ANNUAL REPORT

2016

Manufacturing USA®

About this Document

As required by the Revitalize American Manufacturing and Innovation (RAMI) Act of 2014,[1] this report describes the Manufacturing USA Program's major accomplishments in Fiscal Year 2016, starting October 1, 2015 and ending September 30, 2016. Included are the findings, recommendations and resulting actions planned from two complementary external assessments executed from September 2016 to April 2017. This annual report documents the program's progress in meeting the goals stated in its Strategic Plan.[2] See Appendix A for descriptions of the Federal organizations that actively participated in the program and contributed to this report.

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[1] Consolidated and Further Continuing Appropriations Act, 2015, Pub. L. 113-235, Title VII – Revitalize American Manufacturing and Innovation Act of 2014, codified at 15 U.S.C. § 278s.

[2] *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

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MESSAGE FROM THE U.S. SECRETARY OF COMMERCE

A strong U.S. manufacturing sector is essential to our economic security and national security. American manufacturers contributed $2.18 trillion to the U.S. economy in 2016. However, our trade deficit in manufacturing looms large at approximately $750 billion - including a deficit of more than $90 billion in advanced technology products. This deficit in advanced manufacturing is historically unprecedented for a nation which leads the world in science and technology research. We have a great culture of discovery and innovation, but inventing here while other nations benefit from jobs and manufacturing is not sustainable. We must also build more here to sustain the jobs and income that allow us to continue to research and invent.

The Trump Administration is committed to a great revival of American manufacturing. We will do that by enforcing our trade laws, addressing unfair trade practices, lowering taxes, and streamlining burdensome regulations. These steps will restore a level playing field to our manufacturing sector. The race for leadership in advanced manufacturing hinges on innovation, which creates the jobs and products of tomorrow. Innovation is an American strength. Investing in public private partnerships creates competitive advantage for American industry.

This is what the Manufacturing USA program is about – helping to move discoveries in the nation's universities and research laboratories to the shop floor here in America. The federal role is limited to creating a collaboration space for industry-led applied research on the most important opportunities facing U.S. manufacturers. Institutes have a mission to develop game-changing technology and the skills needed to equip our future U.S. manufacturing workforce.

In fiscal year 2016, there were nine active manufacturing innovation institutes, sponsored by the Department of Defense and Department of Energy, focused on nearly 200 major applied research projects of priority to industry. The participants in – and beneficiaries of – these projects are the 830 industry members, of which 548 (two-thirds) are manufacturing firms and 361 are small businesses.

To gauge impact, a third-party assessment in 2016 found that Manufacturing USA is establishing manufacturing hubs here in America that provide real value to industry. These domestic hubs benefit the public by providing workforce development, improved job opportunities, and increased economic opportunity in promising technology areas that result in higher wages for U.S. workers.

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

Wilbur Ross
U.S. Secretary of Commerce

2016 MANUFACTURING USA® ANNUAL REPORT

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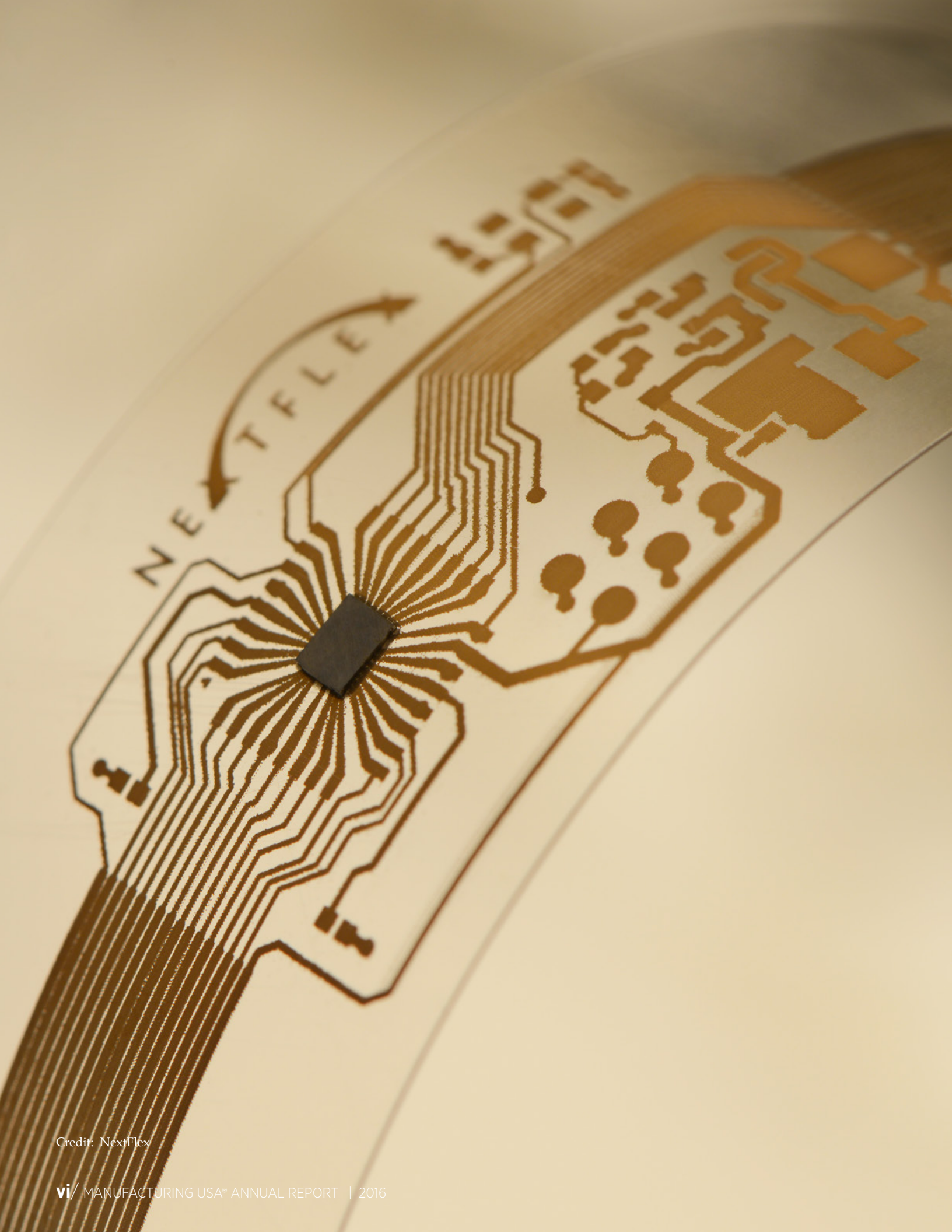
TABLE OF CONTENTS

TABLES

FIGURES

All tables, figures, and photos in this report were produced by the Advanced Manufacturing National Program Office Interagency Working Team Participants, unless otherwise noted.



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EXECUTIVE SUMMARY

The Manufacturing USA network progressed tremendously in Fiscal Year (FY) 2016, meeting its mission of increasing U.S. competitiveness through innovations in manufacturing technology and workforce development. This year, the network grew to nine institutes, with competitions underway to award five more in 2017.

Manufacturing USA brings together public and private investments to improve the competitiveness and productivity of U.S. manufacturing through the creation of a robust network of manufacturing innovation institutes. Each institute is a public-private partnership focusing on a specific, promising advanced manufacturing technology area.

The program advances American manufacturing innovation by creating the infrastructure needed to allow U.S. industry and academia to work together to solve industry-relevant manufacturing problems in research and development, technology transition, workforce training, and education.

The institutes catalyze cooperation between U.S. companies and researchers from universities and federal laboratories to rapidly develop ideas and inventions into products and processes that can be used by U.S. manufacturers. By involving small and large U.S.-based companies, the Manufacturing USA institutes stimulate the formation of manufacturing ecosystems, building advanced capabilities into the domestic supply chain so that new technologies developed in the U.S. are manufactured here in the U.S. rather than in other countries. Each institute works to ensure that American workers are trained for the high-paying jobs needed to manufacture these new technologies.

The hallmark of the Manufacturing USA network, collaborations across industry sectors in partnership with esteemed university research programs, facilitates efficient development of processes that U.S. companies use to manufacture advanced technology products for sale around the world. In FY 2016, some companies in the Manufacturing USA network shaved years from their product development cycles because of access to these innovative processes.

Advanced manufacturing workforce development rose to a new level this year, both within the individual institutes and throughout the network as a whole. The institutes developed a portfolio of diverse programs for students in high schools, community colleges and universities; educators from kindergarten through twelfth grade; manufacturing employees; and transitioning veterans. A network of workforce leaders in each institute was established and met regularly throughout the year to share best practices and new approaches, helping newly founded institutes more quickly establish their own education and workforce programs. Nearly 25,000 students and teachers have participated in institute programs, and over 3,000 individuals have completed certificate, apprenticeship, or training programs led by the institutes.

On September 12, 2016, the Secretary of Commerce announced[3] that the National Network for Manufacturing Innovation had a new public-facing name, Manufacturing USA. The name Manufacturing USA was selected to raise awareness of the value of the program to industry, academia, nonprofits, the public, and the entire U.S. manufacturing community, recognizing the program's impact on securing America's manufacturing future.

Working through the Advanced Manufacturing National Program Office, the lead agencies[4] expanded their coordination of institute start-up and support activities. As part of its role in coordinating the activities of the program, the Department of Commerce's National Institute of Standards and Technology (NIST) provided

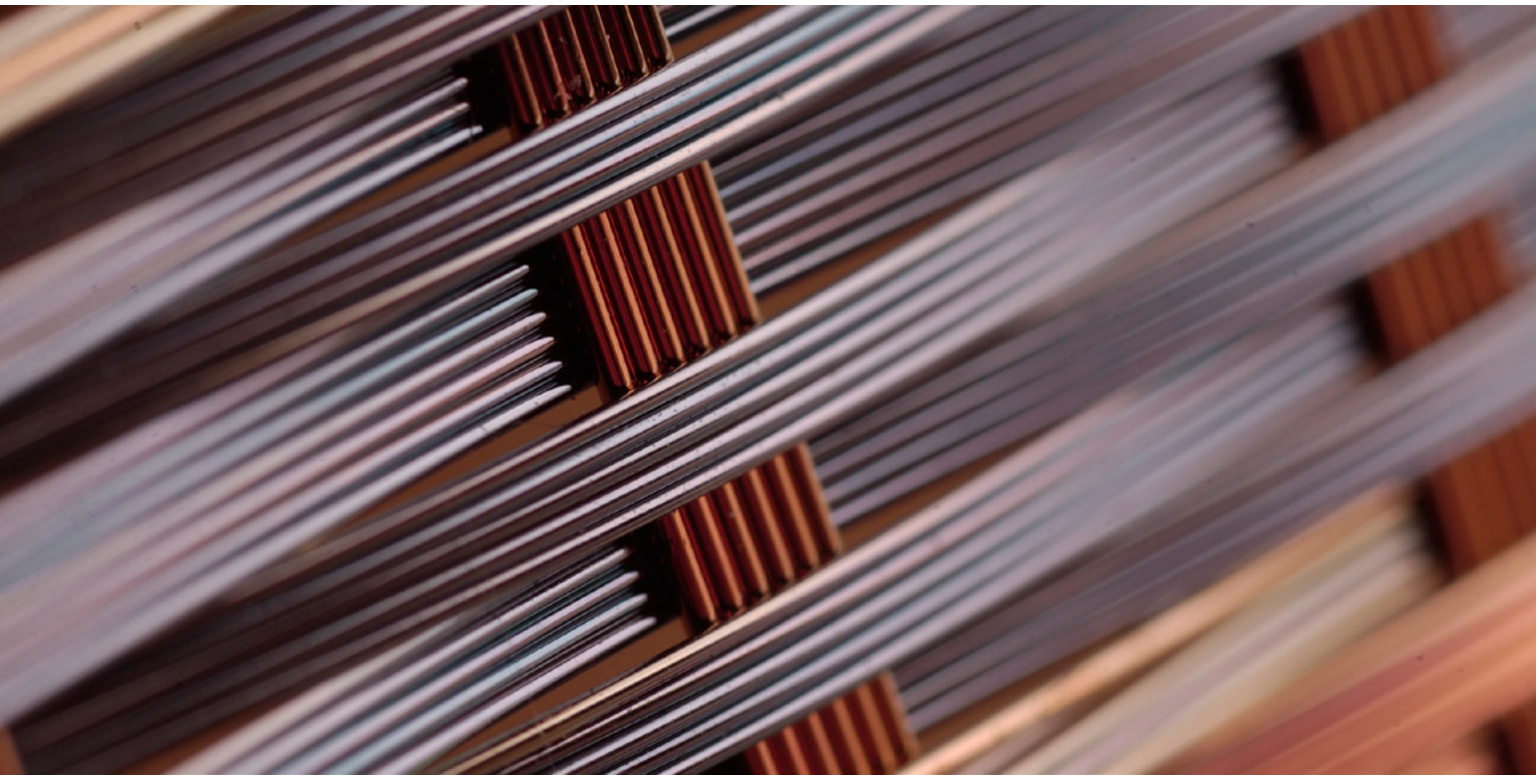
[3] https://www.commerce.gov/news/secretary-speeches/2016/09/us-secretary-commerce-penny-pritzker-delivers-opening-remarks

[4] The Department of Commerce, the Department of Defense, the Department of Energy, the Department of Education, the National Aeronautics and Space Administration, and the National Science Foundation.

secure collaboration services for all institutes. A shared website was established where the institutes collaborate and communicate, and several individual institutes are now using NIST-provided sites for their own internal communications and collaboration, such as managing project calls. Cross-institute working groups, such as workforce development and education, also collaborate through these means.

Significantly, this year marked the first open-topic competition, as mandated by Congress in the RAMI Act.[5] This competition was the first held by the Department of Commerce/NIST. The topics were nominated by industry-led consortia, rather than bound by the mission space of any participating federal agency, allowing the technical areas to reflect U.S. industry's most important issues.

Two outside organizations assessed the Manufacturing USA program for FY 2016, one public sector and one private sector. The public sector assessment was the first biennial Government Accountability Office (GAO) report, as required by Congress, which included recommendations for enhancing effectiveness of the program. Specifically, GAO recommended greater involvement of additional agencies in the Manufacturing USA program – in particular the Department of Labor, which has now become fully engaged. It also recommended expanding Network governance to ensure the roles and responsibilities for how these agencies could contribute to the Manufacturing USA program are fully identified (underway). The private sector assessment was a third-party study by Deloitte[6] to capture private sector stakeholder views. This Deloitte assessment extensively characterized and assessed the program and network, emphasizing the effectiveness of the wide web of relationships catalyzed by the program, and how these relationships accentuate achievement of the program goals.



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

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

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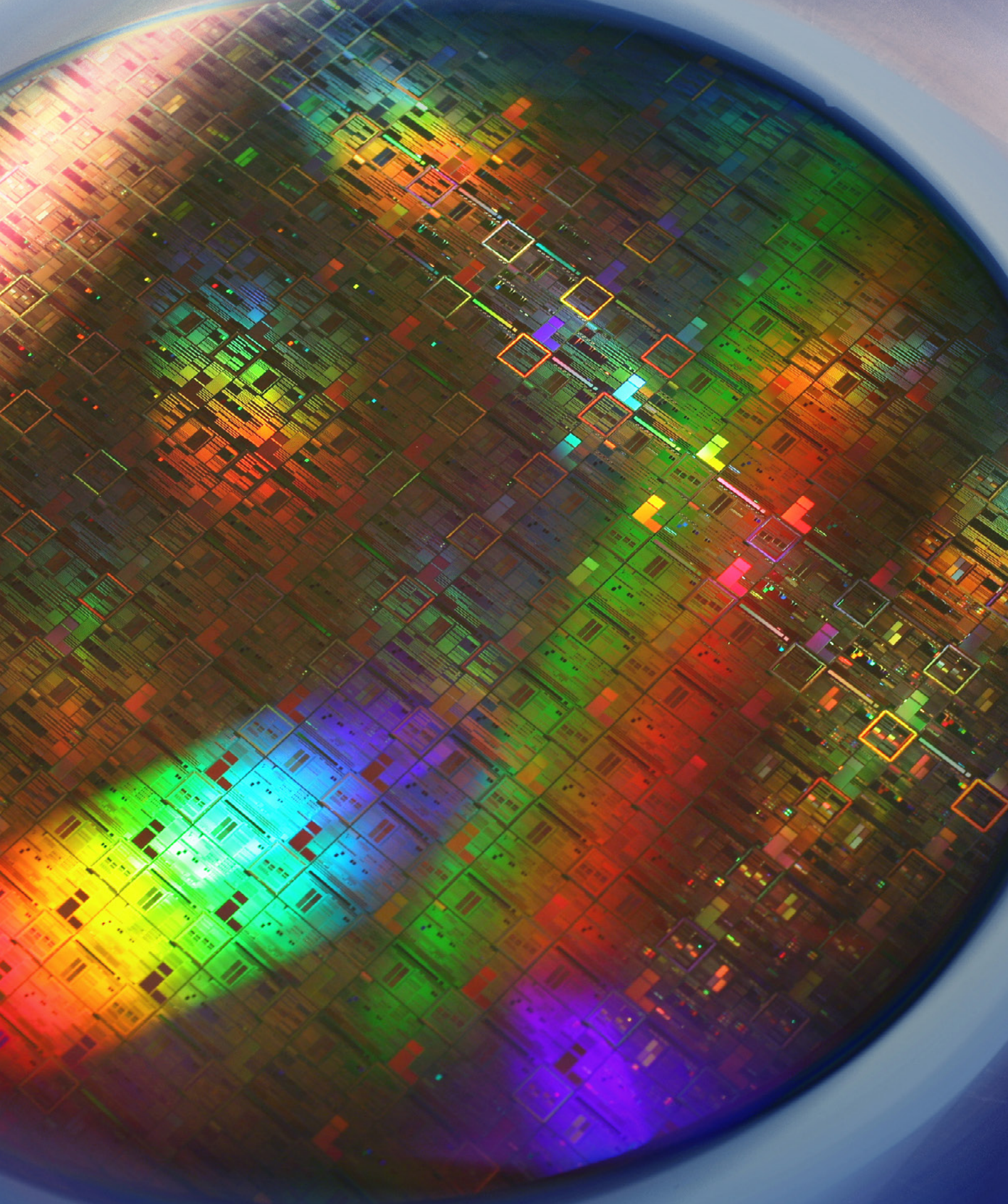

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INTRODUCTION

Revitalizing Manufacturing in the United States

The United States has long thrived on its ability to manufacture goods and sell them in domestic and global markets. Manufacturing activity has supported our economic growth, leading the nation's exports and employing millions of Americans. Throughout the 20th Century, the U.S. manufacturing sector uniquely drove knowledge production and innovation through the transition of research and development into products used throughout the world.

