan State University (Lansing, MI). Attendees include those from organizations including Tesla (San Carlos, CA); Ashland Performance Materials (Columbus, OH); Dassault Systèmes (Auburn Hills, MI); Wabash (Wabash, IN); General Motors (Detroit, MI); Siemens Energy (Boulder, CO); and others.

with a 6-axis robot for part removal and, eventually, preform insertion for injection overmolding applications, a Preform Lab including a prepreg machine, and a range of other cutting-edge equipment for composites development.

All this equipment will be made available to IACMI members on a project basis to develop and evaluate materials and processes for the high-volume manufacture of composite parts and structures for cars and trucks. Members will be supported by knowledgeable engineering staff and have ease of access to composites research and development unavailable anywhere else in the U.S.



Credit: CESMII

CLEAN ENERGY SMART MANUFACTURING INNOVATION INSTITUTE™

CESMII

Mission: Radically accelerate the development and adoption of advanced sensors, controls, platforms, and models to enable Smart Manufacturing to become the driving, sustainable engine that delivers real-time business improvements in U.S. manufacturing

Locations: Headquarters: Los Angeles, CA;
Regional Manufacturing Centers:
California – California Manufacturing Technology Consulting in Los Angeles, CA;
Northeast – Rensselaer Polytechnic Institute in Troy, NY;
Southeast – North Carolina State University in Raleigh, NC;
Gulf Coast – Texas A&M University in College Station, TX;
Northwest – Washington State University Energy Programs in Olympia, Washington

Established: December 2016

Consortium Organizer: Smart Manufacturing Leadership Coalition

Funding: Federal, $70M; Non-federal, $70M+ (planned funding over five years)

Members (as of September 30, 2017): 31

Clean Energy Smart Manufacturing Innovation Institute

cesmii.org

CESMII

Institute Overview

"Smart manufacturing makes it possible for companies to reduce their energy use and save money on their energy bills by optimizing their manufacturing processes. In fact, increased investments in Smart Manufacturing could save American manufacturers $15 billion in annual electricity cost savings by 2035."

– Ethan Rogers, Industry Program Director, American Council for an Energy-Efficient Economy

CESMII focuses on developing and deploying integrated advanced sensors, controls, platforms, and high performance computational models to help U.S. manufacturers benefit from smart manufacturing, making them more competitive globally. With smart manufacturing, manufacturers optimize their business, technology, infrastructure, and workforce practices using engineered systems that integrate operational technologies and information technologies.

CESMII is at the forefront of a new industrial revolution, helping manufacturers of all sizes, and across all industry sectors, in bringing together operation and information technologies built on the open Smart Manufacturing Platform™ to create radically smarter, more productive, and more energy efficient production systems and domestic supply chains across U.S. industry. This new industrial revolution is empowering workers from the plant floor to the corporate's senior executives with actionable information for real-time decision-making. This transformation aims to unlock the true potential of our people, processes, and technology by transcending barriers of cost, risk, and accessibility.

Figure 42. CESMII has operational units focused on technology for operations and information, research and development, and workforce development. Credit: CESMII

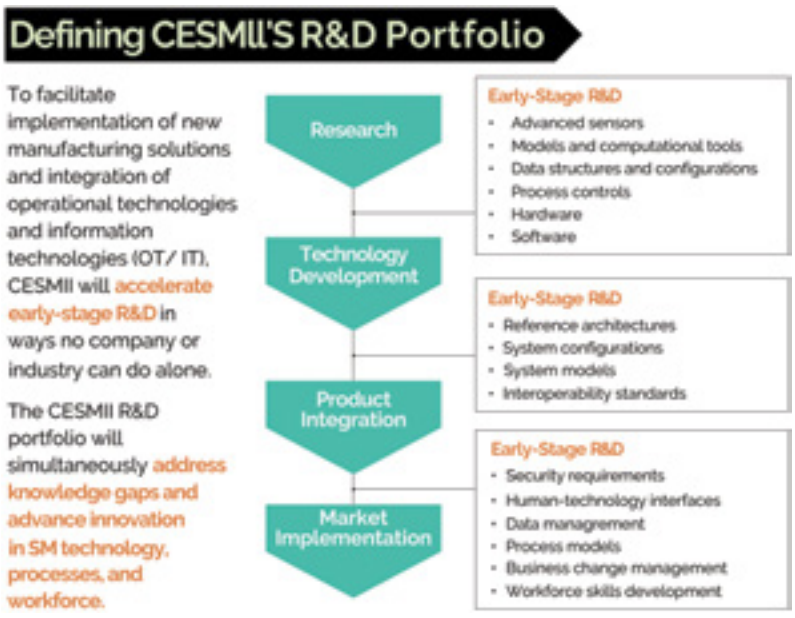


Figure 43. CESMII will focus on critical elements of early-stage research to address knowledge gaps and advance innovation in smart manufacturing. Credit: CESMII

Technology Description

"We're eager to share Savigent Technology and our passion for smart manufacturing with the CESMII network. These projects and initiatives will validate and increase productivity, energy efficiency and overall profitability, significantly improving the capabilities of participating U.S. Manufacturing companies and their supply chain."

– Mark Besser, Vice President of Customer Success, Savigent Software (Bloomington, MN)

Smart manufacturing is manufacturing in 2030, bringing together operation and information technology to the factory floor. CESMII's goals include a 50 percent reduction in cost and time to deploy smart manufacturing in existing processes within 5 years, lowering the risk of adopting of these powerful technologies.

Through a national network of regional manufacturing centers, CESMII experts provide members with expertise, training, and guidance in real-time. Strategically located across the country, the centers work directly with members to plan, develop, and implement their smart manufacturing solutions. The centers are closely coordinated with CESMII headquarters.

The CESMII Kick-off meeting in February 2017 brought together partners from CESMII's national network to learn about the institute's goals and the value of participating with the institute. Executives from industry, academia, national labs, national associations, and government agencies contributed to plan next steps in working together. Leaders from across the nation shared why smart manufacturing is critical to the future of manufacturing innovation, sustainability and growth.

Applications

CESMII integrates advanced sensors, controls, platforms, and modeling across a diverse portfolio of projects to achieve widespread smart manufacturing adoption and industry driven transformation. CESMII leverages an open platform and marketplace for industrial applications to give users and providers secure access to new business opportunities and solutions that optimize energy productivity, efficiency, and other operations.

CESMII's smart manufacturing tools integrate with the installed base of equipment for small, mid-sized and large manufacturers. Our testbeds, regional resources, and expertise create an environment where smart manufacturing concepts can be developed, validated, tested, and implemented to ensure scalable, repeatable solutions to industry challenges. In addition to developing new tools and solutions, CESMII lowers the barriers for all providers and users that want to create new tools or adopt existing tools like advanced data analysis, modeling, and simulation, and creates an environment where energy and other challenges can be optimized.

Early Actions

Membership

A robust membership drive took place in late FY 2017 resulting in a rapid increase in members at all levels. Many new organizations, including a cross section from academia, industry, non-profits, and national labs, have expressed a desire to join.

Member affinity groups were formed to better understand the barriers and opportunities for implementing smart

manufacturing technologies by specific industries. These groups proved beneficial for generating communication amongst industry competitors as they tackle challenges as a collective.

CESMII is planning its first members meeting in 2018, which will provide an opportunity for networking, collaboration, and coordination among members and prospective members alike.

Roadmapping

The CESMII Roadmap[50] completed in August 2017, serves as a blueprint for CESMII's technology priorities, business practices, and workforce training needs.