Manufacturing plays an outsized role in the U.S. economy because of its high economic multiplier effect. U.S. advanced manufacturing supports trillions of dollars of production in other parts of the economy by purchasing from and selling to over 80 other industries. As a result, each advanced manufacturing employee supports an estimated 16 jobs in the rest of the economy.[7]

However, the nation's historic leadership in manufacturing is now at risk. Manufacturing employment fell by one-third between 2000 to 2010 and rose only 8 percent since then. Beginning in 2002 and every year since, the U.S. has become a net importer of advanced technology products.

More alarmingly, U.S. basic research discoveries are frequently translated into manufacturing capabilities and cutting-edge products in other countries. While other countries support technology transition by investing in advanced manufacturing programs, in the U.S., barriers between basic research and production impede the private sector's ability to develop new manufacturing processes and products.

The ability of the U.S. to continue to create new industries that provide its citizens with high-paying jobs while also ensuring national and economic security depends on the nation's capability to successfully scale-up emerging technologies for manufacturing. To address these national needs, in 2012 the President's Council of Advisors on Science and Technology (PCAST) recommended launching a concerted, whole-of-government effort to work with industry to strengthen and develop advanced manufacturing.[8] The requirements identified for such an effort were:

1. Coordinated Federal support to industry and academia to stimulate applied research on new technologies;
2. Public-private partnerships to advance such technologies through pre-competitive consortia that tackle major crosscutting challenges; and
3. Shared facilities and infrastructure to help small and mid-sized enterprises (SMEs) improve their manufacturing capabilities and products to compete globally.

The PCAST report also called for education and workforce development in advanced manufacturing technologies to ensure that the nation has the highly-skilled workforce needed to attract, expand, and sustain advanced manufacturing in the United States. These recommendations led to the creation of the nation's first manufacturing innovation institutes sponsored by the Department of Defense (DoD) and the Department of Energy (DOE).

With passage of the Revitalize American Manufacturing and Innovation (RAMI) Act of 2014, Congress authorized both the establishment of the

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

[8] *Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing*, Executive Office of the President, President's Council of Advisors on Science and Technology (PCAST), July 2012, https://www.manufacturingusa.com/resources/report-president-capturing-domestic-competitive-advantage-advanced-manufacturing

Network for Manufacturing Innovation Program (the "program") and the incorporation of the initial institutes into the program.[9] This law authorizes the Secretary of Commerce to establish and coordinate manufacturing institutes and to collaborate with Federal departments and agencies whose missions contribute to or are affected by advanced manufacturing. The Advanced Manufacturing National Program Office (AMNPO) at the National Institute of Standards and Technology (NIST) is designated as the program office to oversee and carry out the program.

In September 2016, in an effort to raise awareness within industry, academia, nonprofits, the public, and the entire U.S. manufacturing community, the program was given the public-facing identity, Manufacturing USA. This coincided with a period of growth for the program, which saw an increase in the number of institutes and network activities. Between August 2012 and September 2015, seven institutes were established. By September 30, 2016, two more institutes had been established and competitions were underway for an additional five.

Reporting Period

This annual report describes the activities of the Manufacturing USA program, including institute activities and network performance during fiscal year 2016 (FY 2016)—between October 1, 2015 and September 30, 2016. Prior year accomplishments or activities planned for after September 30, 2016 are included as appropriate and are clearly referenced.

Vision, Mission, and Goals

The Manufacturing USA program seeks to address the complex, manufacturing-related technology transition challenges that arise between early stage research and technology adoption. To provide ongoing focus and guidance for its stakeholders, a vision, mission, and program goals were documented in the program's 2015 Strategic Plan, as shown in Figure 1.

Figure 1. Manufacturing USA Program Vision, Mission, and Goals

[9] Revitalize American Manufacturing and Innovation Act of 2014, 15 USC 278s(c)(3)(A).

Network

The RAMI Act authorized the Secretary of the Department of Commerce (DOC) to establish a network of centers for manufacturing innovation, known as the Network for Manufacturing Innovation.[10] The network 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 to 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.

The network provides a variety of functions based on the common and evolving needs of the manufacturing innovation institutes and in response to input from both its public and private stakeholders.

Institutes

The institutes are the core of the Manufacturing USA program. Each institute addresses a focused manufacturing technology area. 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, pre-competitive development of promising technologies. Institutes 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 SMEs, including women and minority owned manufacturing enterprises, in addition to large-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 that initial period.

Manufacturing USA has four program goals:

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: Accelerate the development of an advanced manufacturing workforce.

Goal 4: Support business models that help institutes to become stable and sustainable after the initial federal startup funding period.

[10] Revitalize American Manufacturing and Innovation Act of 2014, 15 USC 278s.

Each institute is established by a lead funding agency after an open competition under individual agency statutory authorities and appropriations. In addition to the nine institutes listed below, an additional five institutes were under competition in FY 2016 and were established following the reporting period of this document:

1. America Makes—The National Additive Manufacturing Innovation Institute (additive manufacturing/3D printing), August 2012.
2. DMDII—Digital Manufacturing and Design Innovation Institute (digital manufacturing and design), February 2014.
3. LIFT—Lightweight Innovations for Tomorrow (lightweight metals manufacturing), February 2014.
4. PowerAmerica—The Next Generation Power Electronics Manufacturing Innovation Institute (wide bandgap power electronics manufacturing), January 2015.
5. IACMI—Institute for Advanced Composites Manufacturing Innovation (fiber-reinforced polymer composites), June 2015.
6. AIM Photonics—American Institute for Manufacturing Integrated Photonics (integrated photonics manufacturing), July 2015.
7. NextFlex—America's Flexible Hybrid Electronics Manufacturing Institute (manufacturing thin flexible electronic devices and sensors), August 2015.
8. AFFOA—Advanced Functional Fabrics of America Institute (fiber materials and manufacturing processes), April 2016.
9. CESMII—Clean Energy Smart Manufacturing Innovation Institute (smart manufacturing), selected June 2016.

Credit: PowerAmerica

PROGRAM PERFORMANCE

Fiscal Year 2016 saw major new activities and outcomes for Manufacturing USA that helped ensure progress toward the strategic goals of the program.[11] This section provides a multi-faceted analysis, tying performance to the program goals and to the complex needs and interests of the program's stakeholders.

Program performance is evaluated both in quantitative and qualitative terms. Fiscal Year 2016 was the first year that interagency-developed quantitative program-level metrics are reported. These quantitative measures add rigor to the assessment of performance and underscore the significant complexity and challenges of measuring program performance against Manufacturing USA's objectives.

As described in the Strategic Plan, the evaluation strategy for the Manufacturing USA Program 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 the Manufacturing USA program 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.
- Provide a trusted measure of the Manufacturing USA program's performance that is broad enough to support process improvement analysis for the future design and activities of the institutes and the network.
- Leverage partnerships to improve Manufacturing USA program data by linking to external sources and to build a community of practice for evaluation.

Program analysis will evolve over time as Manufacturing USA grows and matures and as agencies and institutes gain experience. While this may introduce difficulties in comparing certain metrics over time, the program's leadership is committed to continuous improvement to properly assess the program over the long term.

Like the first annual report covering FY 2015,[12] many of the specific activities highlighted in this FY 2016 report provide a rich and descriptive qualitative measure of program performance. Many such narratives are woven throughout this year's report and indicate solid performance in support of the program's goals.

Overall Performance of the Program

Fiscal Year 2016 was noteworthy in terms of program outcomes and progress. One new institute was established by the DoD and another by the DOE, expanding the network to nine institutes. Three institutes that were launched at the end of FY 2015 commenced their first full year of active operations. Five additional new institute competitions were underway.[13]

At the aggregate program level, a host of accomplishments and activities significantly increased the Manufacturing USA program's reach, effectiveness, and overall momentum. These accomplishments and activities, discussed in the following sub-sections, spanned several major functional areas:

[11] *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.

[12] *National Network for Manufacturing Innovation Program Annual Report*, 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-annual-report.

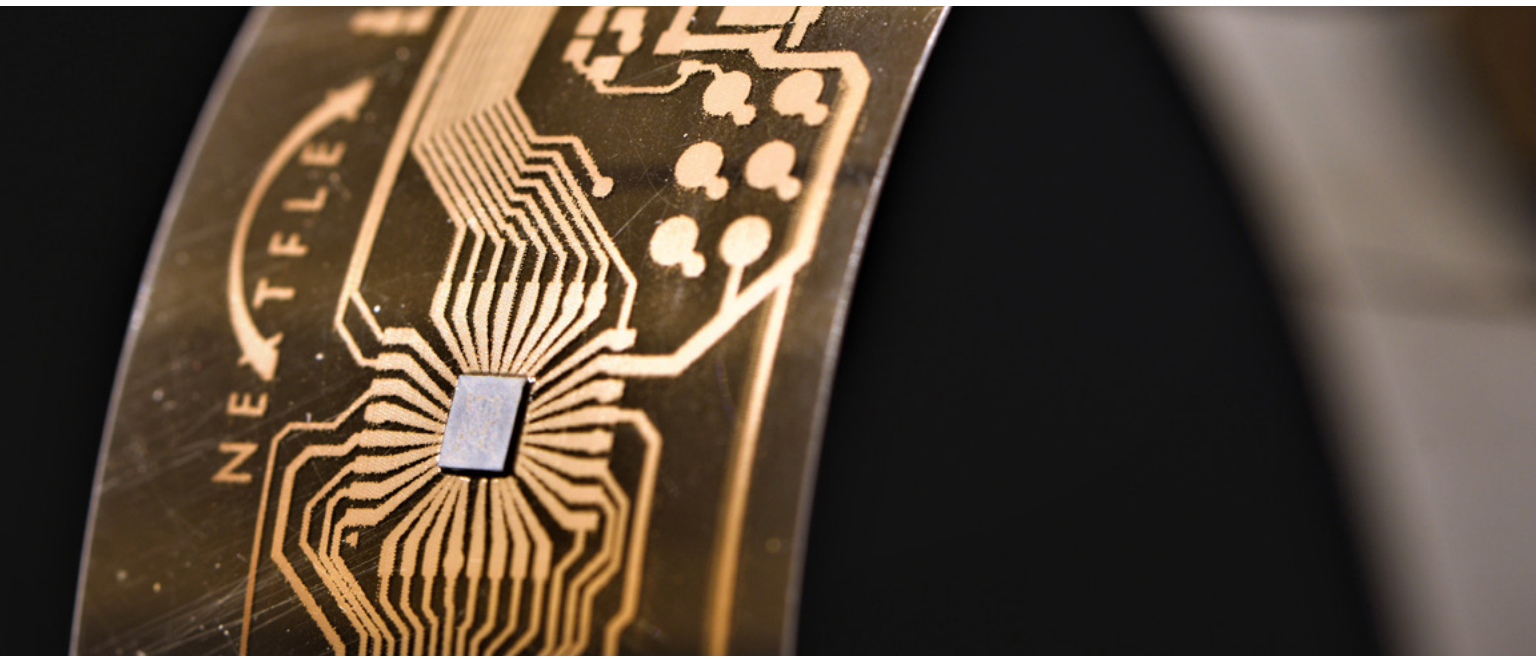
[13] All were successfully launched in FY 2017:

1. The Rapid Advancement in Process Intensification Deployment Manufacturing Institute—RAPID, established March 2017
2. The National Institute for Innovation in Manufacturing Biopharmaceuticals—NIIMBL, established March 2017
3. The Advanced Tissue Biofabrication Innovation Institute—BioFabUSA, established December 2016
4. The Advanced Robotics Manufacturing Innovation Hub—ARM, established January 2017
5. The Reducing Embodied Energy and Decreasing Emissions in Materials Manufacturing—REMADE in America, established May 2017.

1. Further definition and refinement of the program's network-level functions and its governance model;
2. Program identity (focused on both public and internal stakeholder communities);
3. Higher levels of technical and non-technical collaboration, including cross-agency, cross-institute, and cross-member collaboration;
4. Major, network-level progress in advanced manufacturing education and workforce development;
5. Responsible obligation and expenditure of appropriations;
6. Engagement and leveraging the capabilities of related Federal programs and agencies; and
7. Facilitation of third party and independent assessments of the program.

Another important trend in FY 2016 was the extent to which all three major funding agencies—DoD, DOE, and DOC—coordinated their efforts through the AMNPO and with other Federal agencies to expand their active cooperation on institute stand-up and support activities. This highly integrated collaboration stems from a recognition that Manufacturing USA's national imperatives, as reflected in the objectives of the RAMI Act, are best realized by a whole-of-government effort that focuses broadly on increasing U.S. advanced manufacturing competitiveness.

The lead funding agencies supported this unified effort while concurrently ensuring that value delivered by their respective institutes remained closely aligned with their agencies' statutory mission 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.[14]



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[14] Additional discussion and descriptions of the federal sponsors and lead funding agencies supporting the Manufacturing USA Program are provided in Appendix A.

Table 1. Manufacturing USA Program 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	X	X		X
Financial Leverage		X		X
Development of an Advanced Manufacturing Workforce	X		X	
Technology Advancement	X	X		

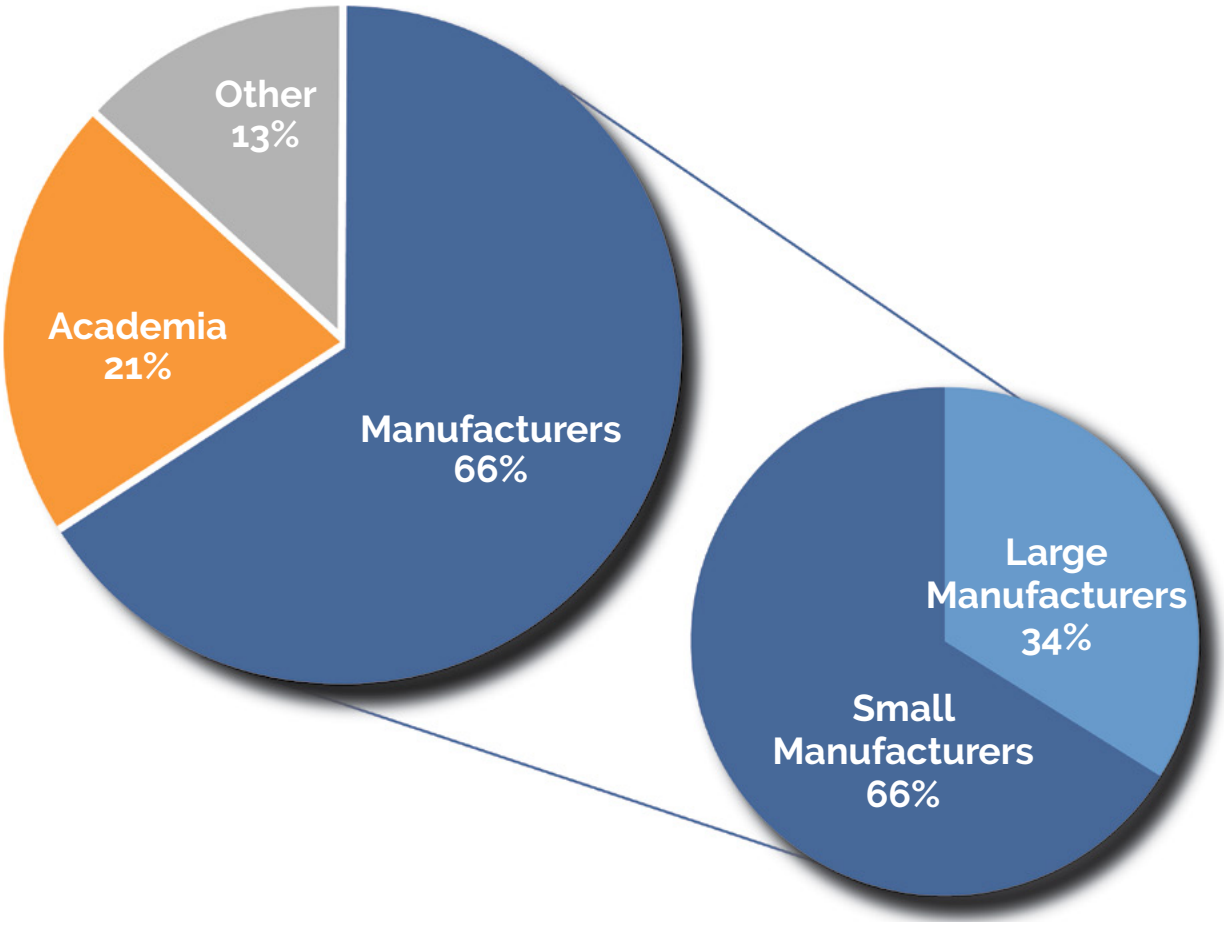


Figure 2. Impact to U.S. Innovation Ecosystem. Of the 830 Manufacturing USA Institute Members, 66 percent were manufacturers. Of that 66 percent, large manufacturers represent 34 percent and small manufacturers represent 66 percent.

Program Performance Metrics

Effective quantitative performance metrics must be tied to measuring the attainment of validated goals and objectives. As seen in Table 1, each institute metric category described in the Strategic Plan[15] provides information for tracking progress toward more than one of the high-level program goals. As noted earlier, FY 2016 is the first year in which an initial and relatively modest set of quantitative, program-level performance metrics is being reported. This set, agreed upon by the agencies contributing to the Manufacturing USA program, reflects an aggregation of certain institute-level metrics. The result is that the four institute metric categories are supported by seven specific metrics as summarized in Table 2.

Because this was the first year for which these metrics were collected by the lead funding agencies, it was necessary to further define specific units of measure for each of these metrics. Table 3 contains the aggregated institute metrics data (actual values), including a description of the 13 specific units of measure used to define the values for each specific metric.

While this is the first year in which these metrics are being reported, important conclusions are already evident.

Manufacturing USA Institutes Have 830 Members – 66 percent are Manufacturers

Industry and academia are responding to the Manufacturing USA public-private partnership model. In FY 2016, the eight operating Manufacturing USA institutes had 830 members. These included 548 manufacturing firms (66 percent); 177 educational institutions (21 percent), including universities, community colleges, and other academic institutions; and 105 other entities (13 percent), including Federal, state, and local government, Federal laboratories, and not-for-profit organizations. Of the manufacturers, 361 (66 percent) were small businesses with 500 or fewer employees and 187 (34 percent) were large manufacturers.

Table 2. Manufacturing USA Program 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 agreement
	Diversity of members
Financial Leverage	Total co-investment in FY 2016
Development of an Advanced Manufacturing Workforce	Science, technology, engineering, and mathematics (STEM) activities
	Educator/trainer engagement
Technology Advancement	Number and value of active research and development projects in FY 2016
	Percentage of key project technical objectives met in FY 2016

[15] 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, 15 U.S.C. Section 278s(a)(2)).

Non-Federal Institute Research and Development Co-Investment Matched Federal Program Funds Nearly 2 to 1

In FY 2016, matching funds provided approximately two-thirds of the funding for institute expenditures, significantly exceeding program design specifications. The remainder of the institutes' funding came from the lead funding agencies. With total institute expenditures in the fiscal year of $333,808,455, Federal program funds totaled $114,893,428 (34 percent) and non-program matching expenditures totaled $218,915,027 (66 percent). This funding went toward all aspects of institute operation, including technology advancement projects, education and workforce training efforts, and capital equipment acquisitions. The original design specifications for the program called for a 1 to 1 (minimum) match of Federal funds from sources outside the Federal funding agencies. In FY 2016, the matching was nearly 2 to 1.

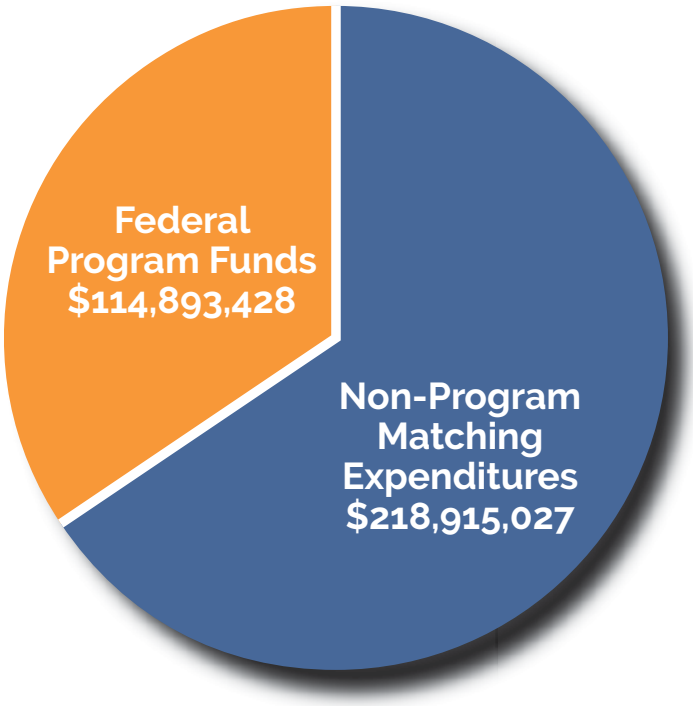


Figure 3. Financial Leverage: 66 percent of institute research and development expenditures came from non-program matching funds

Institutes and Institute Projects are Successfully Advancing Technology and Improving the Innovation Ecosystem

Across the nine institutes established by the end of FY 2016, seven had active research and development activities, with 191 projects among them. While technology research and development (R&D) projects typically take several years to reach production, the high level of participation in these projects by industry and the progress in meeting technical objectives on tight timelines are early indicators of success. An average of 82 percent of key technical objectives were met on projects, per institute. Several selected projects are highlighted in the institute sections.

Furthermore, the process of developing, proposing, and executing projects is fostering new and closer relationships among member organizations. These relationships strengthen the innovation ecosystem and improve the likelihood that projects will have industrial impacts.

In FY 2016, the Manufacturing USA participating agencies sponsored a third-party assessment[16] by Deloitte to provide an outside private-sector evaluation of the effectiveness of the program. A key finding of the resulting study, Manufacturing USA: A Third-Party Evaluation of Program Design and Progress (the "Deloitte report"), was that the first eight advanced manufacturing institutes established between 2012 and 2016 have reached a critical mass of valuable connections among participating companies, universities, and other entities. Those connections are accelerating the innovations needed to develop new products and markets, helping alleviate a shortage of technically trained manufacturing workers and building a sustainable national manufacturing research infrastructure.

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

Table 3. Fiscal Year 2016 Aggregated Institute Performance Metrics Values			
Institute Metric Category	Specific Metric	**Unit(s) of Measure**	**Value**
Impact to U.S. Innovation Ecosystem	Number of partner organizations with institute membership agreement	Total number of memberships	830
	Diversity of members	Number of large manufacturers (more than 500 employees)	187
		Number of small manufacturers (500 or fewer employees)	361
		Number of academic members (universities, community colleges, etc.	177
		Number of other entities (government members, government laboratories, not-for-profit organizations, etc.)	105
Financial Leverage	Total co-investment in FY 2016	Amount of cost share expended in FY 2016 and any Federal funding not part of the base Federal funding	$218,915,027
Technology Advancement	Number and value of active research and development projects	Number of projects ongoing in FY 2016 (projects completed, started and spanning FY 2016)	191
		Total institute expenditures in the fiscal year	$333,808,455
	Percentage of key project technical objectives met in FY 2016	Percentage of key FY 2016 milestones met in the fiscal year	82 percent
Development of an Advanced Manufacturing Workforce	STEM activities	Number of students participating in institute projects or institute internship programs/training	23,560
		Number of individuals in the workforce completing a certificate, apprenticeship or training program led by the institutes	3,386
	Educator/trainer engagement	Number of teachers or trainers participating in institute-led training	1,023

(all data as of September 30, 2016)

As shown in Figure 5, according to the Deloitte report, "nearly 1,200 companies, government agencies, non-profits, and academic institutions shown are linked through institute working groups, steering committees, and the process of planning and conducting research projects. The program provides organizations the flexibility to join one or many institutes that offer the benefits most relevant to their needs."[17]

These organizations formed more than 9,000 substantive relationships, including collaborating on institute-sponsored R&D projects, technology roadmapping, creating industry technical standards, and providing workforce training and curricula to develop the next generation of technology workers.

Nearly 28,000 Participated in Institute-Led Education and Workforce Development Training Programs

Each of the active institutes has initiated programs to support the development of an advanced manufacturing workforce in its respective technology area. In total, 27,969 individuals participated in institute-led workforce programs (Figure 4). These included 23,560 students who participated in institute research and development projects, internships, or training. In addition, 3,386 individuals already in the workforce completed a certificate, apprenticeship, or training program led by the institutes. And 1,023 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 in the individual institute descriptions later in this report. Further, with all institutes pursuing workforce development efforts, this has been an early topic for cross-institute collaboration, as detailed in the following subsection on Manufacturing USA Education and Workforce Development Activities.

Next Steps in Building a Structure for Program Evaluation

The AMNPO, working with agency partners and leadership from across the institutes, will continue to refine an overall program performance management system that identifies the highest impact measures and appropriately integrates qualitative and quantitative program outcomes. This approach will also balance the value of data collection and the resources required to collect and assess the data. Refinements will be described and presented in future annual reports.

The previously described quantitative metrics are complemented by the following subsections describing key 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 2016.

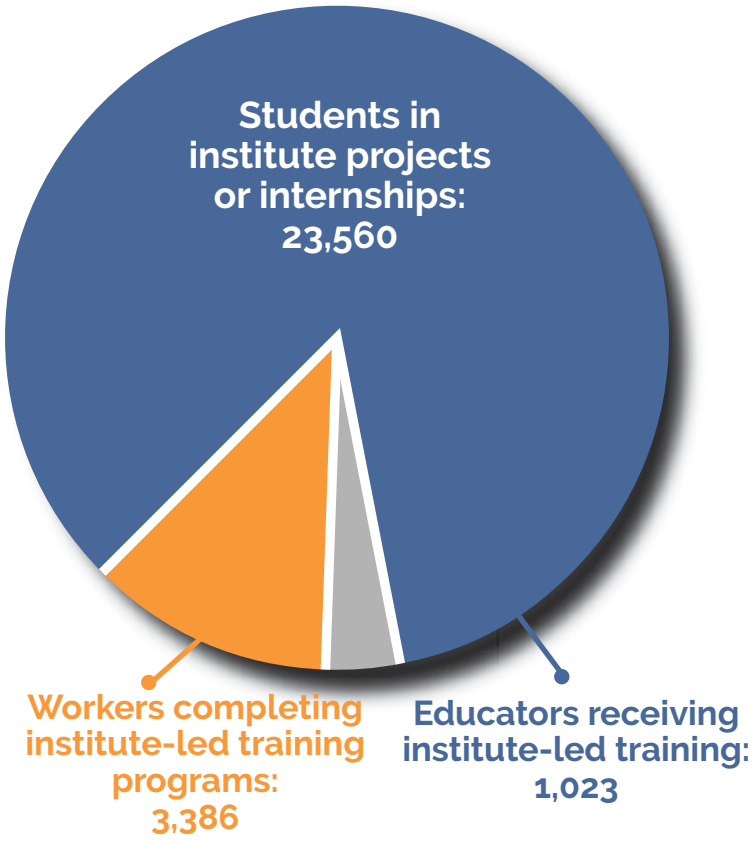
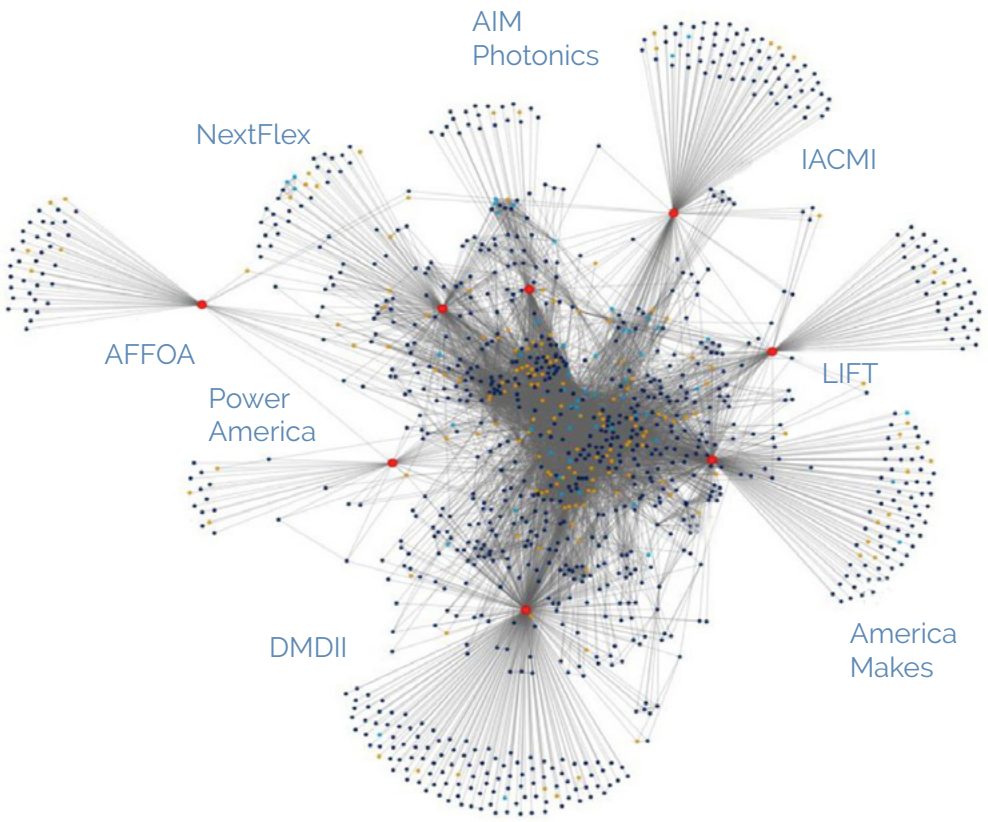


Figure 4. Development of an Advanced Manufacturing Workforce. 27,969 students, workers, teachers, and trainers have participated in institute-led education and workforce development technical training programs.

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



9,424
Relationships between organizations

1,174
Organizations involved with the program

753
Organizations with formal membership

203
Organizations have relationships with multiple institutes

120
Organizations are members of more than one institute

Figure 5. Covening Power of the Manufacturing USA Program Network. The Manufacturing USA institutes convene nearly 1,200 organizations in a network comprising over 9,000 substantive relationships. In this map, the closer two organizations are, the more often or closely the organizations work together. Organizations in the center of the map are highly involved in projects across several institutes and help steer the direction of the program. Credit: Deloitte Report.

Credit: PowerAmerica

Network Functions, Governance, and Coordination

The National Science and Technology Council's (NSTC) Subcommittee on Advanced Manufacturing (SAM) launched the Manufacturing USA Deputies Working Group consisting of representatives from the Office of Science and Technology Policy (OSTP), the National Economic Council (NEC), NIST, DoD, and DOE. In FY 2016, this group established the Manufacturing USA Network Charter.[18]

The Network Charter proposes four operating principles regarding network governance:

1. The network supports its 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 the purview of the lead funding agency and respective institute members. Legislatively mandated 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. Mechanisms and structures are necessary to collect inputs and needs 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 network functions. The AMNPO, working with the lead funding agencies, is also responsible for reporting to Congress on the Manufacturing USA program and related institutes.

Further, the Network Charter formalizes the functions of the Manufacturing USA Network, as seen in Table 4. In facilitating intra-network collaboration, the network fulfills the need for an internal information clearinghouse. By fostering robust communication between the network and external stakeholders, the network serves as the external information clearinghouse for the program.

In August 2016, the directors of the institutes launched the Manufacturing USA Institute Directors Council. This council, formalized in the "Charter of the Institute Directors Council: Manufacturing USA,"[19] supports the Manufacturing USA goals. The council facilitates cooperation and collaboration among the institutes, with advice as needed from the Federal institute sponsors, agencies providing additional support to the institutes, and from the AMNPO. The AMNPO provides financial and staff support to the council.

The council's responsibilities include the following:

- Promote collaboration and cooperation among the institutes in support of the goals of Manufacturing USA;
- Facilitate communications/engagement among the institutes and between the institutes and the Federal government;
- Encourage institute activities that leverage the diversity and strengths of the network to collaborate on cross-cutting activities;
- Facilitate the institutes' collaboration with the Manufacturing Extension Partnership (MEP) program and other established regional assets;
- Support collaborative efforts on workforce development that provide enhanced experiential learning opportunities across the network;
- Recommend to the network common policies/ guidelines for Institutes;

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

[19] Charter of the Institute Directors Council: Manufacturing USA, Advanced Manufacturing Series (NIST AMS) - 600-1, https://www.manufacturingusa.com/resources/charter-institute-directors-council.

Table 4. Functions and Associated Sub-Functions of the Manufacturing USA Network	
Functions	**Sub-Functions**
Establish the Network	Establishing memoranda of understanding (MOU) as needed between AMNPO and affected Federal departments and agencies
	Developing and deploying essential network operational policies, procedures, and protocols
	Developing and deploying the initial version of the Manufacturing USA Program Strategic Plan
Facilitate intra-network collaboration	Establishing forums for network collaboration, information exchange, and knowledge management
	Facilitating the organization and sharing of lessons learned and best practices across the network
	Identifying challenges or problems faced by all institutes and their approaches to addressing them
	Communicating awareness of key legislative and administration activity, relevant international affairs, etc.
	Facilitating network-level discussions between institutes regarding management of technology interfaces, technology gaps, etc.
	Enabling resolution of disputes not addressed by other network functions
Foster robust communication between the network and external stakeholders	Developing and deploying a network identity and public messaging strategy
	Establishing a framework and facilitating two-way information flow across the network boundary
	Promoting U.S. advanced manufacturing to government, non-member industries and academic stakeholders, and the media and public
	Managing administration, congressional, and interagency communications as they relate to the network
Sustain, strengthen and grow the network	Updating the Manufacturing USA Strategic Plan
	Facilitating funding and other resources need to sustain network-level functions
	Identifying and achieving economies of scale in areas of common need of the institutes
	Establishing, maintaining, and executing network membership policies
	Providing network-level support and guidance for newly established institutes
	Assessing and reporting on the program
	Adjusting the governance system and functions over time as needed

- Develop best practices and approaches for project calls involving two or more institutes and support joint project calls by institutes with existing resources;
- Appoint committees to advise the council on matters within its mission and to carry out the responsibilities of the council, as appropriate (with input from the respective project funding agencies);
- Adopt such other policies and rules and perform such other activities as are reasonably incidental to the administration and governance of the Manufacturing USA Council.

Manufacturing USA Identity

On September 12, 2016, the Department of Commerce announced that the National Network for Manufacturing Innovation had a new public-facing name, Manufacturing USA. The name Manufacturing USA, along with its logo, color scheme, fonts, and other complementary messaging were developed to raise awareness of the value of the program to industry, academia, nonprofits, the public, and the entire U.S. manufacturing community. They celebrate the program's impact on securing America's manufacturing future.

The Manufacturing USA identity was developed over a one-year period. The development process involved interviews with staff from all the institutes and with nearly 60 institute members, including large, medium, and small companies. Manufacturing USA was chosen by institute leaders following an online survey involving more than 1,300 manufacturing stakeholders. Manufacturing USA was chosen as the name that unifies how stakeholders describe the network and its functions.