The Roadmap outlines CESMII's four strategic objective areas that underpin Smart Manufacturing:

- **Business Practices** — Develop a clear and compelling smart manufacturing value proposition; address and mitigate business risks; and provide strategies and tools and best practices for smart manufacturing integration and cyber security to facilitate widespread smart manufacturing integration.
- **Enabling Technologies** — Advance key smart manufacturing technologies, including advanced sensors, data analytics tools, process controls, models, and computational platforms for integration into robust, secure and easy-to-configure smart manufacturing systems through collaborative development.
- **Workforce Development** — Develop and continuously update and deploy customizable, interdisciplinary training, resources, and programs to create an innovative, skilled workforce with expertise in smart manufacturing technologies and practices.
- **Smart Manufacturing Platform Infrastructure** — Build a unified Smart Manufacturing Platform marketplace and ecosystem for enterprise data, technologies, and cyber-physical systems to enable cost-effective and time-efficient deployment of functional systems.

Demonstration/ Platform Development

CESMII will enable manufacturers to develop and deploy their own products and solutions using the revolutionary Smart Manufacturing Platform ecosystem in their own industrial settings to achieve new cross-industry benchmarks to dramatically improve safety, energy efficiency, environmental sustainability, operational performance, and economic productivity. The Smart Manufacturing Platform supports delivering real-time applications involving multiple modeling products and multiple data sources by providing reusable infrastructure for interconnecting, ingesting, contextualizing, provisioning, and orchestrating data and models in a workflow environment for integrating operational technologies and information technologies.

CESMII formalized the Smart Manufacturing Platform environment descriptions and is developing the core operational technologies necessary for operating the platform. Using the additive manufacturing line operation at the Gulf Coast Regional Manufacturing Center at Texas A&M University, CESMII demonstrated that the institute's workflow orchestration capability could optimize an additive manufacturing line operation. The Smart Manufacturing Platform used data from operating machine tools to generate real-time usable material characterization displays for machine operators.

[50] Roadmap: 2017-2018, Clean Energy Smart Manufacturing Innovation Institute, p. 24 (2017), https://www.cesmii.org/cesmii-roadmap/

Figure 44. CESMII is working to optimize manufacturing and increase energy productivity by focusing on enabling technologies, building smart manufacturing infrastructure, and workforce development. Credit: CESMII

Workforce Development

"CESMII plays a critical role on the technology front, which is an important part of the smart manufacturing journey. But, it's not the only important part. MESA has spoken with the voice of industry's practitioners for 2 ½ decades, and our members have plenty to say about operational, organizational, and cultural issues that are equally as daunting as any technology challenge. We plan to lend that voice as a strong complement to the great work CESMII is doing."

– Mike Yost, President, MESA International (Chandler, AZ)

In addition to completing a workforce development strategic plan, CESMII entered into an innovative partnership with MESA International to collaborate on sharing and developing smart manufacturing curriculum resources and content. MESA, a 26-year-old industry-driven nonprofit, has long been recognized for generating peer-reviewed, non-commercial content aimed at sharing lessons learned and best practices in leveraging modern information technologies in manufacturing enterprises Other scientific societies, and industry and trade organizations will be evaluated and pursued in the coming years.

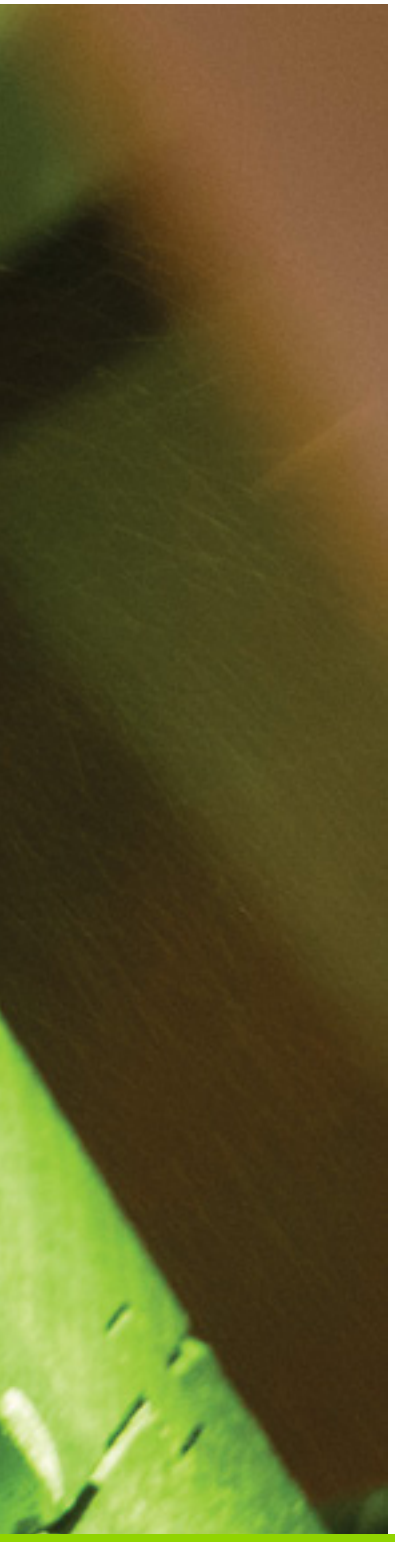
The Future

CESMII's first project call of $10.5 million, expected in late 2017, will extend the Smart Manufacturing Platform's core capabilities by adding application-to-application interoperability, data contextualization, and analytics. With the selection of 10 to 15 roadmap projects scheduled for early 2018, CESMII will have ongoing research and development projects underway throughout 2018.

REMADE

a Manufacturing USA institute

Credit: REMADE



REMADE INSTITUTE

Mission: Enable the early stage applied research and development of key industrial platform technologies that could dramatically reduce the embodied energy and carbon emissions associated with industrial-scale materials production and processing.

Location: West Henrietta, NY

Established: May 2017

Consortium Organizer: Sustainable Manufacturing Innovation Alliance

Funding: Federal, $70M; Non-federal, $70M (planned funding over five years)

Members (as of September 30, 2017):[51] 0

REMADE

Reducing Embodied-energy And Decreasing Emissions

remadeinstitute.org

[51] REMADE welcomed its first members in October 2017. As of December 2017, the institute had 32 members.

REMADE

"REMADE's collaborative consortium and early-stage research will provide us with innovative new ways to address industry challenges and remanufacturing technologies that can extend the life of our products and improve energy efficiency in our processes."

– John T. Disharoon, Director Market Access, Caterpillar Inc. (Peoria, IL)

The REMADE institute is working to improve U.S. manufacturing competitiveness by partnering with industry to develop advanced manufacturing technologies that incorporate energy-reduction and sustainability principles. REMADE aims to drive down the energy and cost required to recover, reuse, remanufacture and recycle four classes of materials: metals, fibers, polymers, and electronic waste.

In conjunction with the development of innovative technologies and subsequent training, REMADE is working to enable the U.S. workforce to access the latest breakthroughs in manufacturing and related fields.

To help reduce the embodied energy (i.e., the sum of all energy required to produce any goods) and the associated emissions associated with materials manufacturing and to improve U.S. manufacturing competitiveness, the institute established the following goals:

- Develop technologies capable of reducing energy related emissions through a reduction in primary material consumption and an increase in secondary feedstock use in energy-intensive industries.
- Develop technologies for secondary feedstock production that require less energy and are cost-competitive with primary feedstocks.
- Promote widespread application of new enabling technologies across multiple industries.

Technology Description

"As a founding member of the REMADE institute, ISRI has long recognized REMADE's great potential to spur advanced recycling technologies that will increase recycling activity, especially for currently difficult to recycle materials. ISRI looks forward to being part of REMADE's success in advancing recycling and sustainable materials manufacturing."

– David L. Wagger, Ph.D., Chief Scientist, Director of Environmental Management, Institute of Scrap Recycling Industries, Inc.

U.S. manufacturing accounts for nearly 25 percent of the nation's total annual energy use. The physical products that are created and manufactured embody most of that energy. Research and deployment of cost-effective technologies could reduce the energy used in materials production and offer significant savings to U.S. manufacturers annually.