The identity was introduced in three phases. Beginning summer 2016, the institutes and the interagency team worked to develop awareness about the upcoming release and to prepare internal stakeholders. The launch of the new identity was the central announcement by the Secretary of Commerce during keynote remarks opening the International Manufacturing Technology Show in Chicago, IL, which was attended by 115,000 people in the manufacturing community. Since then, consistent incorporation of the new identity in program press releases, agency and institute activities, and stakeholder engagements has encouraged participation and awareness, helping to further develop the overall Manufacturing USA strategy.

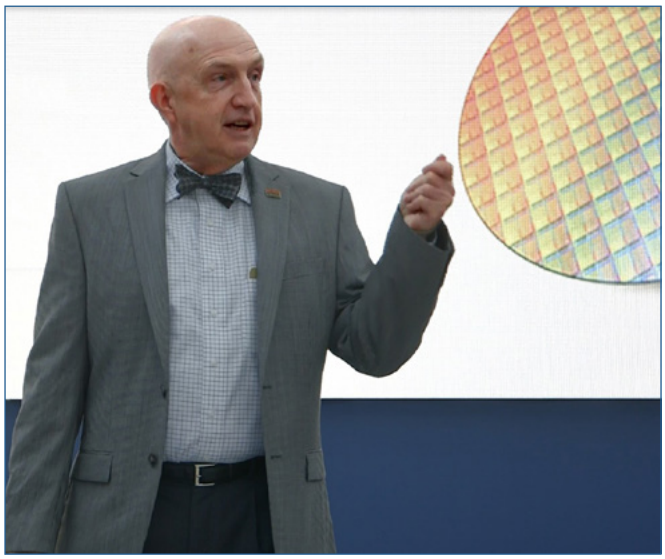


Figure 6. Announcement of the Manufacturing USA identity. Executive Director of PowerAmerica and Chair of the Institute Directors Council, Major General Nick Justice (ret.), discussing Manufacturing USA at the 2016 International Manufacturing Technology Show in Chicago, IL. Credit: DOC

The individual institute names remain unchanged and the program's official name remains the National Network for Manufacturing Innovation. However, as this program continues to expand, the public-facing identity will provide powerful, national recognition. By augmenting the public recognition of each individual institute, Manufacturing USA will become a critical component in expanding the reach and success of the program.

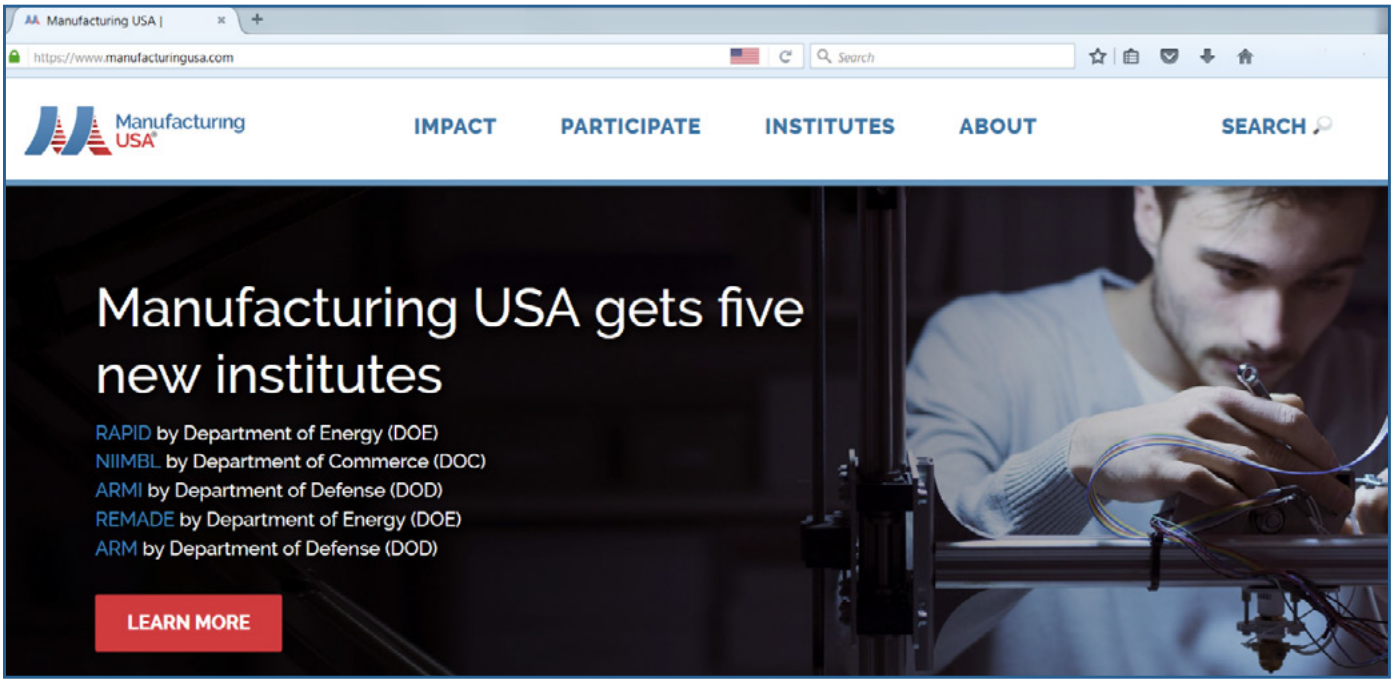


Figure 7. ManufacturingUSA.com is the public information portal for the Manufacturing USA program.

Public Clearinghouse of Information

The AMNPO provides information to the public about the Manufacturing USA program. In October 2016, www.ManufacturingUSA.com was launched to serve as the public access point for the program. The site:

- Highlights the role of Manufacturing USA for U.S. manufacturing, including examples of how the institutes and their partners are moving promising, early-stage research into proven capabilities ready for adoption by U.S. manufacturers.
- Informs potential new members about how to participate in institute activities and engage in the program.
- Updates the manufacturing industry on the opportunities available through Manufacturing USA.

The AMNPO also maintains Twitter and LinkedIn accounts to communicate status updates about Manufacturing USA to the public. The www.manufacturing.gov website, which previously provided information about the Manufacturing USA program, remains the portal for all advanced manufacturing programs across the Federal government, including links to the new ManufacturingUSA.com site.

Network Meetings and Collaboration

In the past year, the AMNPO has worked closely with its agency partners to continue establishing and convening the Manufacturing USA network. During FY 2016, the AMNPO convened two network meetings:

- November 4, 2015, in Chicago, IL
- August 4, 2016, in Gaithersburg, MD

The November 2015 network meeting was hosted in Chicago by the Digital Manufacturing and Design Innovation Institute (DMDII). Participants were grouped into working teams to identify and provide input on the Manufacturing USA's first annual report, which documented the program's major accomplishments through September 30, 2015. The participants also provided input on the program's first strategic plan.

The August 2016 network meeting was hosted by NIST. It was at this meeting that the group agreed to adopt the Manufacturing USA public identity. A session was also held on governance, during which the institute directors formally constituted the Directors Council and approved a charter, by-laws, and operating procedures. Nick Justice, Director of PowerAmerica, was elected as the first chair of the Directors Council.

These network meetings have proven to be productive information sharing and idea generation forums. Each included formative dialogue on potential network-level functions for both the initial phase of standing up an institute and for ongoing operations.

Collaboration among the Federal agencies range from biweekly meetings on management and coordination of the Manufacturing USA program, to higher level policy discussions to define and move the network functions forward.

Manufacturing USA Secure Collaboration Site

The AMNPO maintains a Manufacturing USA web-based portal to support intra-network collaboration. This site facilitates communication for all institute and agency partners. The Manufacturing USA Secure Collaboration Site was established in mid-2016 and is expanding to support the growing number of institutes and program activities.

Four key areas of the portal are:

1. A calendar for key events hosted by the institutes or agencies.
2. A library for sharing documents, including operational procedures, protocols, success stories, and best practices.
3. Topic-based collaborative sections through which participants can discuss and develop annual reports, plan network meetings, etc.
4. A directory of agency and institute contacts.

In addition, subsites have been set up for network working groups (such as the education and workforce development working group described below) and for individual institutes to facilitate their members' collaborations. These sites are accessible only by members of the respective groups.

Manufacturing USA Education and Workforce Development Activities

Manufacturing USA accelerates the development of an advanced manufacturing workforce through activities aimed at developing a domestic advanced manufacturing capability to meet current needs and to support critical emerging technologies.

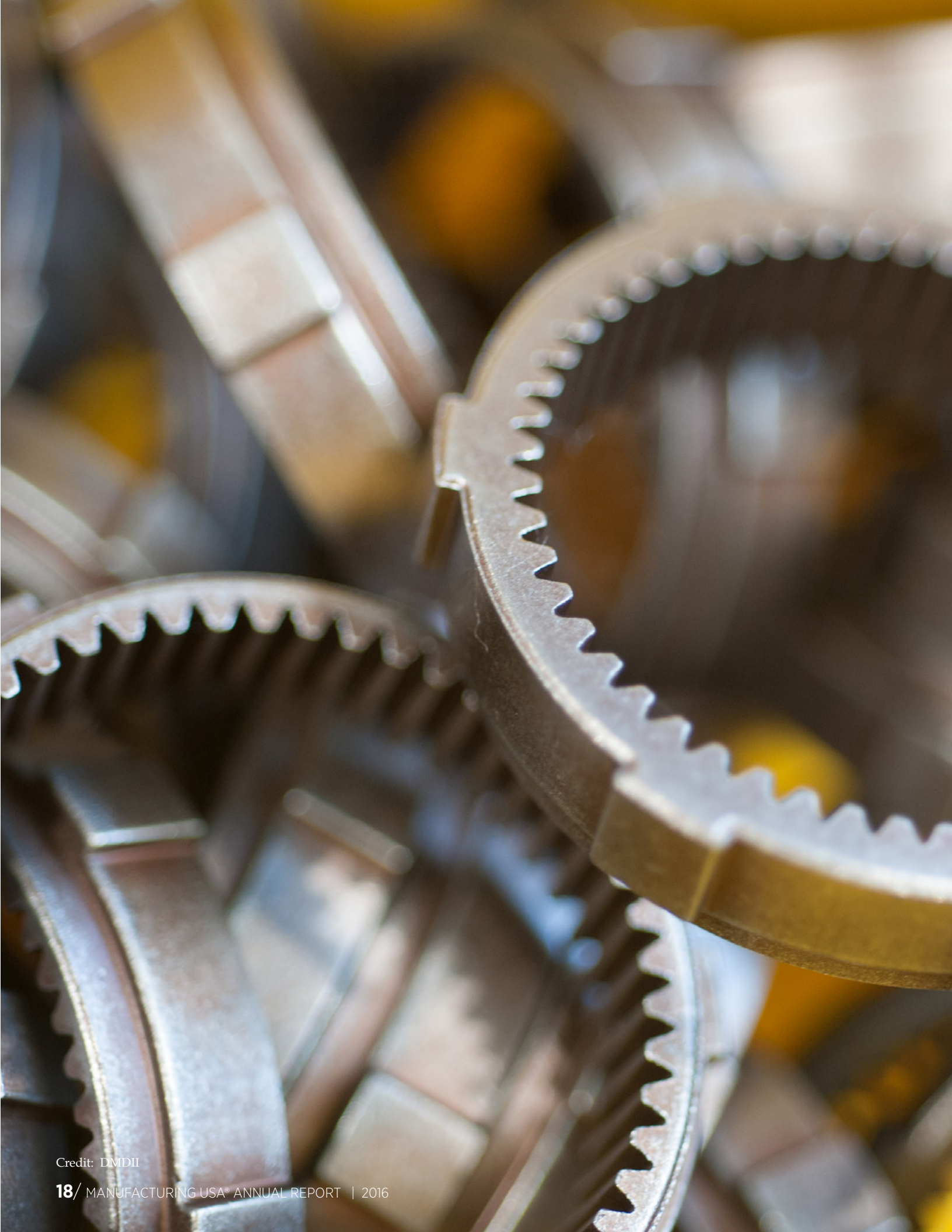
Institute Activities

In FY 2016, the Manufacturing USA institutes launched a number of programs, including: internships for high school, community college and university students; resources for K-12 educators; career information workshops for middle and high school students; technology-specific training for manufacturing employees; and training programs to help future veterans prepare for civilian life and manufacturing jobs. Many of these programs are highlighted in the individual institute sections.

To maintain alignment between the workforce training programs and emerging technologies, each institute has a workforce advisory committee that includes industry, education, and government partners.

Network Coordination of Education and Workforce Development Programs

The Manufacturing USA Education and Workforce Development Team—consisting of education and workforce experts from each institute and from participating Federal agencies—meets monthly via phone and quarterly in person to share lessons learned and project updates. Via the meetings, the established institutes in the network provide invaluable support as each new institute launches their own education



Credit: DMDII

Figure 8. The Manufacturing USA Secure Collaboration Site supports intra-network collaboration. It is designed to include subsites for network working groups and for individual institutes to facilitate collaborations among their members.

and workforce development efforts. Examples of best practice areas include the creation of workforce development advisory committees, state and local government collaboration, community college engagement, and educator programs.

To better facilitate information sharing, the Manufacturing USA Education and Workforce Development Team plans to launch a collaborative online portal for knowledge management. The AMNPO will host the collaborative portal as a subsite of the Manufacturing USA Secure Collaboration Site.

"The AIM Photonics team is extremely satisfied with this solution, as it has enabled us to overcome some of our most challenging collaboration issues, especially on high-profile activities, such as our Rochester Hub tool selection process. Additionally, the availability of the NIST-hosted SharePoint site obviated the need for AIM Photonics to devote time and resources to establishing and maintaining its own, standalone solution."

— Amie Kaplan, Director of Program Management, AIM Photonics

Identifying and Developing Common Skills Needed Across Advanced Manufacturing Technologies: The Multi-Skilled Technician Core Competency Model

In FY 2016, the Manufacturing USA Education and Workforce Development Team began development of a major cross-network initiative: the Multi-Skilled Technician Competency Model (Figure 9). The model evolved as each of the individual institutes thought through competencies for their specific technology areas. Through ongoing discussion, the team identified core competencies needed across the advanced manufacturing landscape, upon which each institute can add their technology-specific competencies. LIFT will be using the model as they create a veteran transition program focused on manufacturing.

The Multi-Skilled Technician Competency Model also shortens the startup time for the new institutes, allowing them to incorporate their specific technology needs into the model, using it to shape curriculum and training development. This example of strong cross-network collaboration is a critical demonstration of the network changing the way we teach and train our advanced manufacturing workforce.

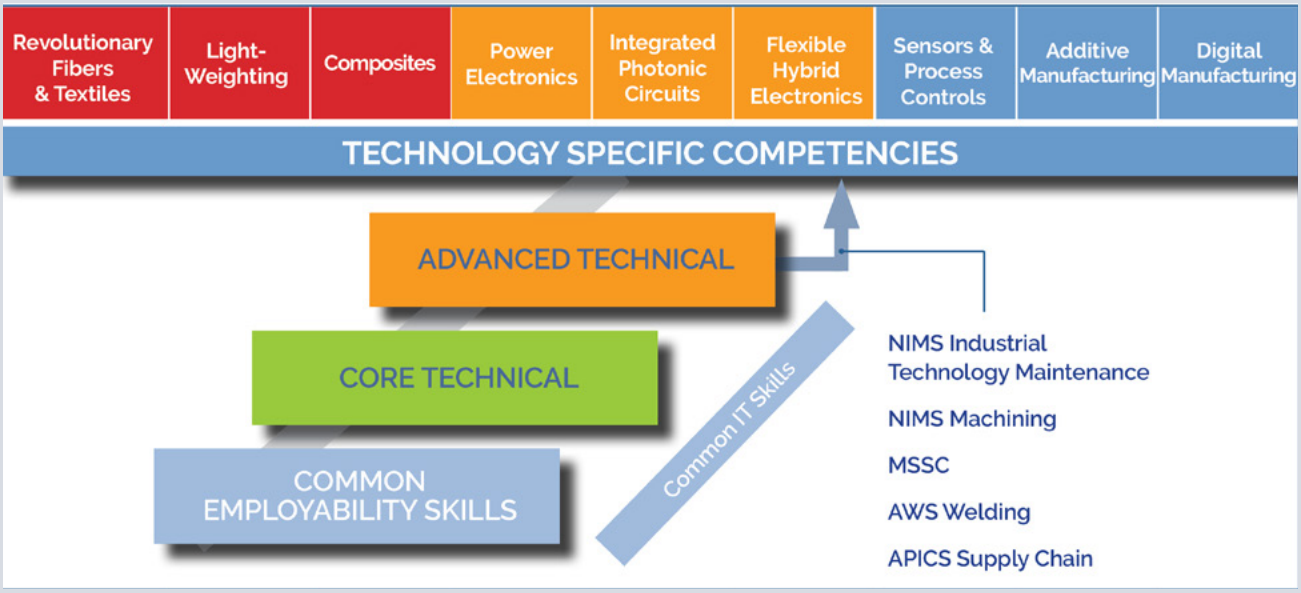


Figure 9. Multi-Skilled Technician Competency Model. The competency model builds from skills common to all manufacturing technicians to specific skills in each advanced manufacturing technology area. Existing industry certifications and credentials, such as the National Institute for Metalworking Skills (NIMS), Manufacturing Skill Standards Council (MSSC), the American Welding Society (AWS), and the Association for Supply Chain Management (APICS) can be incorporated into the model to support employability and help with curriculum development and training.

Funds Expended by the Department of Commerce for Manufacturing USA

In FY 2016, approximately $4.7 M was spent by the DOC for the provision of network services supporting Manufacturing USA, the operation of the National Program Office, the management of an open-topic competition for institutes to be funded in FY 2017, and for compliance with legislative reporting requirements, including the preparation of this report. In addition, approximately $0.5 M of FY 2015 carryover funds were used to manage the Advanced Manufacturing Technology Consortium (AMTech) program, whose activities were merged into the Manufacturing USA program by the FY 2016 Appropriations Act. No awards were made by the Department of Commerce to institutes in FY 2016.