Traditionally, original equipment manufacturers have focused their design efforts on product performance, quality, and cost. With products now routinely required to perform for multiple lifecycles, designers are recognizing the central role that design can play in enabling recycling, recovery, reuse, and remanufacturing at product end-of-life. To achieve this, products must be designed for disassembly and for the total lifecycle, which may require components to be remanufactured. This life cycle approach takes advantage of the initial material, design, and process investments while saving on the total replacement cost.

By improving recycling and remanufacturing technologies, the lifecycle energy consumption for products can be greatly reduced. For example, extracting and processing raw materials like aluminum for manufacturing consumes 10-20 times more energy than is required when recycled aluminum is utilized. Improvements can also be made in overall manufacturing efficiencies, enabled by new methods for information collecting, gathering, identification, and sorting of end-of-life and waste materials.

To achieve its goals, the REMADE institute has organized its research and development around five focus areas:

- Design for recovery, reuse, re-manufacturing, and recycling — Research and development of design tools to improve material utilization at product end of life.
- Manufacturing materials optimization — Technologies to reduce in-process losses, reuse scrap materials, and utilize secondary feedstocks in manufacturing.
- Remanufacturing and end-of-life reuse — Efficient and cost-effective technologies for cleaning, component restoration, condition assessment, and reverse logistics.
- Recycling and recovery — Rapid gathering, identification, sorting, separation, contaminant removal, reprocessing, and disposal of manufacturing materials.
- Systems analysis and integration — Data collection, standardization, metrics, and tools for understanding material flow.

The first four are aligned with the material lifecycle stages and the fifth will develop a consistent set of protocols, data sets, and tools for quantifying material flows and the lifecycle impacts of institute activities. This framework will allow REMADE to address the cross-cutting challenges that occur at each stage of the material lifecycle for metals, polymers, fibers, and electronic waste.

Applications

Worldwide demand for aluminum, paper, and steel is expected to grow two to three times by 2050. Today, the United States is dependent on foreign countries to supply 100 percent of its material needs for 18 commodities, and it is more than 50 percent reliant on imports for another 22 commodities.[52]

By developing cost-competitive technologies that enable increased recycling, recovery, reuse, and remanufacturing of energy-intensive materials required to manufacture our automobiles and produce our steel, the REMADE institute is positioning manufacturers to help the U.S. reduce its dependence on imports, compete globally, and reduce the energy required to manufacture its products.

[52] Minerals Commodity Summaries 2016, U.S. Geological Survey, p. 6 of 201 (2016), https://minerals.usgs.gov/minerals/pubs/mcs/2016/mcs2016.pdf, Mineral commodity summaries 2016: U.S. Geological Survey, 202 p. 6, http://dx.doi.org/10.3133/70140094

In FY 2018, REMADE will focus on the following cross-cutting themes: 1) materials processing and recovery techniques; 2) characterization, qualification and inspection; 3) simulation and engineering analysis tools; 4) value chain integration and impact; and 5) workforce development.

Early Actions

The REMADE institute's focus on supporting U.S. manufacturing with more efficient technologies and processes for industrial reuse and recycling is very much in line with our institution's values and commitment to our region. Monroe Community College is partnering with REMADE to integrate new and emergent technologies into our technician and engineering curricula, supplying our local manufacturing community with graduates educated in these relevant technologies and best practices around industrial-scale sustainable manufacturing.

– Todd Oldham, Vice President, Economic Development; Workforce and Career Technical Education, Monroe Community College (Rochester, New York)

FY 2017 was an exciting time for REMADE as it began the process of establishing itself and proceeding through the startup operations. Leadership positions were filled, a governance structure was established, and the DOE approved the intellectual property management plans and membership agreements in preparation for new members.

Rochester Institute of Technology successfully completed the transition of the leadership of the institute, including finance functions, contract administration, marketing and communications, and overall operations, to the Sustainable Manufacturing Innovation Alliance. The Sustainable Manufacturing Innovation Alliance's first board meeting was held September 22, 2017.

In preparation for the FY 2018 Technology Research and Development activities, REMADE established a process for issuing project calls, solicited proposals for foundational projects, and provided feedback to the proposal teams.

Membership

Negotiations with potential members from across the remanufacturing, reuse, and recycling ecosystem including industry, academia, and trade associations are in progress.

Roadmapping

In September 2017, the institute hosted a technology roadmapping workshop in Rochester, New York that welcomed over 100 participants from companies, universities, associations, and national labs. Challenges and insights from that session are being incorporated into a technology roadmap that will guide institute research activities and future project calls that will address key challenges and enable the institute to meet its technical performance metrics.

Credit: REMADE

Workforce Development

In FY 2018, the REMADE institute plans to form a workforce development advisory committee and prepare an Education and Workforce Development plan that will focus on occupations, competencies and career pathways of interest to the institute. As part of this process, the institute plans to partner with the National Coalition of Advanced Technology Centers to engage two-year post-secondary institutions who have historically invested in curricula, training and apprenticeship programs targeted to remanufacturing and recycling technology.

The Future

The REMADE institute's technology roadmap, first project call and project selections will be completed in early FY 2018. In addition, all governance and advisory committees will be established to ensure the goals and objectives set forth by the institute are achieved.

RAPID

a Manufacturing USA institute

Credit: RAPID

RAPID
Transforming Process Industries

Mission: Advance Modular Chemical Process Intensification (MCPI) technologies to reduce energy consumption, improve process efficiencies, and lower investment and operating requirements.

Location: New York, NY

Established: March 2017

Consortium Organizer: American Institute of Chemical Engineers (AIChE)

Funding: Federal, $70M; Non-federal, $70 M (planned funding over five years)

Members (as of September 30, 2017): 47

RAPID

Rapid Advancement in Process Intensification Deployment Institute

aiche.org/rapid

RAPID

Technology Description

"RAPID enables R&D collaborations with partners by helping to simplify a process that can be daunting to a small company. It's a significant benefit for a small business like ours."

– Dr. Hannah Murnen, VP – Business Development, Compact Membrane Systems (Newport, DE)

The Rapid Advancement in Process Intensification Deployment (RAPID) manufacturing institute leads a national effort focused on the research, development, and implementation of high impact technologies and hardware equipment solutions that enable advances in the process industries—notably, chemicals, oil and gas, pulp, and paper. Process industries are facing fierce global competition and require innovation and investment, yet progress has remained stagnant in these industries due to factors such as prohibitive capital costs, the high complexity of intensified modular systems, and insufficient software, design tools and data.

The RAPID Institute ensures that American manufacturing remains vital and robust by fostering an intellectually diverse and engaged community focused on a shared goal: Modular Chemical Process Intensification (MCPI). RAPID focuses on the development of standardized modular components and other hardware prototypes that can increase efficiencies in six key technical focus areas: chemical and commodities processing, renewable bioproducts, natural gas upgrading, module manufacturing, intensified process fundamentals, and modeling and simulation.

The potential benefits of MCPI to industry and society are many: lowered capital and operating costs; improved process and energy efficiencies; reduced waste and a decreased carbon footprint. Equally important, RAPID's work will result in enhanced global competitiveness and a better educated workforce capable of operating these new technologies and cutting-edge equipment.

Early Actions

"I have been impressed with the level of engagement and intellectual stimulation between academic institutions like Iowa State University and RAPID industry partners. We've been able to put theory into practice and develop commercial applications from our research based on the substantive feedback and input we have received through our involvement with RAPID."

– Professor Robert C. Brown, Director, Bioeconomy Institute, Anson Marston Distinguished Professor of Engineering, Iowa State University

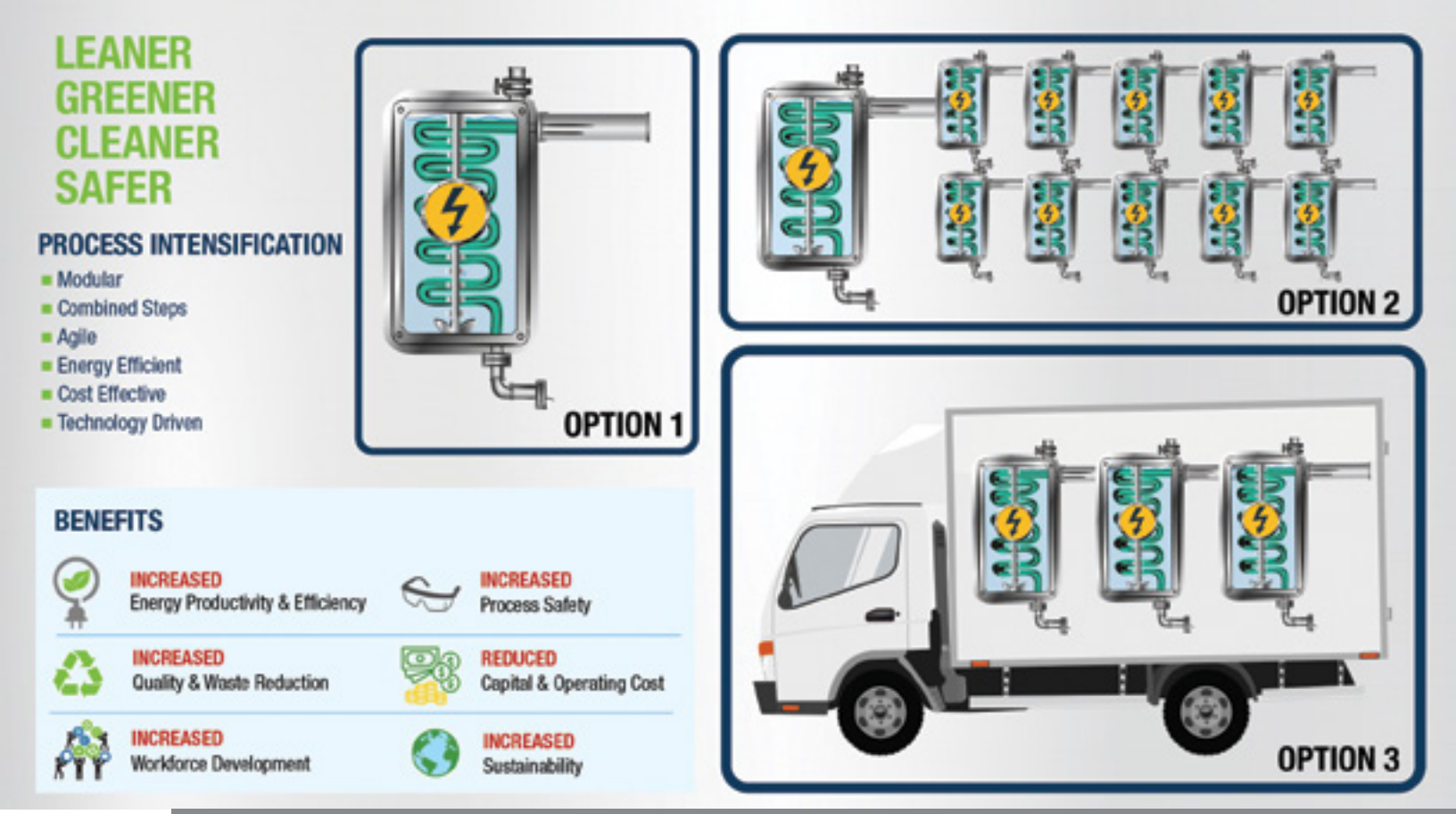


Figure 45. Modular chemical process intensification (MCPI) provides a new paradigm for leaner, greener, cleaner, and safer manufacturing. MCPI uses standardized modular components and other hardware prototypes to increase efficiency and flexibility while reducing costs. MCPI reactors can be used in a variety of configurations as single units (option 1), in different combinations (option 2), and even as portable systems (option 3). Credit: RAPID

Immediately after its inception, the RAPID Manufacturing Institute in conjunction with the Department of Energy and the American Institute of Chemical Engineers (AIChE), drafted action plans allowing it to serve members in a more comprehensive and strategic way. From day one, RAPID established a solid infrastructure with effective governance including a governing board, a technical advisory board, and governing by-laws. It also established legal, intellectual property and membership documentation bolstered by effective communications to ensure that members were informed about important issues every step of the way. Finally, RAPID developed roadmaps for six critical technical focus areas and workforce development.

Four projects have been selected as jump starts for FY 2017, with 21 additional projects identified for funding to begin in FY 2018. Examples of projects that demonstrate the institute's mandate of creating paradigm shifts in manufacturing are:

- RAPID members Praxair (Danbury, CT) and Georgia Tech (Atlanta, GA) will focus on developing energy-efficient separation technology, reducing potential environmental issues by allowing broader use of nitrogen instead of water to fracture for natural gas from unconventional sources, such as shale and other low permeability rock formations.

- RAPID members at Iowa State's Bioeconomy Institute (Ames, IA), along with Easy Energy Systems (Emmetsburg, IA), are developing a modular system to convert biomass into sugars and other value-added products. The project can provide new markets for the makers of modular manufacturing systems as well as new uses for agricultural residues such as corn stover (plants and plant parts left in the field after harvest). The goal is to design modular energy production systems (MEPS) capable of processing 50 tons of stover per day. These MEPS will fit inside standard shipping containers so they can be easily delivered and installed close to the source of biomass.

- RAPID members Oregon State University (Corvallis, OR), Pacific Northwest National Lab (Richland, WA), and STARS Technology Corporation (Richland, WA) are taking a novel technology for the solar thermal conversion of natural gas to hydrogen and defining a manufacturing plan that will allow for broad commercial deployment. Projections show an opportunity to produce the two largest components at nearly 1/10th of the current cost if the manufacturing technology and associated supply chain are in place.

- RAPID members Dow Chemical Company (Midland, MI) and the University of Texas at Austin are leading a project on the use of modeling and optimization to define process intensification opportunities in existing hardware for advanced distillation systems.

Membership

RAPID methodically seeks to create a balance of public and private member organizations that can enrich both the chemical community and American manufacturing as a whole. By bringing together recognized thought leaders from within industry, academia and other sectors, greater synergies have been captured and leveraged.

Roadmapping

To ensure the creation of a high-impact project portfolio, RAPID undertook a structured roadmapping process. Workshops were held, attracting 125 participants from over 30 companies, 28 universities, and 11 federal agencies to reach the following goals:

- Define gaps within each of the six focus areas that are large enough to have a significant impact if addressed and that can be bridged to make a significant contribution to modular chemical process intensification;

- Identify which of these gaps span focus areas and have the potential to create the broadest benefit if addressed; and

- Align RAPID members on which gaps are the most relevant to allow for prioritization.

- The roadmap end product is a set of gaps or areas designated for improvement that was used to guide project selection in the fall of 2017.

Figure 46. Researchers from RAPID members Praxair and Georgia Tech (led by Professor Krista Walton, shown here) are using a proprietary nitrogen adsorbent to scale down a pressure swing adsorption system for use in removing nitrogen well head natural gas. Image credit: Georgia Tech.

Workforce Development

"We must find ways to engage talented young people who can contribute to innovation within the manufacturing sector of the Chemical Process Industries. RAPID's focus on educating and training this next generation of PI leaders through webinars, workshops and other activities is critical in making that happen."