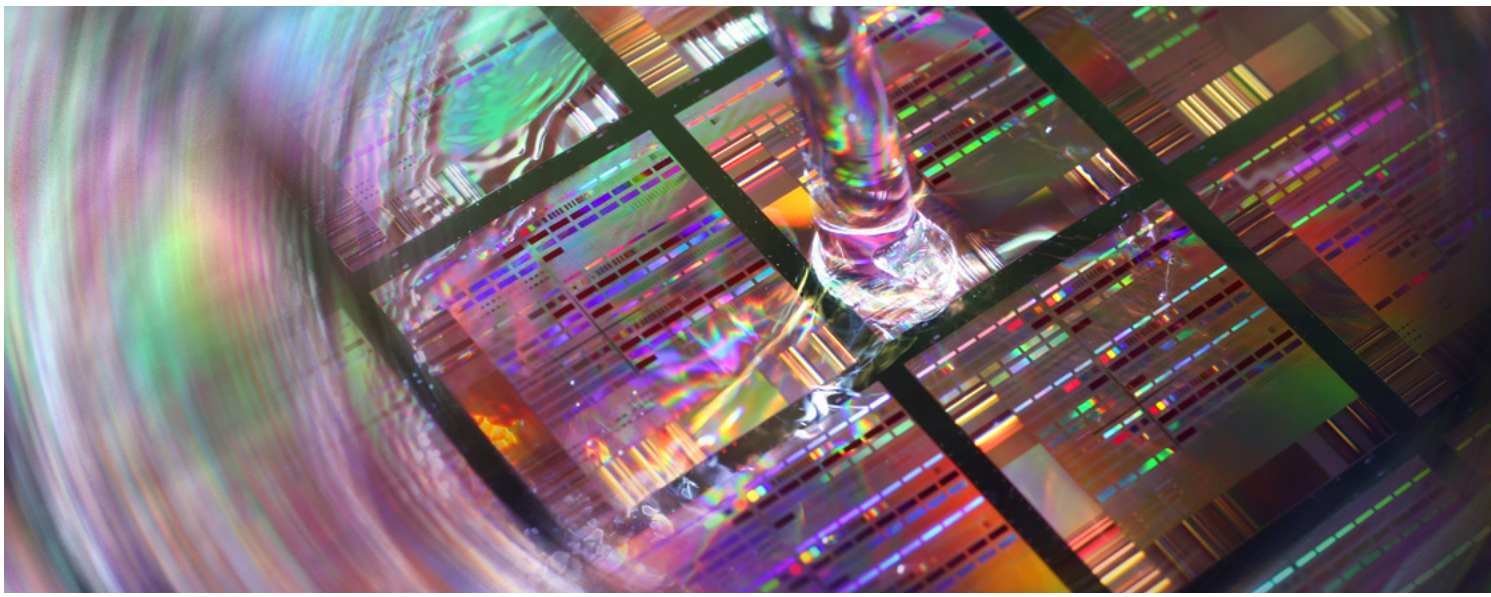
Supporting Engagement Across the U.S. Industrial Base

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

Manufacturing USA institutes had a major presence at the 2016 International Manufacturing Technology Show (IMTS), providing the focus for the opening address and the featured "Grand Concourse" presentations that kicked off two days of the show. The institutes were also among the 2,400 exhibitors on the floor of the IMTS, displaying case studies of industry collaborations that facilitated breakthrough transitions from concept to production. The institutes also exhibited at the Hanover Messe in Hanover, Germany, the world's largest industrial conference.

Serving Small Business

NIST operates the Hollings Manufacturing Extension Partnership (MEP), which funds a national network of 51 non-federal state-based technical assistance centers that provide high quality consulting to the nation's 292,000 small manufacturing establishments. The RAMI legislation specifically recognized the value of the MEP Program by directing the AMNPO to incorporate "the Hollings Manufacturing Extension Partnership into [Manufacturing USA] Program planning to ensure that the results of the Program reach small and medium-sized entities."[20]



Credit: AIM Photonics

[20] Revitalize American Manufacturing and Innovation Act of 2014, 15 USC 278s(f)(5).

A memorandum of understanding (MOU) between MEP and DoD executed in FY 2015 became the framework to leverage MEP's national resources to assist Manufacturing USA institutes. MEP provided funding to MEP centers to develop pilot collaboration projects between centers and Manufacturing USA institutes. By October 2016, five pilot projects (at DMDII, AIM Photonics—American Institute for Manufacturing Integrated Photonics, IACMI—Institute for Advanced Composites Manufacturing Innovation, NextFlex—America's Flexible Hybrid Electronics Manufacturing Institute, and PowerAmerica—The Next Generation Power Electronics Manufacturing Innovation Institute) had been confirmed. These pilot projects were designed to:

- transfer technology from Manufacturing USA institutes to small manufacturers based on the technological needs of manufacturers;
- create approaches to engaging small manufacturers in the work of the institutes through hands-on assistance mechanisms and services such as those that are currently, or could be offered by MEP centers;
- develop and test business models by which MEP centers and Manufacturing USA Institutes can viably and effectively serve the needs of small manufacturers in the institutes' technology areas;
- facilitate knowledge and best practice sharing between Manufacturing USA institutes and MEP centers; and
- cultivate an enhanced nationwide network of partnerships among Manufacturing USA institutes and MEP centers for the benefit of small manufacturers.

NIST MEP works with Manufacturing USA institutes in numerous ways to serve small businesses. MEP convened a group of MEP centers to work with DMDII on a "Train the Trainer" program to develop center practitioners' knowledge in digital manufacturing. This will enhance the MEP center staffs' ability to assess the gaps at their small manufacturing clients and to assist these clients, with support from DMDII, to improve their digital footprint. The MEP Michigan Manufacturing Technology Center conducted activities to increase awareness of LIFT within the small business community. In 2016, the engagement of MEP centers and small businesses was expended to the four other LIFT region states: Indiana, Kentucky, Ohio, and Tennessee.

Leveraging Other Government Investments

Federal agencies support projects and facilities that provide resources and expertise to the Manufacturing USA institutes. The agencies also and can benefit from the resources and expertise of the institutes. Such collaborations spin-off advanced concepts 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, technicians, designers, planners, researchers, engineers, and managers that U.S. industry needs to move from theory to practice.

National Science Foundation

The National Science Foundation (NSF) issued Dear Colleague Letter (DCL) NSF 16-007, "Advanced Technological Education (ATE) Program Support for Manufacturing Innovation Institutes (MIIs) and Investing in Manufacturing Communities Partnerships (IMCPs)."[21]

NSF 16-007 encourages community college faculty to seek NSF funding to partner with the Manufacturing USA institutes in crafting workforce development plans that use the mechanisms and resources developed in the ATE program to prepare a world-class, entry-level technical workforce.

[21] NSF 16-007: https://www.nsf.gov/pubs/2016/nsf16007/nsf16007.jsp

MForesight: The Alliance for Manufacturing Foresight, a national consortium focused on identifying and assessing national needs and opportunities in manufacturing technology innovation, was 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 2016, MForesight issued three reports: *Biomanufacturing Technologies for Regenerative Medicine*, *Biomanufacturing Technologies for Engineering Biology*, and *Democratizing Manufacturing*.[22] These reports helped inform Manufacturing USA agencies make important decisions regarding the program's direction, including the funding opportunity announcement for a new DoD institute focused on biomanufacturing.

NIST Laboratories and AMTech

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 NIST laboratories fit naturally with the needs of the various institutes, especially in the areas of measurement science and standards needed for new manufacturing innovations. The strong technical depth 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 and marshal NIST laboratory resources to support each institute.

NIST staff have active technical collaborations and advisory roles within the institutes. These roles range 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. In FY 2016, NIST staff served on an institute executive board, supported workforce activities in four institutes, and provided subject matter experts for technical or government advisory boards for all the active institutes.

The NIST Advanced Manufacturing Technology Consortium (AMTech) program develops industrial consortia to work together to address precompetitive challenges in order 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 new institutes, and institutes are using ten other AMTech roadmaps to shape the direction of their technical research.

Third-Party Private-Sector Assessment

The Manufacturing Deputies of the DoD, the DOE, and NIST, with input from the NEC and OSTP, agreed in early 2016 that Manufacturing USA would benefit from a third-party assessment to evaluate and validate the program model and to identify its collective impact across the program's established institutes, members, and ongoing projects. After interviews were conducted with multiple organizations, Deloitte USA was selected to perform the assessment, Manufacturing USA: A Third-Party Evaluation of Program Design and Progress (the "Deloitte report").[23]

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[22] Biomanufacturing Technologies for Engineering Biology, MForesight, August 2016, Report Number: MF-RR-2016-0101. Biomanufacturing Technologies for Regenerative Medicine, MForesight, July 2016, Report Number: MF-RR-2016-0102. Democratizing Manufacturing, MForesight, December 2016, Report Number: MF-RR-2016-0104. These reports can be downloaded at http://mforesight.org/publications/

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

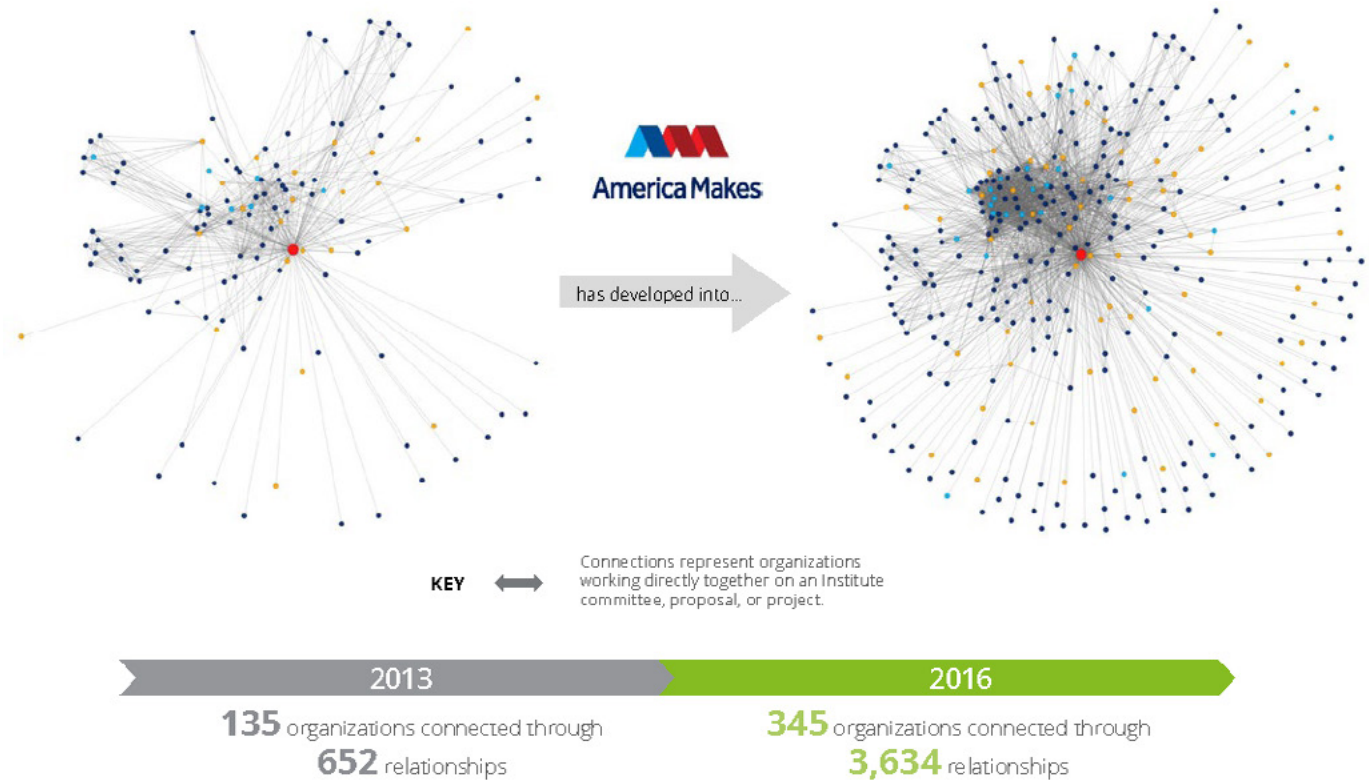


Figure 10. The Manufacturing USA Network Effect. As each institute increases membership, the members' connectivity increases, along with the value delivered to each member. For example, at the first institute established, America Makes, membership has grown and member connectivity has increased as members collaborate on working groups, steering committees, and projects. Credit: Deloitte Report

The assessment concluded that Manufacturing USA is successfully achieving its program goals. It found that the program design is valid and appropriate. Manufacturing USA is breaking down market barriers in the right technological areas to accelerate U.S. manufacturing research and development. Additionally, the report highlights the institutes' most effective initiatives that are reducing the talent gap through industry workforce assessments, community engagement events, post-secondary apprenticeship programs, and creation of effective industry- and skill-based credentials.

The Deloitte report used an "outside-in" approach to its assessment that accessed insights from experts through traditional outreach methods and innovative crowdsourcing techniques. Findings in the report were based on both qualitative and quantitative analysis of the Manufacturing USA investment areas' ability to impact U.S. manufacturing competitiveness. The end goal was to have a report that would be value-added to both the network and the institutes, as well as to the program's public and private stakeholders.

The evaluation covered the following areas: (1) an assessment/validation of the strength of the underlying Manufacturing USA model and theory for achieving the program's objectives and planned impacts, (2) the progress of the network to date in achieving program objectives and impacts, (3) recommendations to improve network performance and effectiveness in achieving the desired impacts, (4) insights into appropriate metrics that link institute activities to program objectives and impacts,

Credit: America Makes

and (5) recommendations regarding Manufacturing USA and institute sustainability strategies beyond the initial period of Federal investment.

The report found that Manufacturing USA's approach of having a portfolio of technology-centric institutes is valid. The public-private partnership, institute-based model attracts significant and meaningful participation from industry (including large companies and SMEs), academia, and local, state, and Federal government. Institute members have made substantial joint investments in collaborative approaches to research and development of cutting-edge advanced manufacturing technologies and are receiving significant, leveraged returns on investment. Institutes are laying the groundwork for building the skills of the U.S. manufacturing workforce to meet the needs of 21st century employers.

The Deloitte report's seven specific recommendations for improvements focus on developing strategies for long-term growth and sustainability, maintaining institute focus on U.S. national priorities, making the most of existing programs in workforce development and other resources. Critical to these improvements is the recommendation for applying staged metrics for program evaluation. As the report noted, the existing metrics appear to align well with the recommendations for early stage evaluation.

Independent Federal Assessment

The RAMI Act of 2014, authorizing the Manufacturing USA program, requires that at least once every two years, the Comptroller General of the Government Accountability Office (GAO) submit to Congress an assessment of the program's operation during the most recent two-year period.[24] The first GAO report on Manufacturing USA commenced in FY 2016 and was released on April 6, 2017.[25] GAO staff held multiple meetings with officials from The Departments of Commerce (DOC), Defense (DoD), Energy (DOE), Labor (DOL), and, Education (DOEd); made visits to or had interviews with representatives of each Manufacturing USA institute; and led several discussion groups with a non-generalizable sample of institute member representatives. The report summarizes the program and provides profiles of each institute, with no negative findings about either the program or institutes.

GAO recommends that the DOL should be more engaged with the Manufacturing USA program. GAO also recommends an expansion of the Manufacturing USA governance document to detail roles and responsibilities of agencies that have not sponsored institutes.

Manufacturing USA Plans for Addressing External Assessments

The third-party private-sector and independent Federal assessments were valuable for the Manufacturing USA program by providing valuable recommendations for program improvements.

The Manufacturing USA program intends to follow the Deloitte report's recommendation for expanding and modifying metrics as the program matures and as new technologies developed at the institutes are deployed into the economy.

In the short time since GAO's report was released, DOC has already recruited a senior DOL leader as a representative in Manufacturing USA, and DOL participated in the most recent network meeting.

The three sponsoring agencies and the participating non-sponsoring agencies concur with GAO's recommendation to expand the program's governance document to detail roles and responsibilities of the non-sponsoring Federal agencies.

[24] Revitalize American Manufacturing and Innovation Act of 2014, 15 USC 278s(g)(3).