– Paul Dimick, General Manager, IntraMicron, Inc. (Auburn, AL)

Education is crucial to American competitiveness and RAPID recognizes the importance of establishing a technical education and workforce development (EWD) program that will leverage existing resources to train a skilled and knowledgeable workforce that can research, develop, and operate new process intensification and modular chemical process intensification (MCPI) solutions widely within U.S. industry. We have the following activities planned for 2018:

- A 10-part Process Intensification Webinar Series
- A Fundamentals of Process Intensification eLearning Course
- A Teaching the Fundamentals of Process Intensification Faculty Workshop @ AIChE Annual Meeting

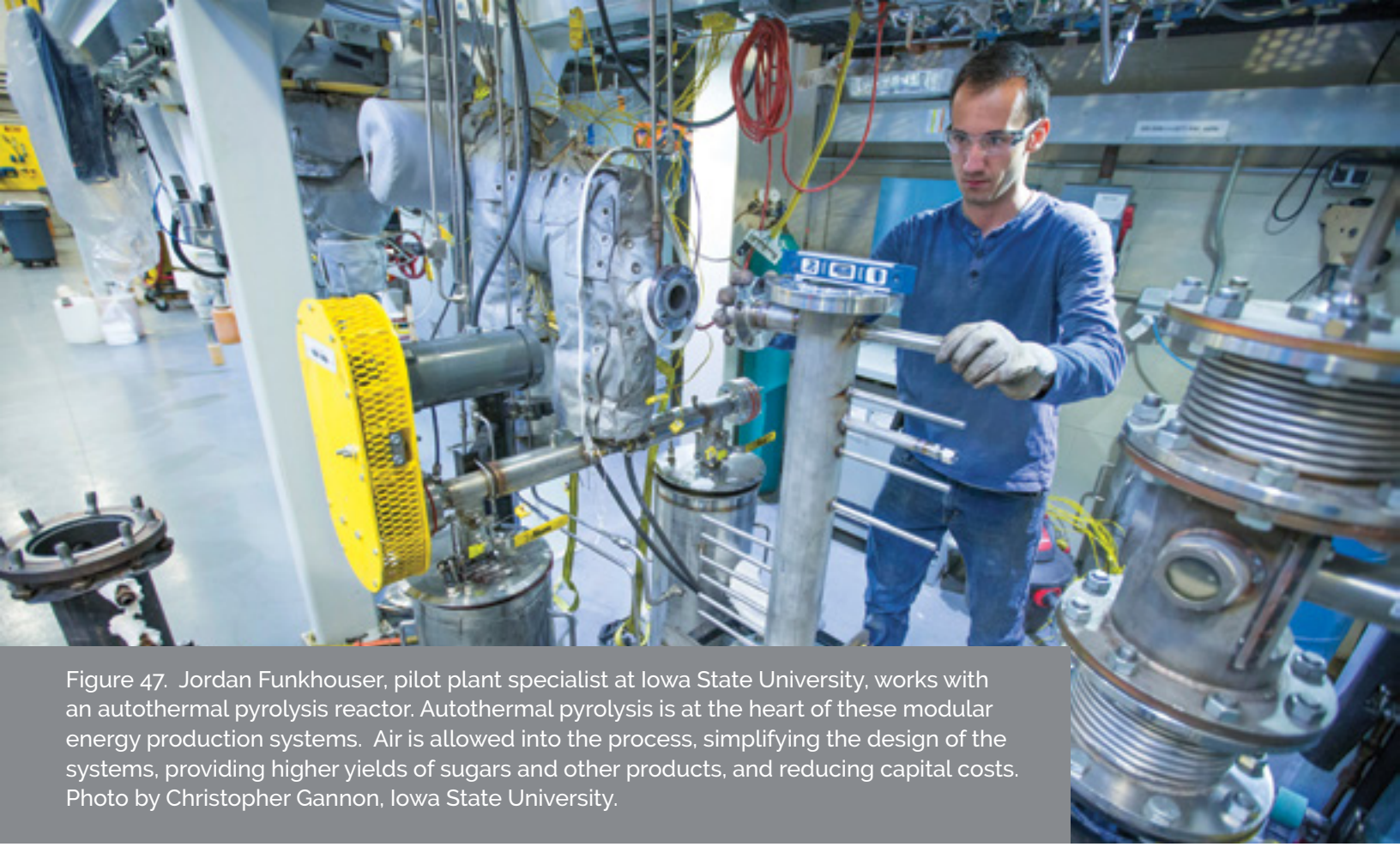


Figure 47. Jordan Funkhouser, pilot plant specialist at Iowa State University, works with an autothermal pyrolysis reactor. Autothermal pyrolysis is at the heart of these modular energy production systems. Air is allowed into the process, simplifying the design of the systems, providing higher yields of sugars and other products, and reducing capital costs. Photo by Christopher Gannon, Iowa State University.

- A Challenges of EWD in Process Intensification & MCPI Panel Session at the AIChE Spring Meeting
- A Pilot Summer Intern Program

The Future

Unleashing the power of U.S. ingenuity through process intensification officially began with an open call for project submissions in late FY 2017. Numerous activities are planned for FY 2018, including: 1) convening members at the AIChE Annual Meeting to discuss selected jump start projects, new project submissions, and review opportunities for 2018; 2) formal interaction with the Oregon, New York, and Iowa State Manufacturing Extension Partnership (MEP) organizations. MEP representatives from all three states will begin mapping areas of potential impact; 3) the formal acceptance of the EWD Roadmap by the Technical Advisory Board; 4) hosting a two-day Manufacturing USA EWD Directors meeting in New York with representation from across the Manufacturing USA institutes as well as representatives from the departments of Defense, Commerce, Energy, Labor, and other governmental agencies.

APPENDIX A
EXTERNAL STAKEHOLDERS MEETINGS

Advanced Robotics in Manufacturing: Enabling New Technology and Increased Opportunity

Organizer: House Manufacturing Caucus and Senate Competitive Caucus, Sponsored by ASME

Purpose: Highlight the importance of advanced robotics in manufacturing and identify R&D and workforce development issues

Topics: What the manufacturing industry might look like in the future; what impact robotics could have on the manufacturing jobs; and how small and medium-sized companies can best be helped to succeed with — and adapt to — new technologies.

Speakers: Senator Chris Coons (DE), Howie Choset, Professor of Robotics at Carnegie Mellon University, Larry Sweet, Professor of the Practice in Robotics at Georgia Institute of Technology; Erik Nieves, founder and CEO of PlusOne Robotics; and Michael Dudzik, President of the Scientific Research Institute IQM; Chuck Thorpe, Senior Vice President and Provost of Clarkson University; and Keith Rowe, President of ASME.

Date: December 13, 2016

Remarks: Well attended by over 100 House and Senate staff as well as representatives from various private and public organizations.

Improving the Energy Productivity and Competitiveness of U.S. Manufacturers

Organizer: House Manufacturing Caucus

Purpose: Improving the competitiveness of our nation's manufacturers and manufacturing workforce

Topics: High Performance Computing Applications in Steel; The US Dept. of Energy Industrial Assessment Center program; The Biggest and Best 3D Printer in the World, BAAM; How the DOE and Cyclotron Road Advance US Hard Technology Development; and Th Business Value of Manufacturing USA.

Speakers: Larry Kavanagh, Steel Market Development Institute; Bryan P. Rasmussen, Texas A&M University; Richard Neff, Cincinnati, Inc.; Chris Kaffer, Mallinda; Steven Betza, Lockheed Martin, Mark Johnson, DOE Advanced Manufacturing Office.

Date: January 24, 2017

Remarks: Well attended by over 100 House and Senate staff as well as representatives from various private and public organizations.

Responding to Global Manufacturing Challenges: The Business Case for Manufacturing USA

Organizer: Senate Competitive Caucus and House Manufacturing Caucus

Purpose: Industry perspective on the success of 14 established institutes that are engaged with industry to advance critical technologies and grow emerging industries in the United States. These private-public partnerships increase competitiveness, accelerate technology transfer, and train the manufacturing workforce.

Topics: The rationale for private investment, industry-wide benefits realized to date, and how the institutes are advancing these critical technologies and key industries.

Speakers: Senator Chris Coons (DE), Senator Dick Durbin (IL), Representative Tim Ryan (OH).

Recurrence: Major General Nick Justice, Chair, Institute Directors Council and Executive Director, PowerAmerica; Kelly Marchese, Principal, Deloitte; Carolynn Nowinski Collens, CEO, UI Labs; Kelvin Lee, NIIMBL Institute Director and Gore Professor of Chemical and Biomolecular Engineering, University of Delaware; Jorg Thommes, Senior Vice President at Visterra; and Raj Batra, President of Siemens USA's Digital Factory business.

Date: March 1, 2017

Remarks: Attended by over 150 House and Senate staff as well as representatives from various private and public organizations.

Cyber Security for Manufacturers: Creating the Secure Factory

Organizer: House Manufacturing Caucus, Sponsored by MForesight

Purpose: Discuss a range of cyber-security issues facing U.S. manufacturers

Topics: Emerging cyber-threats to manufacturing systems; potential collaborations and investments to accelerate development of tools to prevent; manufacturing-specific cyber-attacks; implementation of security tools by small and medium sized manufacturers (SMMs) to protect the entire supply chain; and effective cyber-intelligence methods for prioritizing and sharing future threats and solutions.

Speakers: Sridhar Kota, Exec. Director, MForesight; Michael Russo, Corporate Lead – Govt. & Regulatory Affairs, Global Foundries; Kevin Fu, Prof. of Electrical Eng. & Computer Science, University of Michigan; and Kirk McConnell, Senate Armed Services Committee.

Date: April 12, 2017

Remarks: Attended by over 80 House and Senate staff as well as representatives from various private and public organizations.

Building America's Skilled Technical Workforce'—A new report from the National Academies

Organizer: House Manufacturing Caucus, Sponsored by the National Academies of Sciences, Engineering and Medicine

Purpose: Examine the coverage, effectiveness, flexibility, and coordination of the policies and various programs that prepare Americans for skilled technical jobs; and provide recommendations to improve the image, training, and deployment of the nation's skilled technical workforce within our federal system of governance and market-driven economy.

Topics: Workforce development challenge, understanding the scale and dynamics of the skilled technical workforce, as well as the complex and rapidly changing environments within which Americans provide and acquire skills and training for the jobs of the future.

Speakers: Harry Holzer, the John LaFarge Jr. Professor of Public Policy at Georgetown University; and Sujai Shivakumar, Director, Study on Supply Chain for Middle-Skill Jobs, National Academies of Sciences, Engineering & Medicine.

Date: May 19, 2017

Remarks: Attended by over 50 House and Senate staff as well as representatives from various private and public organizations.

Manufacturing USA: Securing Advanced Manufacturing in the United States

Organizer: U.S. National Academies of Sciences, Engineering, and Medicine

Purpose: Bring together representatives of government, industry, national laboratories, research institutes, and universities—foreign and domestic—to exchange views on current challenges and opportunities for Manufacturing USA.

Topics: 1. Manufacturing USA institutes 2. Regional Economic Development, 3. Assessing Manufacturing USA institutes. 4. Advanced Manufacturing strategies worldwide. 5. Policy Roundtable

Speakers: David Hart, George Mason University and Innovation Policy Forum co-chair; Jeffrey Wilcox, Lockheed Martin; Ravi Shanker, Dow Chemical; Lawrence Brown, LIFT; Yoel Fink, AFFOA; Maj.-Gen Nickolas Justice, USA, Ret., PowerAmerica; Kelvin Lee, NIIMBL; David Hart, George Mason University and Innovation Policy Forum co-chair; Brennan Grignon, Department of Defense; Katie Stebbins, Commonwealth of Massachusetts; Jennifer Hagan-Dier, MEP Tennessee; Charles Wessner, Georgetown University; Brett Lambert, Northrop Grumman; Susan Helper, Case Western Reserve University; Mark LaViolette, Deloitte; Christopher Murray, Government Accountability Office; Mike Molnar, National Institute of Standards and Technology; William Bonvillian, MIT; Erica Fuchs, Carnegie Mellon University; Patrick Bressler, Fraunhofer USA; Jonas Nahm, Johns Hopkins University; Michael Russo, GLOBALFOUNDRIES; André Gudger, Eccalon; Sridhar Kota, University of Michigan and MForesight; Kirk McConnell, Senate Armed Services Committee; and Arun Seraphin, Senate Armed Services Committee.

Date: May 23, 2017

Remarks: Well attended by the full range of stakeholders.

NIST Manufacturing Extension Partnership (MEP): Delivering Value to U.S. Manufacturers

Organizer: House Manufacturing Caucus and Senate Competitive Caucus

Purpose: Background information on the MEP program and success stories from MEP Centers and their clients on the work they do every day to improve operations, adopt new technologies, expand into new markets and find/retain a high-quality workforce.

Topics: Economic impact of the MEP program; workforce issues; advanced control technology; technology adoption; and defense manufacturing and market diversification.

Speakers: Representatives Tom Reed (NY) and Dave Cicilline (RI); Karen Heins, Executive Director, Foundation for Manufacturing Excellence; Randall Eberts, W. E. Upjohn Institute for Employment Research; Christian Cowen, Director, Polaris MEP; Chris Hogoboom, President, Goetz Composites; Joe Houldin, CEO, Pennsylvania MEP; Nick Hackett, President, New Way Air Bearings; Bill Donohue, President, GENEDGE; Gregory Glaros of Synexus; and Bart Heenan, Morphix Technologies.

Date: June 7, 2017

Remarks: Attended by over 100 House and Senate staff as well as representatives from various private and public organizations.

Ensuring American Manufacturing Leadership: Through Next Generation Supply Chains

Organizer: House Manufacturing Caucus, Sponsored by MForesight

Purpose: Examine a fundamental question for the future of American manufacturing: the evolution of the supply chain that is essential to U.S. manufacturing competitiveness.

Topics: Pervasive technology changes in areas such as information systems, sensors, intelligent controls, materials, and production processes; Business practices, skill requirements, and research needs across supply chains; and effective policies and investments from government, business, educators, and researchers.

Speakers: Mike Russo, Director, GLOBALFOUNDRIES; Susan Helper, Carlton Professor of Economics, Case Western Reserve University; Thomas Mahoney, Associate Director, MForesight; Bill Donohue, Director, Genedge; and Scott Paul, President, Alliance for American Manufacturing.

Date: July 18, 2017

Remarks: Attended by over 80 House and Senate staff as well as representatives from various private and public organizations.

DoD's Manufacturing Engineering Education Grant Program

Organizer: House Manufacturing Caucus and Senate Competitive Caucus, Sponsored by ASME

Purpose: The new DoD Manufacturing Engineering Education Program

Topics: The need to strengthen national security and increase economic competitiveness by improving and modernizing the U.S. industrial base; how to best equip students, technologists, and manufactures to take advantage of new advanced technologies.

Speakers: Said Jahanmir, ASME President-Elect; Tom Kurfess, ASME Manufacturing Public Policy Task Force; Brennan Grignon, Department of Defense (DoD); Stephen Ezell, Vice President, Global Innovation Policy ITIF; Laurie Leshin, President WPI; Laine Mears, Chair of Automotive Manufacturing Clemson University; Denise Peppard, Corporate Vice President Northrop Grumman Corporation.

Date: July 25, 2017

Remarks: Well attended by over 120 House and Senate staff as well as representatives from various private and public organizations.

Cybersecurity for Manufacturers: Securing the Digital and Connected Factory

Organizer: House Manufacturing Caucus, Sponsored by MForesight and Computing Community Consortium

Purpose: Discuss various types of cyber-attacks that cost time and money to industrial firms and their customers with a potential loss of intellectual property; discuss looming cybersecurity challenges.

Topics: The scale and variety of cyber-threats to manufacturers; malware attacks on industrial firms and cyber-attacks on manufacturers; efforts to corrupt data, steal intellectual property, sabotage equipment, and disable networks.

Speakers: Jim Davis, Vice Provost for Information Technology & Chief Academic Technology Officer, UCLA; David Vasko, Director of Advanced Technology, Rockwell Automation; Mike McGrath, Principal Consultant, McGrath Analytics LLC; Carol Hawk, Program Manager of Cyber Security for Energy Delivery Systems, Department of Energy; Donna Dodson, Chief Cybersecurity Advisor, NIST

Date: September 22, 2017

APPENDIX B

FEDERAL AGENCIES PARTICIPATING IN THE MANUFACTURING USA PROGRAM

Department of Commerce

As part of its mission to create the conditions for economic growth and opportunity, DOC supports the work of the Manufacturing USA program in establishing industry-led manufacturing innovation institutes. The Department hosts the Advanced Manufacturing National Program Office, an interagency team with participation from Federal agencies that oversees the planning, management, and coordination of the Manufacturing USA program.