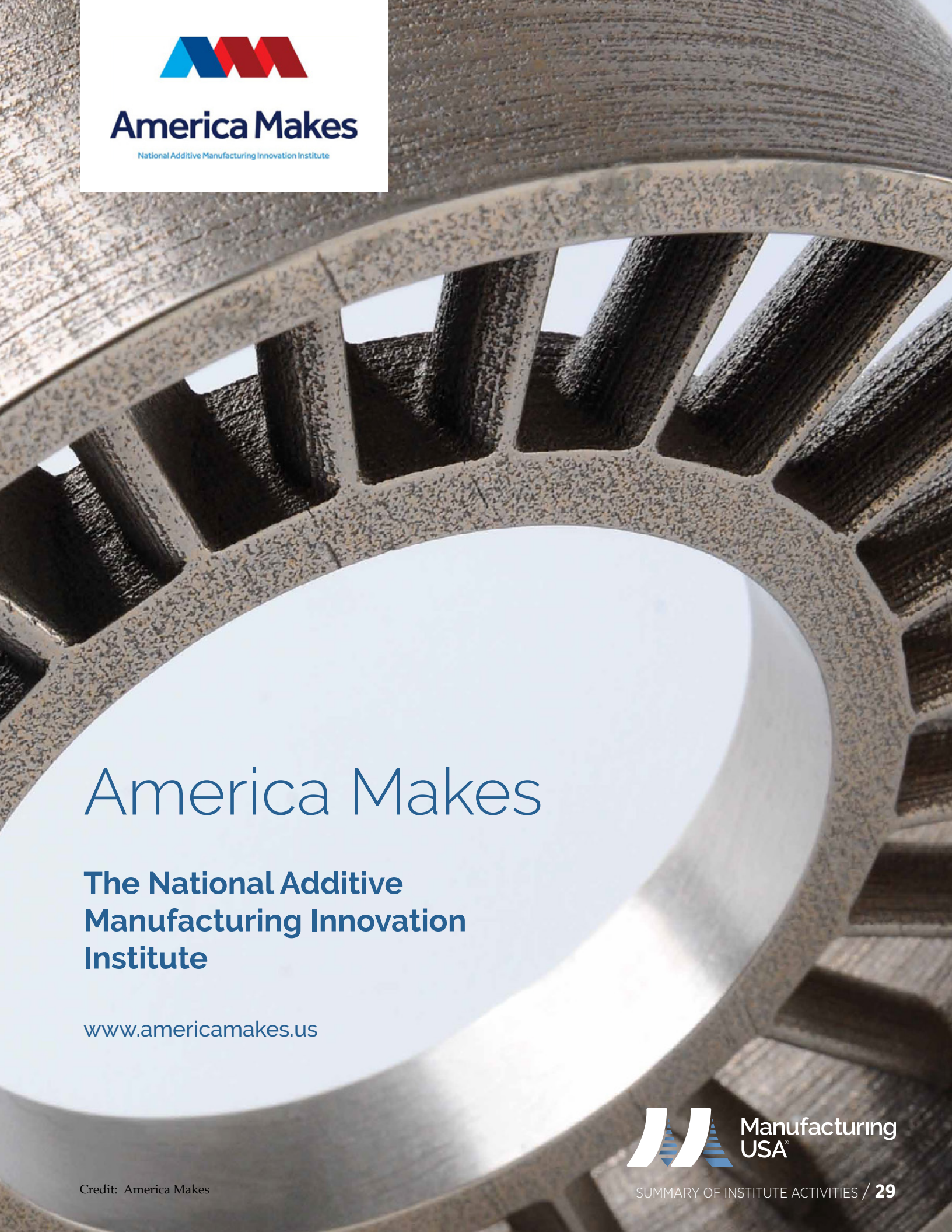
[25] GAO-17-230: http://www.gao.gov/products/GAO-17-320

SUMMARY OF INSTITUTE ACTIVITIES

Department of Defense

Credit: U.S. Air Force

Credit: U.S. Marine Corps



America Makes

National Additive Manufacturing Innovation Institute

America Makes

The National Additive Manufacturing Innovation Institute

www.americamakes.us

Manufacturing USA®

Credit: America Makes

AMERICA MAKES

Mission: To accelerate the adoption of additive manufacturing technologies in the U.S. manufacturing sector and increase domestic manufacturing competitiveness.

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

Established: August 2012

Consortium Organizer: National Center for Defense Manufacturing and Machining (NCDMM), headquartered in Blairsville, PA

Funding: $56M, including support from DoD, DOE, NSF, and NASA; Non-Federal, $58M; Both planned over five years; Follow-on Five-Year Cooperative Agreement: $50M Ceiling Federal funding and $25.8M Non-Federal funding

Members: 177

Background

America Makes is the national accelerator for additive manufacturing (AM) and 3D printing, and is the nation's leading collaborative partner in AM and 3D printing technology research, discovery, creation, innovation, and dissemination. The institute's members and public partners work together to bridge the gap between basic research and technology development and deployment.

Three major focus areas of activity define the scope of America Makes' activities: additive manufacturing technology development, technology dissemination and transition, and workforce and educational outreach. These focus areas address all areas of additive manufacturing, with the priorities established collaboratively by the public and private members of America Makes. The focus areas' activities are supported by core functions consisting of the program and business management infrastructure, member engagement, roadmapping, data systems, digital collaboration, and public outreach.

Additive manufacturing allows for the design and production of never-before-possible products and for quicker and cheaper production of many existing products, thanks to innovations such as low-cost, quick-response additive manufactured tooling. America Makes' research and development (R&D) projects are producing results for multiple product sectors, from aerospace and defense to life-saving medical applications. Use of additive manufacturing for aerospace products improves performance, reduces costs, and shortens manufacturing lead-times. Few technologies can deliver product improvements in all three areas. Medical applications include patient-tailored joint and cranial implants, implanted tracheal support structures to treat birth defects, custom-fitted hearing aids, tools to precisely manufacture dental braces, and patient-specific surgical models based on computed tomography scans to plan and rehearse complex surgical procedures before operating on a patient.

Technology Advancement

"Sharing ideas and results between members of the additive manufacturing community will lead to new ideas and innovation. The collaboration and sharing in America Makes is allowing acceleration of innovation and development as compared to individually funded programs."

— Jim Dobbs, The Boeing Company, Huntsville, AL

"America Makes represents the best opportunity for us, a small business, to take informed risks with the support of the wider additive manufacturing community in new R&D avenues that further our growth."

— Dhruv Bahte, Phoenix Analysis & Design Technologies, Tempe, AZ

America Makes has developed a rigorous member-driven technology development roadmapping process based on systems engineering principles to categorize and address the complex barriers hindering the use of additive manufacturing. When traveled, the resulting technology roadmap becomes the America Makes strategic R&D investment plan. The second-generation roadmap was released August 2015 (https://www.americamakes.us/projects/techroadmap) and the third-generation roadmap is in development.

As a result of this roadmapping, by the end of 2016 America Makes had more than $97 million in R&D projects either completed or underway that included significant in-kind cost share and involved more than 180 unique engaged industry and academic organizations within the institute's innovation ecosystem.

Projects Completed in FY 2016

Fifteen R&D projects were completed in FY 2016, from high-throughput and ultra-low-cost metal AM systems to AM of bioresorbable biomedical devices. The following are highlights from three of the completed projects that address items in the technology roadmap:

- One of the fundamental challenges in metal powder bed additive manufacturing is how to mitigate distortion caused by stress from heating metal powder to molten metal then cooling to the final material state, all within a fraction of a second. A collaborative team of three highly competitive aerospace manufacturers—GE, Honeywell, and United Technologies Research Center (UTRC)—worked with three software developers: start-up companies 3DSIM, based in Park City, UT, and Pan Computing in State College, PA, along with Philadelphia-based CDI Corporation. This team developed accurate and reliable software that predicts distortion caused by thermal additive processes, allowing a 75 percent reduction in product development times and shortened time to production.
- Medical industries widely use titanium in electron beam melting (EBM) additive manufacturing, but a lack of proven material properties has limited its use for flight-critical military aircraft and space applications. A team led by Northrop Grumman Aerospace Systems in El Segundo, CA, developed

Credit: U.S. Air Force

Figure 11: America Makes Additive Manufacturing Bootcamp Graduate Explaining the Therapeutic Hand Brace that She Designed and Created. Top Credit: 3D Veterans/America Makes. Left Credit: America Makes

LIFE-CHANGING ADDITIVE MANUFACTURING TRAINING FOR VETERANS AND INDIVIDUALS WITH DISABILITIES

Supported by a Google.org "Impact Challenge Grant," America Makes worked with 3D Veterans and the Department of Veteran Affairs Center for Innovation to build a pilot program to train and employ veterans and individuals with disabilities in the use of additive manufacturing. 3D Veterans is a veteran-owned and operated small business that provides training and finds employment in additive manufacturing for veterans.

The team created and conducted a six-week Additive Manufacturing Boot Camp held in San Antonio, TX, in the fall of 2016. The boot camp consisted of hands-on, project-based additive manufacturing technology and business skills training. From more than 70 applications, 15 veterans were selected to participate in the program.

During the boot camp, 3D Veterans taught participants how to use design tools and 3D printers to create assistive devices for veterans with disabilities. The students built 13 new assistive technology and prosthetic prototypes, including a prosthetic hand and a lightweight, affordable ankle attachment for leg prosthetics. Five prototypes made for veterans/by veterans were funded to move from prototypes to working prototypes. The program then supported two veteran entrepreneurs who want to take their working prototypes to market.

To date, 77 percent of the veterans completing the boot camp have been placed in additive manufacturing jobs, exceeding the initial goal of placing 50 percent of participants.

Completing the pilot program, the team built a turnkey curriculum including a 100-page playbook for program replication. America Makes plans to deploy the Additive Manufacturing Bootcamp in Pittsburgh, PA, and San Francisco and Los Angeles, CA, with a goal of placing 100 percent of participants in jobs.

"This boot camp featured project-based learning activities. Participants designed and created prototypes for assisted devices that can have real impact for disabled veterans. As the program expands, these prototypes can be used to demonstrate quality-of-life improvements and eventually become real products." – Michael Mondaca, 3D Veterans Co-Founder and leader of the boot camp

3D Veterans Bootcamp videos:
America Makes Moment: An Introduction to 3D Veterans Bootcamp (1:57 Min)
https://www.youtube.com/watch?v=8nWCa02rZHo
America Makes Moment video: 3D Veterans Initiative (11:52 Min)
https://www.youtube.com/watch?v=DMEm3pW9vnE

statistically significant design values for titanium products using EBM additive manufacturing, enabling widespread use of Ti-6Al-4V alloy for the highly loaded or elevated temperature exposed components for which that alloy is ideally suited.

- Current metal powder production methods for use in direct metal additive manufacturing machines are based on the needs of the traditional powder metallurgy industry, and metal powders have not been developed specifically for additive manufacturing. A team led by Carnegie Mellon University in Pittsburgh, PA created a first-of-its kind database relating metal powder properties to process outcomes such as geometric precision and material hardness. This database lays the framework for introducing new, diverse powder materials that will lower the cost of AM or take advantage of its unique characteristics.

New Projects Launched in FY 2016

America Makes issued its fourth major project call based on its technology roadmap in March 2016 and announced seven awardees in July 2016. Highlights from these projects:

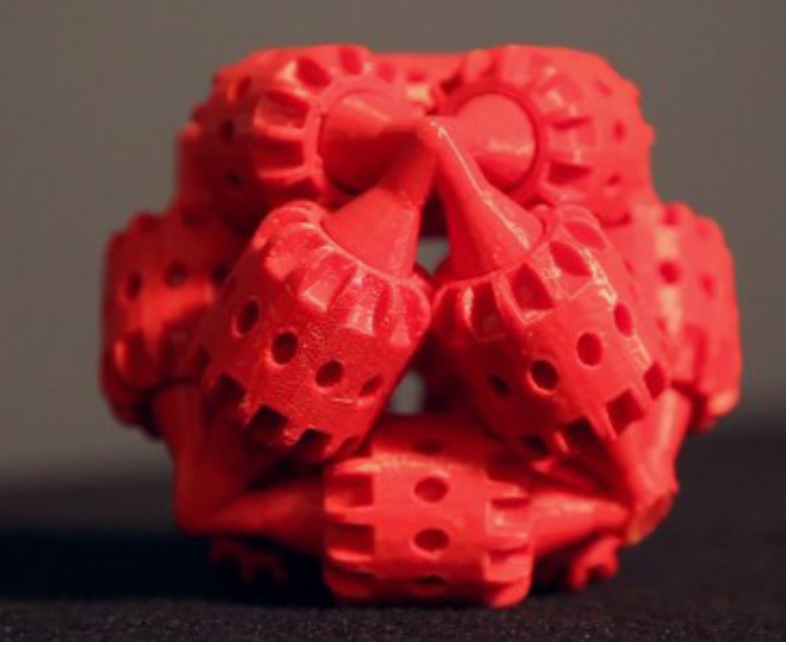
- **Multi-functional Big Area AM (BAAM): BAAM with Multi-Purpose Wire Embedding** – University of Texas at El Paso with two team members. This project will advance additive manufacturing build volumes and production rates by combining large-scale additive manufacturing with electrical wire embedding due to AM's ability to introduce wire harness features directly into structural components.
- **MULTI: Source/Feedstock/Meter-Scale METAL AM Machine** – Wolf Robotics, LLC - A Lincoln Electric Company with nine team members. This project will position additive manufacturing industrial users to take advantage of the lower cost and increased flexibility associated with scalable, multi-axis (nine and above) robot systems.
- **AM for Metal Casting (AM4MC)** – Youngstown Business Incubator with nine team members. This project will strive to transform the U.S. industrial base via the development of next-generation sand printers that offer line speed production of printed cores and molds that are affordable for small- and mid-sized manufacturers to procure and integrate into full production lines.
- **Multi-material 3D Printing of Electronics and Structures** – Raytheon with five team members. This project will seek to enable multi-material printing of integrated 3D electronics and complex curved structures. The commercial, aerospace, biomedical, and defense industries have many applications that could benefit from novel, dense, and affordable 3D electronic packaging.

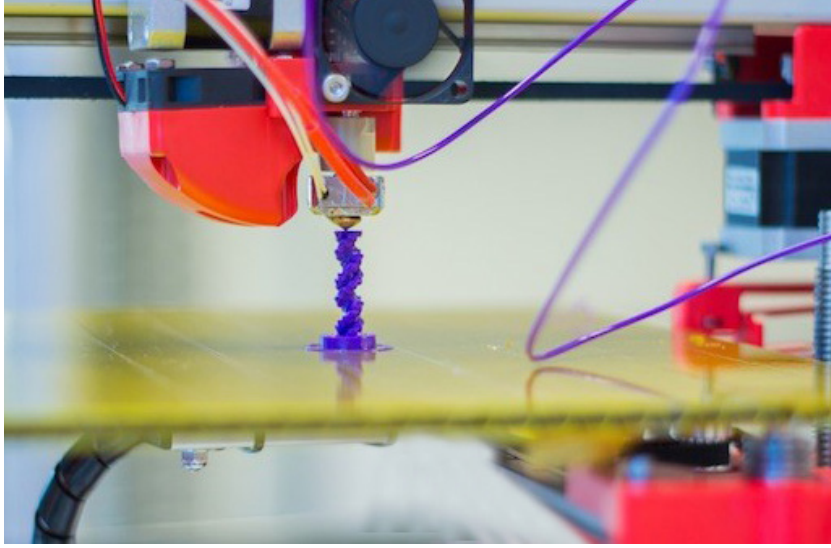
Workforce Development

"Education in advanced manufacturing is essential to improving U.S. manufacturing competitiveness in emergent, fast-growing 21st-century technologies such as additive manufacturing, automation, and advanced insight and analytics. The education work that America Makes is facilitating though efforts such as 3D Veterans, ACADEMI, and training at their innovation factory is directly targeted at developing the skills that employees need to successfully compete in an advanced manufacturing world."

— Dr. Kirk Rogers, General Electric Center for Additive Technology Advancement, Pittsburgh, PA

America Makes' workforce and educational outreach (WEO) mission is to create and grow an agile additive manufacturing workforce capable of meeting current and emerging industry needs that will increase overall domestic manufacturing competitiveness. To focus its workforce development actions, America Makes developed an Additive Manufacturing WEO Roadmap (see https://www.americamakes.us/workforce/weoroadmap) that identifies measurable and meaningful education and training challenges to promote inquiry, knowledge-sharing, and technical advancements across the additive manufacturing industry.





Credit: America Makes

INNOVATIVE MODELING AND SIMULATION SOFTWARE TO REDUCE THE COST AND WEIGHT OF ADDITIVE MANUFACTURED STRUCTURAL PRODUCTS

Additive manufacturing enables the manufacture of complex parts previously impossible to machine. To fully exploit the additive manufacturing advantage, the field needs design tools to optimize component geometry for strength and weight by incorporating features such as lattice and porous structures. Current modeling and simulation tools lack efficiency in designing these complex geometries for additive manufacturing.

The University of Pittsburgh led a team of ANSYS, United Technologies Research Center, the ExOne Company, GE, ALCOA, Materials Science Corporation, and ACUTEC Precision Machining, along with the Department of Defense and National Science Foundation to develop robust modeling and simulation software for the design and optimization of additive manufactured structural products based on cellular structures.

The key innovation involved the use of micromechanical models to capture the effective behavior of cellular structures in a finite element analysis (FEA). This enabled topology optimization problems to be solved via FEA software more efficiently. Further, the project team also integrated cost modeling and design requirements for several additive manufacturing processes.

The project team successfully developed software to design realistic additive manufactured cellular structured components. A beta version of the software was successfully deployed to United Technologies Research Center, ExOne, and Materials Sciences Corporation. ANSYS, a world-leading computer aided engineering/ computer aided design software vendor, is implementing the developed modeling and simulation technology into its software, which is expected to be available in their next release.

Enabling design optimization of additive manufactured cellular structures achieved a direct reduction in material use and process energy in manufacturing cellular structures by 50 percent, as compared to bulk solids, and enhanced mechanical properties (e.g. stiffness increased by >100 percent; strength increased by >200 percent). This is a significant technical accomplishment benefitting weight-sensitive applications such as aircraft and satellites that also require high structural strength.