Under its authority in RAMI,[53] the department conducts "open topic" competitions for institutes, in which industry is invited to propose institutes dedicated to any advanced manufacturing area not already addressed by existing institutes. In FY 2017, the new National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) was awarded. This is the first institute with a focus area proposed by industry and the first funded by the DOC.

The Department more broadly increases regional and national capacity for innovative manufacturing through partnerships with state and local governments, academic institutions, and the private sector. Through the Department's convening power, regional economic development programs, and statistical and economic analysis, it empowers industry-driven solutions to the shortage of in-demand skills. Finally, the Department supports research and development leading to transformative changes in technology and promotes intellectual property policy that supports and protects innovation. By supporting public-private partnerships, such as Manufacturing USA, the Department helps to accelerate technology development, and strengthen the nation's position in the global competition for new products, new markets, and new jobs.

National Institute of Standards and Technology

The Commerce Department's National Institute of Standards and Technology (NIST) is the only research laboratory in the U.S. government specifically focused on enhancing industrial competitiveness, with a robust research portfolio concentrated on the technical challenges associated with advanced manufacturing. In addition, the NIST Manufacturing Extension Partnership (MEP) is a critical resource to engage small and mid-size manufacturers to develop new products, expand into global markets, and adopt new technologies, such as those in development at the Manufacturing USA institutes. NIST also serves as headquarters for the interagency Advanced Manufacturing National Program Office.

Department of Defense

The Department of Defense (DoD) considers the Defense Industrial Base to be a part of its force structure. It is as essential to national security as its people in uniform and DoD civilians. The Department requires investments in advanced manufacturing technologies to shape the capabilities of an innovative industrial ecosystem and aid in the economical and timely acquisition of our nation's defense systems for tomorrow. For over 60 years, the DoD Manufacturing

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

Technology (ManTech) Program, overseen by the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, has led these investments. The eight Manufacturing USA institutes established by the DoD are a key part of the Department's ManTech investment strategy for overcoming challenges and reducing risks faced by the U.S. industrial base in developing and transitioning emerging technologies.

The eight Manufacturing USA institutes established by the DoD are: America Makes, the National Additive Manufacturing Innovation Institute; the Digital Manufacturing and Design Innovation Institute (DMDII); Lightweight Innovations For Tomorrow (LIFT); the American Institute for Manufacturing Integrated Photonics (AIM Photonics); NextFlex, America's Flexible Hybrid Electronics Manufacturing Institute; Advanced Functional Fabrics of America (AFFOA); the Advanced Regenerative Manufacturing Institute (ARMI); and the Advanced Robotics for Manufacturing (ARM) Institute.

Department of Education

The mission of the Department of Education is to promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access. The Department administers the $1.1 billion Carl D. Perkins Career and Technical Education Act, the purpose of which is to develop more fully the academic and career and technical skills of secondary education students and postsecondary education students who elect to enroll in career and technical education programs.

The Department has been active in helping to develop Manufacturing USA from its formation, and collaborates with other federal agencies, in those areas that focus on the knowledge and skill needs of the economy and efforts related to student success. Pertinent technical assistance to manufacturing communities is planned for 2018.

Department of Energy

The Department of Energy (DOE) mission is to ensure America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions. This includes catalyzing the timely, material, and efficient transformation of the nation's energy system and securing U.S. leadership in advanced manufacturing technologies, as well as maintaining a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity. To accomplish these goals, DOE has established multiple manufacturing initiatives as cross-cutting innovative programs within the department to strengthen U.S. manufacturing competitiveness and to increase U.S. manufacturing competitiveness across the board by boosting energy productivity and leveraging low-cost domestic energy resources and feedstocks.

Advanced manufacturing involves the minimization of the energy of the production, use, and disposal of manufactured goods, which range from fundamental commodities

such as metals and chemicals to sophisticated final-use products such as automobiles and wind turbine blades. The manufacturing sector, a subset of the industrial sector, consumes 25 exajoules (24 quads) of primary energy annually in the United States — about 79 percent of total industrial energy use. DOE partners with private and public stakeholders to support the research and development of innovative technologies that can improve U.S. competitiveness, save energy, and ensure global leadership in advanced manufacturing technologies.

DOE uses manufacturing innovation institutes to develop advanced manufacturing technologies to support these initiatives. As of the end of the fiscal year 2017, DOE has a total of five institutes. The first, PowerAmerica, is focused on wide bandgap semiconductor technologies for next generation power electronics. The second, the Institute for Advanced Composites Manufacturing Innovation, is focused on composite technologies for vehicles, wind turbine blades, and compressed gas storage tanks. The latest additions to the DOE institute portfolio include: Clean Energy Smart Manufacturing Innovation (CESMII); Rapid Advancement in Process Intensification Deployment (RAPID); and the Clean Energy Manufacturing Innovation Institute for Reducing Embodied Energy and Decreasing Emission (REMADE) in Materials Manufacturing.

Department of Health and Human Services

The mission of the United States Department of Health and Human Services (HHS) is to enhance and protect the health and well-being of all Americans. HHS achieves this mission by providing for effective health and human services and fostering advances in medicine, public health, and social services. From the pharmaceutical, biotechnology, and healthcare sectors, to the food and beverage sectors, HHS considers robust manufacturing to be critical to the United States' public health security and resilience.

The HHS Food and Drug Administration (FDA) is responsible for protecting the public health by assuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our Nation's food supply, cosmetics, and products that emit radiation. To encourage the adoption of innovative approaches in pharmaceutical manufacturing and to prepare for reviews and inspections involving technology for which there is limited experience such as continuous pharmaceutical manufacturing, FDA's Center for Drug Evaluation and Research (CDER) established the Emerging Technology Team (ETT) Program. The ETT is a small cross-functional team that works in concert with industry and other stakeholders to identify and resolve potential scientific and policy issues that may impact technologies new to the pharmaceutical industry.

FDA continues to support the advancement of regulatory science. To this end, FDA is actively engaged with DoD and DOC/NIST in select Manufacturing USA institutes that intersect with FDA regulated products, specifically America Makes, NIIMBL, and BioFabUSA. Furthermore, FDA, in collaboration with HHS Assistant Secretary for Preparedness and Response (ASPR) Biomedical Advanced Research and Development Authority (BARDA), has recently awarded two projects through the FDA's broad-area announcement to support emerging and enabling technologies for continuous manufacturing. To inform future federal funding and stakeholder community research and development efforts FDA has

partnered with ASPR/BARDA to sponsor a National Academies of Science, Engineering, and Medicine (NASEM) workshop on the continuous manufacturing of biologics to foster an in-depth discussion of the technical challenges and opportunities for collaboration, especially in the pre-competitive space.

Department of Labor

The U.S. Department of Labor's Employment and Training Administration (ETA) is the principal workforce development agency in the federal government. ETA supports sustainable economic growth, through leadership and a national investment portfolio that develops workforce skills necessary to support the jobs of today and is positioned to support the jobs of tomorrow, to the benefit of the American job seekers and job creators. This portfolio includes significant investments in employment and workforce development solutions.

ETA administers several programs which make up the public workforce system. The public workforce system contributes to strong, growing regional economies by responding to the workforce needs of job seekers and job creators, including advanced manufacturing, to ensure positive employment outcomes for job seekers. Partnerships at the federal, state, and regional levels connect employers, educational institutions, the public workforce system, and economic development partners. These partnerships ensure job creators have the talent they need to grow and thrive and that provide job seekers the opportunity to develop skills in-demand through work-based learning and apprenticeship and to earn industry-recognized credentials.