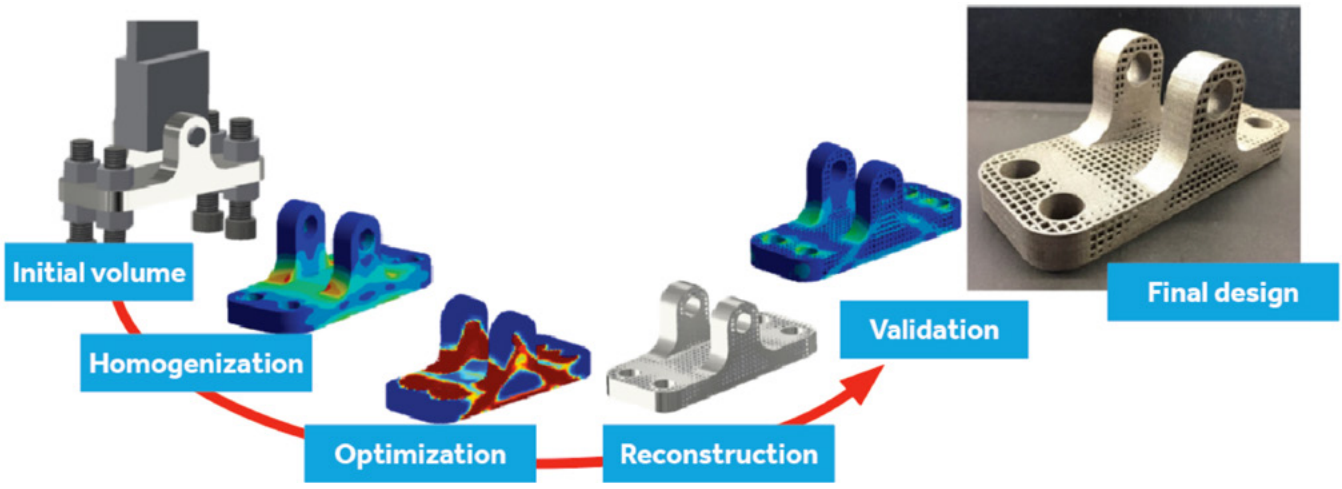


Figure 12: Application of Homogenization-Based Topology Optimization Method for a Pillow Bracket Made with Ti-6Al-4V. Credit: America Makes/University of Pittsburgh

These are some key WEO accomplishments in 2016 that address needs identified in the roadmap:

- Conceived and initiated the creation of the America Makes ACADEMI (Advanced Curriculum in Additive Design, Engineering and Manufacturing Innovation), partnering with The Lanterman Group. This immersive, hands-on training program will play a meaningful role in addressing unmet needs in the market, particularly among businesses that have recently invested in additive manufacturing and need skills, education, and access to technology know-how to move forward.
- As described below, through a Google.org Impact Challenge grant, America Makes, in collaboration with the Veterans Administration and 3D Veterans, brought hands-on, project-based technology training to U.S. veterans at an Additive Manufacturing Bootcamp held in San Antonio, TX.
- Created a five-state (Ohio, Pennsylvania, Michigan, Indiana, and Kentucky) Regional WEO Roadmap Implementation Strategy
- Leveraging the fourth America Makes technical project call, awarded the development of multiple workforce and educational outreach assets, including:
  - Design for additive manufacturing course
  - E-learning courses for metal casting (AM4MC) using additive manufacturing
  - Community college courses on additive manufacturing and precision tooling
  - A digital on-line additive manufacturing text book
  - Additive manufacturing training for medical providers

Innovation Ecosystem

America Makes has afforded Johnson & Johnson the opportunity to connect with and share the challenges facing industry across the U.S. in the adoption of additive manufacturing. Together we have partnered with multiple U.S. academic institutions to develop the science while also establishing the education curriculum required for tomorrow's workforce. This is an integral part of the overall Manufacturing USA network's impact on the American workforce and manufacturing capabilities."

— Joseph Sentra, Johnson & Johnson, Miami Lakes, FL

As the National Additive Manufacturing Innovation Institute, America Makes fosters a highly diverse, multi-disciplinary, innovation ecosystem spread across the U.S.

Membership, as of September 2016, consisted of

- 46 large business
- 62 small businesses
- 40 academic organizations (universities, community colleges, and research institutions)
- 14 government organizations that have signed the America Makes Membership Agreement
- 11 non-profit organizations that include four professional societies and a business incubator
- 4 Manufacturing Extension Partnership (MEP) centers

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

The Institute's 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 overlaps in technical issues to be solved and a rapidly growing urgency for a skilled, multi-disciplinary additive manufacturing workforce. *Under the America Makes infrastructure, a powerful, connected, and deeply collaborating innovation ecosystem is now in place and producing benefits and value for all involved.*

Credit: U.S. Air Force

These are some sample "connecting the dots" examples of activities within the America Makes innovation ecosystem that complement the collaborative R&D projects underway:

- Facilitated a nine-workshop collaborative effort among the Army, Air Force, Department of the Navy, and Defense Logistics Agency to develop a DoD-wide roadmap for additive manufacturing technology development.
- Brought together 40 senior DoD acquisition executives and 35 senior industry executives for an enlightening additive manufacturing business model wargame.
- Partnered with Siemens and Deloitte to establish an innovative data management solution that provides rapid, but secure, access to over 1,000 deliverables from America Makes additive manufacturing R&D projects.

Targeting the need for standards, the lack of which is a significant roadblock to increased government and industrial use of additive manufacturing in the U.S., we formed a partnership to launch the America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC) in March 2016. The AMSC is a cross-sector coordinating body whose objective is to accelerate the development of industry-wide additive manufacturing standards and specifications consistent with stakeholder needs and thereby facilitate the growth of the additive manufacturing industry. The AMSC plans to publish a standardization roadmap for additive manufacturing in FY 2017. Content for the roadmap is being developed by multiple teams encompassing over 225 subject matter experts from government, industry, and academia, leveraging the Institute's "power to convene and coordinate."

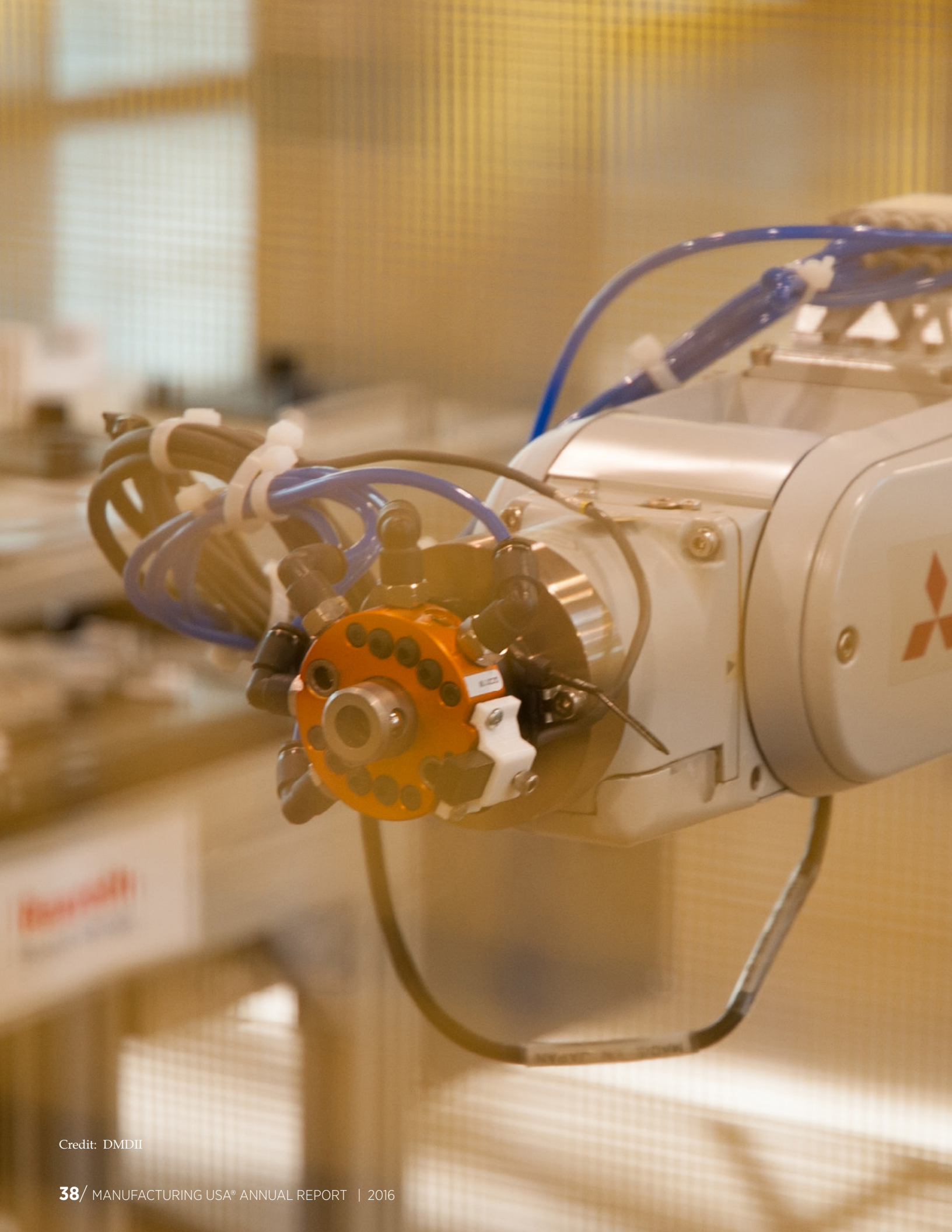
Sustainability

"America Makes is a national asset with unique and specialized capabilities that the Air Force and other government agencies will need to access to address their R&D needs well into the future. It is in the best interests of the Air Force, in particular, and the government, in general, to ensure it maintains continued access to America Makes through an effective and efficient mechanism, such as the follow-on cooperative agreement awarded by AFRL."

— Thomas Lockhart, Director of the Material and Manufacturing Directorate, Air Force Research Laboratory, Wright Patterson Air Force Base, OH

Membership retention and growth is rooted in delivering value to America Makes' members in return for their annual membership fees. The execution of technical and workforce and educational outreach projects, combined with workforce development training courses in additive manufacturing, are additional revenue streams ensuring America Makes' sustainability.

Recognizing the enduring value America Makes is providing to its public partners and private members, in February 2016 AFRL awarded America Makes a follow-on cooperative agreement: a cost-reimbursement/cost share agreement with a value up to a combined $75M of government cost and America Makes cost share. The first project under the agreement is to develop additive manufacturing technologies for Air Force sustainment applications. Additional special topic projects appropriate for a public-private partnership are being added as funding becomes available. This provides an opportunity for any government agency to partner with America Makes and its diverse membership to address additive manufacturing and 3D printing needs.



Credit: DMDII

DMDII

a UI LABS Collaboration

DMDII

Digital Manufacturing and Design Innovation Institute

www.dmdii.uilabs.org

Credit: DMDII

Manufacturing USA®

DMDII

Mission: The Digital Manufacturing and Design Innovation Institute seeks to transform American manufacturing through digitization of the supply chain.

Locations: Chicago, IL

Established: February 2014

Consortium Organizer: UI LABS

Funding: Federal, $70M; Non-Federal, $106; both planned over five years

Members: 270

Background

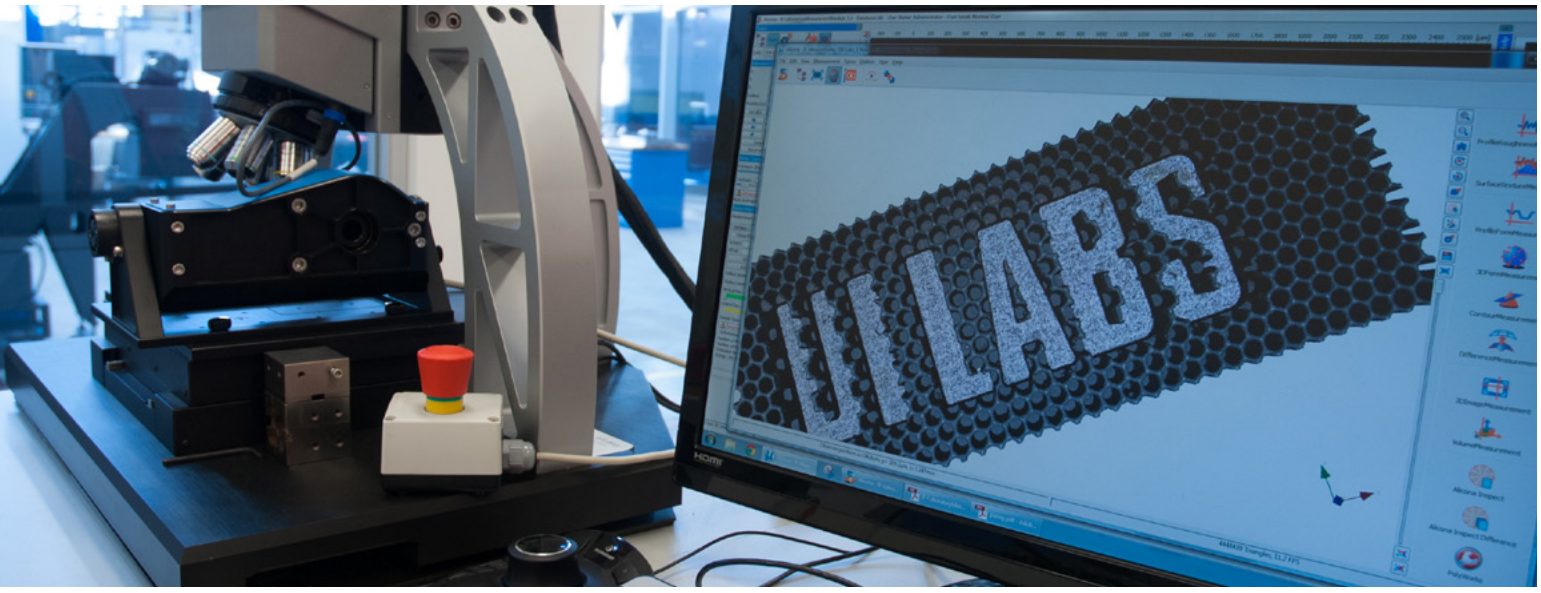
DMDII collaborates with its partners to address the most intractable manufacturing challenges and make U.S. manufacturing more competitive using digital technologies. Digital manufacturing and design involves connecting every aspect of the manufacturing life cycle through data and using that information to inform smarter business decisions and drive better end-to-end design.

To achieve that goal, DMDII is engaged in more than 60 technical projects that focus on product design and systems engineering, future factory, agile supply chain, and cybersecurity in manufacturing. DMDII's mission includes equipping U.S. workers with the skills and expertise required for tomorrow's manufacturing jobs and building deployment channels to accelerate the adoption of digital manufacturing solutions in factories of all sizes across the country.

Technology Advancement

"What we really like about the concept of DMDII was not just ideas and thinkers and white papers, but a physical place where we can bring technology, we can bring the best minds, and we can see how manufacturing technology and autonomous robotics work together with additive manufacturing in an environment where we're trying to integrate knowledge-based systems."

— Chuck Grindstaff, Executive Chairman, Siemens PLM Software



Credit: DMDII

DMDII's projects develop innovative new technology that can be deployed within manufacturing environments of all sizes to help improve efficiency and cost-competitiveness. The institute's projects range from software solutions that reduce production errors and prevent scrapped materials, to augmented reality applications that help instruct workers on shop floors, to open-source collaboration tools that enable suppliers and original equipment manufacturers to collaborate more effectively.

Projects Completed in FY 2016

In FY 2016, three projects were completed. Highlights of the project outcomes include:

- Green Dynamics, a California-based technology startup, led a project that originated with the Department of Defense's Adaptive Vehicle Make program. The project team developed design software that will help small wind turbine blade manufacturers by reducing the wide-ranging expertise needed to analyze a complex turbine or blade system. The software has applications beyond the wind power sector—it can be used for other products with cross-sectional geometry, like a propeller, bicycle frame, or car chassis, for example, and may help introduce advanced materials such as carbon fiber into new markets. Green Dynamics is actively working to take the product to market.

- Through DMDII, Illinois-based PDA LLC led a project that developed a set of methods, framework, and software to predict distortion and reduce the setup time for machining large castings. The technology can virtually eliminate scrapping of these high-value parts, often used in the aerospace and defense industries. It has demonstrated an 80 percent reduction in setup time, creating an opportunity to bring down the cost of labor for large-scale castings, and to bring back jobs that have moved to other countries hosts particularly large effort despite a reduction in quality associated with foreign-made castings. The technology will be made available to DMDII members under a licensing agreement with plans to commercialize it for wider industry use.

- A project led by Arizona State University developed a set of software modules to assess and define geometric tolerances of components in a mechanical assembly to ensure parts align correctly. With this technology, a less experienced designer can generate and analyze geometric dimensions and tolerances, while more experienced designers can spend minutes on a task that would have otherwise taken hours, saving time and money. DMDII members have expressed interest in the technology, and the project team is currently pursuing routes to commercialization.

New Projects Launched in FY 2016

In FY 2016, DMDII launched 19 new projects that address challenges in manufacturing using digital technology. Several examples include:

- A project led by GE Global Research is easing the process by which small and medium-sized manufacturers adopt advanced modeling, simulation, and analysis tools, such as general manufacturability assessment or foundry configuration tools. The technology developed through this project will reside on DMDII's Digital Manufacturing Commons, an open source software platform for manufacturing collaboration, to make the tools easily accessible to companies across the country.

- Many small and medium-sized manufacturers rely on paper documentation and different planning tools that cause challenges when integrating software systems. A project led by the Rochester Institute of Technology is developing and evaluating mobile and wearable computing systems that have the potential to provide improved connectivity between shop floor workers and information, and resources that can help workers perform their jobs more effectively and accurately.

- As the deadline to comply with Defense Federal Acquisition Regulation Supplement cybersecurity rules at the end of 2017 approaches, many manufacturers remain unaware of the rules, or how they apply to them. A project led by DMDII partner, and Colorado-based small business, Imprimis, Inc. is assessing manufacturers' compliance and creating software tools to help ensure companies are meeting the cybersecurity requirements.

Credit: DMDII

SMALL MANUFACTURER USES DMDII TO "HACK" ITS DATA

ITAMCO, an Indiana-based manufacturer of precision-machined components, has used the DMDII network and resources to its advantage in creative ways, including by making available several years' worth of manufacturing data from its facilities for use during DMDII's inaugural hackathon in July 2016.

A third-generation U.S. company, ITAMCO has grown from a 4,000 square-foot machine shop when it was founded in 1955 to nearly 500,000 square feet of space between two facilities, containing several hundred machine tools.

Over the past several years, ITAMCO has actively monitored its operations using an open-source, royalty-free manufacturing communications protocol called MTConnect. Gathering information in real time has allowed the company to adjust and avoid problems rather than solve them after machines malfunction.

ITAMCO's leadership knew there were deeper insights to be found within their data and looked to DMDII to help discover them. ITAMCO provided data during the DMC hackathon and about a dozen teams explored it, unearthing findings that ITAMCO used to optimize its functions. Apps developed through the hackathon addressed areas like predicting machine and tool failure, interpreting data, showing alarms and issues within the user interface, and utilizing augmented reality.

"To develop new ideas and remain competitive, we need to break out of our silos—and that's exactly what we're able to do by working with DMDII. The DMDII network connects us with people we wouldn't have been able to access otherwise—from large OEMs to entrepreneurs and hackers," said Joel Neidig, ITAMCO's Development and Technology Manager.

Workforce Development

"Having access to industry experts, other universities, and government partners has been invaluable for Georgia Tech. As part of the powerful DMDII network, we've been able to collaborate on technical manufacturing problems and help ensure the American workforce is equipped for the jobs of tomorrow."