ETA supports and participates on the Manufacturing USA Interagency Working Team and the Manufacturing USA Education and Workforce Subcommittee. ETA is also represented on the White House Subcommittee on Advanced Manufacturing (SAM). ETA continues to engage in partnerships, share tools and resources, and identify strategies that can be leveraged and aligned to support the Manufacturing USA institutes.

National Aeronautics and Space Administration

NASA's Space Technology Mission Directorate (STMD) serves as the Agency's principal organization supporting Manufacturing USA. STMD rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost for other government agencies and commercial space activities. These collective efforts give NASA the ability to do first-of-a-kind missions and longer-term advancements in research and technology — those beyond what industry will take on and those focused on national advancement in aeronautics and space that also align with NASA's role in Manufacturing USA.

NASA's Human Exploration and Operations Mission Directorate also supports advanced technology development through the Advanced Exploration Systems Division. The In-Space Manufacturing (ISM) program is responsible for the development of 3D printing capabilities to produce components on the International Space Station (ISS) for both NASA and commercial objectives, paving the way for future factories in space.

Advanced manufacturing research and development at NASA is focused in several areas including: materials for extreme environments, additive manufacturing, polymer matrix composites, metals

processing/joining, robotics, computational physics-based modeling, non-destructive evaluation, and other highly specialized areas. Research and development is conducted through a combination of in-house activities at NASA centers, competitively-funded research with universities and industry, and collaborations with other agencies, universities, and industry. The rapid infusion of advanced manufacturing technologies into mission applications is a major emphasis of NASA's technology investment strategy.

NASA is expanding its efforts to engage industry and academia on advanced manufacturing topics central to the nation's space mission through its National Center for Advanced Manufacturing, with a focus to develop manufacturing technologies that enable major advances in systems capabilities that mitigate the risk aversion of development and operations programs.

National Science Foundation

The National Science Foundation (NSF) supports fundamental advanced manufacturing research, education, and workforce training in its Directorates for Engineering, Computer and Information Science and Engineering, Mathematical and Physical Sciences, and Education and Human Resources. It also promotes advanced manufacturing innovation through a variety of translational research programs, including the Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and Grant Opportunities for Academic Liaison with Industry (GOALI) programs, and by partnering with industry, states, and other agencies. NSF and NIST jointly sponsor MForesight: Alliance for Manufacturing Foresight, a think-and-do tank that harnesses the expertise of the broad U.S.-based manufacturing community to forecast future advanced manufacturing technologies.

The NSF advanced manufacturing investment is primarily through its Cyber-Enabled Materials, Manufacturing and Smart Systems (CEMMSS) priority area. Programs in CEMMS support fundamental research leading to transformative advances in manufacturing that address size scales from nanometers to kilometers. These include process modeling, advanced sensing and control techniques, smart manufacturing using sustainable materials, chemical reactor design and control, and manufacturing processes and enabling technology to support the biopharmaceutical, biotechnology, and bioenergy industries, with emphases on efficiency, economy, and minimal environmental impact. Advanced manufacturing is also supported through the Engineering Research Centers (ERC), Industry/University Cooperative Research Centers (I/UCRC), and Advanced Technological Education (ATE) programs. With an emphasis on two-year colleges, the ATE program focuses on the education of technicians for the high-technology fields that drive our nation's economy.

All NSF programs welcome the submission of proposals to collaborate with Manufacturing USA institutes in cutting-edge research and educational projects. Projects that are currently funded by NSF are also encouraged to request funding supplements to perform collaborative research and/or educational projects in collaboration with institutes. It is expected that the incorporation of the resources, expertise, and experience of the institutes and their member companies will increase the competitiveness of such proposals in merit review.

U.S. Department of Agriculture

Worldwide, bioenergy and bioproducts are emerging as new and rapidly growing sectors of the highly productive agricultural and forest industries. Manufacturing bio-based products (e.g. biofuels, industrial chemical intermediates, performance polymers, and finished higher value products) represent a significant opportunity for the United States to support growth of a bio-economy. Expansion of the bio-economy has the potential to sustainably harvest and use one billion tons of renewable biomass in the United States annually while continuing to support existing food, feed and fiber markets, growing the current market five-fold over the next 15 years, and adding $500 billion to the annual bio-economy and creating thousands of jobs, many in rural areas.

The agricultural and forest sectors are essential for ensuring sustainable, reliable, and accessible production of bio-based products that: 1) replace the use of petroleum and other strategic materials that would otherwise need to be imported; 2) create higher-value revenue streams for producers in agricultural communities and forest landowners; 3) improve the nutrition and well-being of animals and humans; 4) provide ecosystem services such as ensuring clean air and water, biodiversity, and nutrient cycling to the environment and society; and 5) enable the integration of sustainable bio-based products production into existing U.S. agricultural and forest systems in support of existing and new markets for food, feed, and fiber.

The USDA recognizes manufacturing plays an important role in maximizing the benefits of a sustainable, rural economy. Areas of interest include bio-manufacturing and bioproducts development to: 1) establish processes and chemical platforms leading to high-value intermediate and end-use products; 2) support commercialization of products developed from basic and applied research; 3) improve U.S. global competitiveness by building domestic capability for ongoing bio-manufacturing and bioproducts development; and 4) educate and train needed workforce.

APPENDIX C
ABBREVIATIONS

3DP	Three-Dimensional Printing
ACADEMI	Advanced Certification/Curriculum in Additive Design, Engineering and Manufacturing Innovation
AFFOA	Advanced Functional Fabrics of America (DoD)
AIChE	American Institute of Chemical Engineers
AIM Photonics	American Institute for Manufacturing Integrated Photonics (DoD)
AM	Additive Manufacturing
AMNPO	Advanced Manufacturing National Program Office (NIST)
AMTech	Advanced Manufacturing Technology Consortium (NIST)
ARM	Advanced Robotics for Manufacturing (DoD)
ARMI	Advanced Regenerative Manufacturing Institute
ATE	Advanced Technological Education
BOM	Bill of Materials
CESMII	Clean Energy Smart Manufacturing Innovation Institute (DOE)
Cobots	Collaborative Robots
CoMET	Composites Manufacturing Education and Technology Facility
DCC	Digital Capability Center
DFARS	Defense Federal Acquisition Regulation Supplement
DMDII	Digital Manufacturing and Design Innovation Institute (DoD)
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
EWD	Education and Workforce Development
FHE	Flexible Hybrid Electronics
FLIP	Future Leaders in Integrated Photonics
GAO	Government Accountability Office
GOALI	Grant Opportunities for Academic Liaison with Industry (NSF)
GE	General Electric
GPS	Global Positioning System
IACMI	Institute for Advanced Composites Manufacturing Innovation (DOE)

IOT	Internet of Things
LIFT	Lightweight Innovations for Tomorrow (DoD)
MBE	Model-Based Engineering
MCPI	Modular Chemical Process Intensification
MEP	Manufacturing Extension Partnership
MES	Manufacturing Execution Systems
MPWA	Multi Project Wafer and Assembly services
NCMEP	North Carolina MEP
NIIMBL	National Institute for Innovation in Manufacturing Biopharmaceuticals (DOC)
NIST	National Institute of Standards and Technology
PIC	Photonic Integrated Circuit
RAMI	Revitalize American Manufacturing Innovation Act
RAPID	Rapid Advancement in Process Intensification Deployment (DOE)
REMADE	Reducing Embodied-energy And Decreasing Emissions (DOE)
R&D	Research and Development
SAM	Subcommittee on Advanced Manufacturing
SBIR	Small Business Innovation Research (NSF)
SiC	Silicon Carbide
SME	Small and Medium-sized Enterprise
SMM	Small and Medium-sized Manufacturer
STEM	Science, Technology, Engineering, and Mathematics
STTR	Small Business Technology Transfer (NSF)
SURF	Scale-Up Research Facility
UPS	Uninterruptible power supplies
WBG	Wide Bandgap

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