— Thomas R. Kurfess, PhD, P.E., Professor and Husco/Ramirez Distinguished Chair in Fluid Power and Motion Control, Georgia Institute of Technology

Preparing the U.S. workforce for the new technology that will impact their jobs is an important focus for DMDII. Initiatives include identifying the new roles emerging in digital manufacturing, introducing new audiences to the fundamental principles of digital manufacturing and design, and developing resources for small and medium-sized manufacturers.

Here are some key workforce development accomplishments that to support the above initiatives:

- In July 2016, DMDII announced a partnership with workforce solutions provider ManpowerGroup that pairs top U.S. manufacturing firms, research universities, and technical colleges from the DMDII network to define and map the roles and skills required by organizations on the forefront of digital manufacturing and design, creating profiles for 20 roles in the industry. The effort will help align workers, employers, and educators to ensure the U.S. workforce is prepared to drive the growth of advanced manufacturing. In 2017, we expect that all job roles will be integrated through a series of strategic engagements with all members and industry partners.
- Throughout 2016, the University at Buffalo's Center for Industrial Effectiveness led the curriculum development for a first-of-its-kind massive open online course in digital manufacturing, which launched on the Coursera platform in 2017. (See below for full details)
- In September 2016, DMDII received a $1.2 million award from NIST, along with the Illinois Manufacturing Excellence Center and Purdue Manufacturing Extension Partnership, to establish "fellows in residence" to engage small and medium-sized manufacturers on their digital readiness and needs.

Innovation Ecosystem

"Partnering with DMDII has helped us broaden our network and work with a diverse group of organizations, and the new DMDII chapter in the Quad Cities expands the opportunities for collaboration with local small and medium-sized manufacturers."

— Curt Burnett, Executive Director, Quad Cities Manufacturing Innovation Hub

The innovation ecosystem DMDII has fostered exists both on a local level—within the DMDII facility and the greater Chicago area—and nationally.

The Goose Island headquarters in Chicago is a central convening place for institute partners from across the country, who attend events such as the quarterly Technology Showcase to network, exchange ideas, and build project teams. At the September 2016 showcase, two startups, Los Angeles-based Covisus and Chicago-area-based ARIS, first met and discovered synergies between their technologies. The outcome was a collaboration: Covisus' virtual part-tagging paired with ARIS' scanning technology creates a seamless process for tracking and scanning parts on a production line, currently demonstrated on the DMDII manufacturing floor.

DMDII opened its facility to startups in other ways, too, from providing office space within the facility, to welcoming a local entrepreneur to use equipment on the manufacturing floor. Benjamin Bullis, a local IT professional, designed a new type of flexible LED work light, but needed a place to manufacture early prototypes for his young startup, Frelux. He began working out of DMDII on a part-time basis to develop several different prototypes.

Top Credit: DMDII. Left Credit: U.S. Marine Corp.

NEW DIGITAL MANUFACTURING COURSE SERIES MAKES MANUFACTURING ACCESSIBLE

A project team led by the University at Buffalo's Center for Industrial Effectiveness (TCIE) has developed a new online series of digital manufacturing and design 101 courses available as a "specialization" through massive open online course provider Coursera. A first-of-its kind series, the "Digital Manufacturing and Design Technology" course can be accessed by anyone with an internet connection, notably recent graduates interested in exploring this field for the first time or current shop floor employees looking to expand their skill set to remain competitive as roles within manufacturing change.

TCIE designed the curriculum alongside industry partners, including Siemens PLM, SME, the Association for Manufacturing Technology, Moog Inc., and Buffalo Manufacturing Works. Its development was funded with a $380,000 award from DMDII. The series will introduce a broad range of digital manufacturing and design technologies and demonstrate how they can be used throughout a product's life cycle.

"For decades, universities and factories were worlds apart, but the speed of innovation is drawing them closer and closer," said Liesl Folks, Dean of the UB School of Engineering and Applied Sciences. "Creating a first-of-its-kind, impactful curriculum on digital manufacturing is an important step in strengthening and retraining our manufacturing employment base."

Content for the courses was developed throughout 2016. The first courses within the series launched on the Coursera platform in early 2017 and subsequent courses will roll out throughout the year.

Outside of Chicago, DMDII established regional chapters in Rockford, IL, and the Quad Cities. The chapters serve to bring manufacturing resources and expertise into the workplaces of small and medium-sized manufacturers. The chapters enable DMDII to directly engage with industry clusters: Rockford is an aerospace and defense hub, while the Quad Cities is home to the Rock Island Arsenal and Deere & Company, among others.

In July 2016, we held our first-ever hackathon with participants from across the country. Teams developed manufacturing apps that will reside on DMDII's open-source collaboration platform, the Digital Manufacturing Commons (DMC). The DMC will serve as an online convening space for DMDII members to share information and project outcomes and collaborate on projects. The platform's role as an innovation ecosystem extends beyond members: the platform will feature a marketplace where developers can host manufacturing apps that can be accessed by manufacturers of all sizes from across the country.

Sustainability

DMDII worked to diversify its funding beyond the government support provided through the cooperative agreement, including continuing to attract new dues-paying partners, developing new ways to fund projects, leveraging its facility, and pursuing new revenue streams.

- **Membership Dues:** DMDII demonstrated value to its industry, academic, nonprofit, and startup partners, whose contributions to the institute in the form of membership dues support innovative digital manufacturing projects.
- **Partner-Funded Projects:** In 2016, DMDII introduced "Partner Innovation Projects," wherein partners team up to independently fund projects of mutual interest, without government funds. The projects must align with DMDII's strategic mission, but need not align with a specific project call topic and don't require participation in a formal selection process, allowing for faster execution.
- **Facility Usage:** DMDII is located at the UI LABS Innovation Center, a 94,000 square-foot facility where industry partners, community groups, and civic organizations pay a rental fee to host events. Work spaces are also available for paid rental within UI LABS's open-floor office space, several of which are already occupied by paying groups.
- **Services Revenue:** Organizing workshops around digital manufacturing for both members of the institute and non-members generated services revenue for DMDII, as did delivering training to the small and medium-sized manufacturers that make up the supply chain.
- **Digital Manufacturing Commons (DMC):** Progress continued for development of DMDII's open source platform for collaboration among original equipment manufacturers (OEMs) and suppliers. The DMC underwent its beta launch in 2016; In 2017, we expect the platform to begin generating revenue from new users and developers of applications hosted within the DMC marketplace.

Credit: DMDII

Credit: U.S. Navy


LIFT
Lightweight Innovations for Tomorrow
www.lift.technology

Credit: LIFT

LIFT

Mission: 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

Established: February 2014

Consortium Organizer: American Lightweight Materials Manufacturing Innovation Institute

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

Members: 98

Background

LIFT and its members develop and deploy new lightweight manufacturing 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

"Right now, too much time and money is tied up by a production process that we believe can be improved upon through other methods. By pulling this team of experts together through LIFT, we will explore and refine those new methods to benefit not only our work, but that of the entire industry."

— Keith Smith, Materion (Perrysburg, Ohio)

The technology projects underway at LIFT work toward lightweight solutions in the aerospace, shipbuilding, automotive, and defense sectors by improving manufacturing processes, investigating new materials, and using new technologies.

Road-mapping

Nearly 100 LIFT members from across various industries and research institutions gathered in Detroit in April 2016 for a two-day technology roadmapping session. This session provided the opportunity for large and small members to discuss current and future lightweighting technologies, ongoing projects, and those possible down the road. Large company attendance included representatives from all 16 LIFT Gold and Silver members; they were joined by small and mid-sized enterprises, government, and academic institutions. The outcome of this workshop was a plan for the long-term direction of LIFT's technology development, including possible projects to undertake based on industry's needs and trends.

"We are at the cusp of a revolution, and it all starts with the people here in this room," LIFT Chief Technology Officer Alan Taub said. "With the knowledge and ideas from everyone gathered here, there can be no question that our current projects, and those we'll pursue going forward, will result in dramatic changes to the metal and manufacturing industries."

Projects Completed in FY 2016

LIFT is in its second full year of operation and its first projects are scheduled to be completed in FY 2017.

New Projects Launched in FY 2016

In FY 2016, LIFT launched 10 new projects addressing key problems in lightweighting such as:

- Integration of Computer Modeling and Thermo-Mechanical Processing in Large Titanium Structures – Boeing (St. Louis, MO), GE Aviation (Cincinnati, OH), and the small business Scientific Forming Technologies (Columbus, OH), along with six others, are collaborating to better predict mechanical properties of components during large-deformation metalworking and heat treatment processes. The project will result in material behavior databases and models that better predict the strength and failure resistance of metal components used in aerospace applications.
- Processing for Assured Properties in Aluminum-Lithium (Al-Li) Forgings by Development, Application and Validation - United Technologies Research Center in East Hartford, CT, is leading a group of five others to study which material properties in Al-Li alloys are best suited for specific structures and how to achieve the best corrosion resistance, strength, and toughness combination during material processing. The new modeling toolkits that result from this project will reduce the amount of development hardware and processing trials required for developing next generation aircraft turbine engines, reducing the time from concept to product.
- Robust Distortion Control Methods and Implementation for Construction of Lightweight Metallic Structures – The large, complex structures used in shipbuilding often suffer from distortion if not properly controlled during the welding process. Huntington Ingalls Industries (Pascagoula, MS), is leading six others in a project designed to prevent distortion of large steel plates used in shipbuilding by delivering recommended shop-floor operating procedures, simple distortion estimation equations that optimize designs, and distortion control analysis procedures for more in-depth analyses.

Workforce Development

"As a national institute, LIFT has the support, reach, and workforce education know-how to help us reach students across Ohio and encourage them to consider careers in advanced manufacturing."

— Eric Burkland, President, Ohio Manufacturers' Association

Credit: U.S. Navy

Figure 13 Pouring Iron Into Castings of Differential Housing Used in Heavy Trucks. Credit: LIFT
Left Credit: Pexels

LIFT PROJECT SHOWS TRADITIONAL MATERIALS CAN BE MADE LIGHTER

A common misconception about lightweighting is that one can simply swap out the materials used to manufacture an item and replace them with a lighter material. Just swapping steel for aluminum, for example, is not always the best solution.

A key tenet of lightweighting is to find ways to reduce the weight of a structure while maintaining—or improving—its performance.

One of the earliest projects launched by LIFT deals with that challenge by developing a process to reduce the wall-thickness, and therefore the weight, of a ductile iron differential housing used in heavy trucks—not typically a lightweight material. Swapping out the ductile iron for a lighter material would not meet the strength requirements of the housing, so the team had to take another approach.

The project team is revising the design to allow the part to be cast close to its final shape, thereby reducing the need to machine the cast metal. The team will employ a new ductile iron alloy that can be cast into thinner walls while maintaining its strength.

LIFT and its partners—MPG Casting Technologies (Southfield, MI), Eaton (Cleveland, OH), and Michigan Technological University (Houghton, MI)—have already reduced the weight of castings close to the project goal of 40 percent.

"Thin-wall technology is an industry game-changer in the battle to trim weight, and it is gaining impetus from LIFT," said Jay Solomond, Vice President of Engineering and Technology, MPG Casting Technologies.

According to research done by the Massachusetts Institute of Technology, another research partner on the project, reducing 40 percent of the weight of iron components is like removing the emissions of 400 billion pounds of coal, equivalent to 2 million railcar loads, from the atmosphere.

This project is undergoing its final testing and validation steps and will be completed in 2017.

Through the design and implementation of demand-driven, results-oriented, replicable, and scalable solutions, LIFT is developing an educated and skilled workforce confident in using new lightweighting technologies and processes. In FY 2016, LIFT launched or supported 14 initiatives, including:

- Work & Learn in Indiana: Career Exploration in Lightweight Metals – LIFT and Conexus Indiana launched an initiative to expand the Conexus Interns model to 184 students—a 120 percent increase from the 84 interns the previous year. Participating students completed six-week paid internships with manufacturers across Indiana and gained on-the-job training with 38 Indiana companies specializing in automotive, aerospace, and lightweight metal applications.

- ASM Teacher Camps 2016 Enhancement – LIFT, ASM International, and the ASM Educational Foundation announced the ASM-LIFT Materials Camp program, a one-week training program designed to enrich, stimulate, and enhance the technical competence and teaching skills of middle and high school STEM teachers.

- LIFT Prize in Robotic Blacksmithing – LIFT and the Center for Design and Manufacturing Excellence at The Ohio State University launched a new competition for students from around the country, introducing them to "Robotic Blacksmithing," which merges the ancient skills of the blacksmith with the digital age of robotics to create new material-forming capabilities. The program challenges students to make objects by re-shaping materials through incremental forming processes.

- On Track: Hands-On Applied Learning to Fill the Manufacturing Workforce Pipeline in Kentucky - LIFT and the Bowling Green Chamber of Commerce supported the "On Track Initiative" to increase participation and improve access to education in STEM through a program in which student teams at local community and technical colleges compete in designing, lightweighting, and rebuilding cars throughout the 2016-17 school year.

- Pathways to Jobs in Detroit – LIFT partnered with Goodwill Industries of Greater Detroit, Focus: HOPE, and TechShop Detroit to launch Pathways to Jobs in Detroit. Through a series of mobile outreach rallies, the program brought manufacturing career opportunities to life for students and adults who are in need of inspiration or local career opportunities and training.

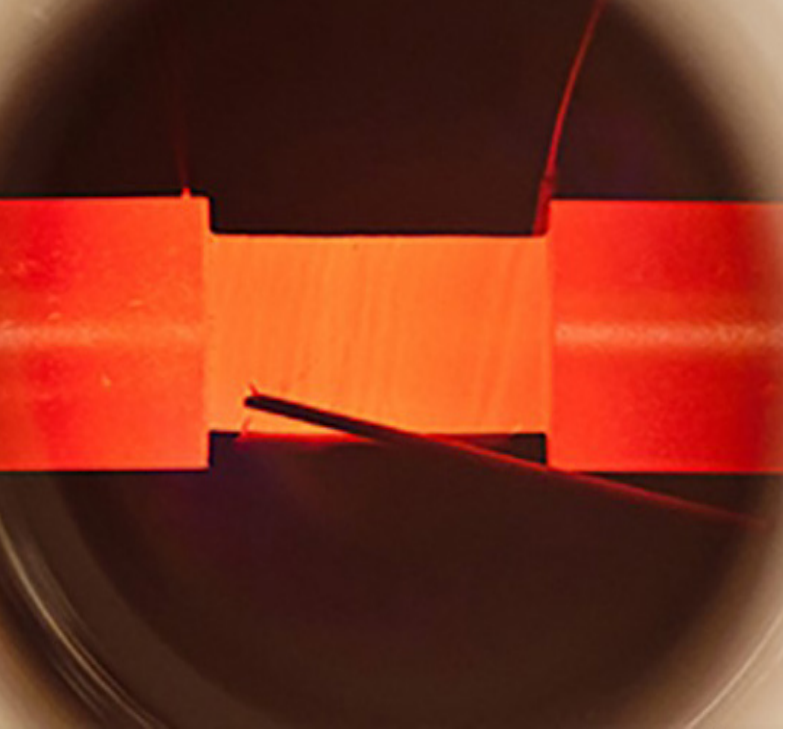
- Manufacturing Technology: High School Career Pathways in Kentucky – LIFT joined Jefferson County (KY) Public Schools to launch the Doss High School Manufacturing Technology career pathway program. The program provides students with a four-course major in manufacturing, work-based learning experience with local employers, certifications—including the National Career Readiness Certification—and a Manufacturing Skills Standards Council - Certified Production Technician.

- Right Skills NOW for Veterans - LIFT and Vincennes University launched the Right Skills NOW program for machinist training, rolling out a computer numerical control machinist program and featuring national credentials from the National Institute for Metalworking Skills. The program prepares veterans to transition to civilian jobs as skilled employees with upward mobility potential.

Innovation Ecosystem

LIFT has provided Ingalls Shipbuilding an avenue to collaborate with world class experts from industry-leading organizations to systematically address the issues associated with thin steel distortion from a variety of innovative approaches."

— Harry J. Rucker, Director, Huntington-Ingalls Industries (Pascagoula, MS)



Left: Credit: LIFT

Top Credit: U.S. Navy

MAKERMINDED ROLLS OUT INTO MORE STATES

In June 2016, LIFT, with help from its partners the Tennessee Technological University and the Tennessee STEM Innovation Network (TSIN), launched MakerMinded, a web-based competition and campaign platform that connects students to the leading-edge manufacturing and STEM learning experiences

The platform was kicked off in Tennessee as part of LIFT's commitment to investing in replicable and sustainable education and workforce development initiatives. By the end of the fiscal year, 39 middle and high schools were participating.

The program was subsequently adopted in Kentucky and additional state rollouts are on tap for 2017.

The platform's goal is to provide students in the U.S. with access to world-class experiential learning programs that encourage and prepare them for further STEM education and careers in advanced manufacturing. In each state, direct engagement opportunities with local manufacturers are included among the activities.

"Over the course of their high school careers, too many students lose interest in STEM-related courses and careers," said Wes Hall, director, TSIN. "By delivering these fun, yet challenging and engaging activities directly to classrooms, we hope to keep more students interested in continuing their STEM education beyond high school and into the workforce. Engaging students early in middle school increases their knowledge of future STEM careers."

LIFT is planning to continue the MakerMinded expansion in 2017 with rollouts in Ohio and Michigan.

LIFT is driving innovation of new lightweight metals technology. Through its ongoing applied research and development projects, LIFT is linking large and small manufacturers, academia, trade associations, and professional organizations to revolutionize the transportation sector. From researching how the hulls of ships can be welded together using lighter materials, to developing new ways to cast iron into lighter components, to using computers to predict corrosion of protective coatings on airplane parts, LIFT and its partners are expanding how the industry looks at metalworking.

LIFT is also working to shape the manufacturing workforce of the future. By convening experts in education, workforce development, economic development, and

Figure 14: Maryville, TN students participate in STEM Night. Credit: MakerMinded

manufacturing across the Midwest, LIFT is investing in local and regional initiatives to link and leverage them with existing resources to have an even greater impact and drive today's students to the manufacturing jobs of tomorrow.

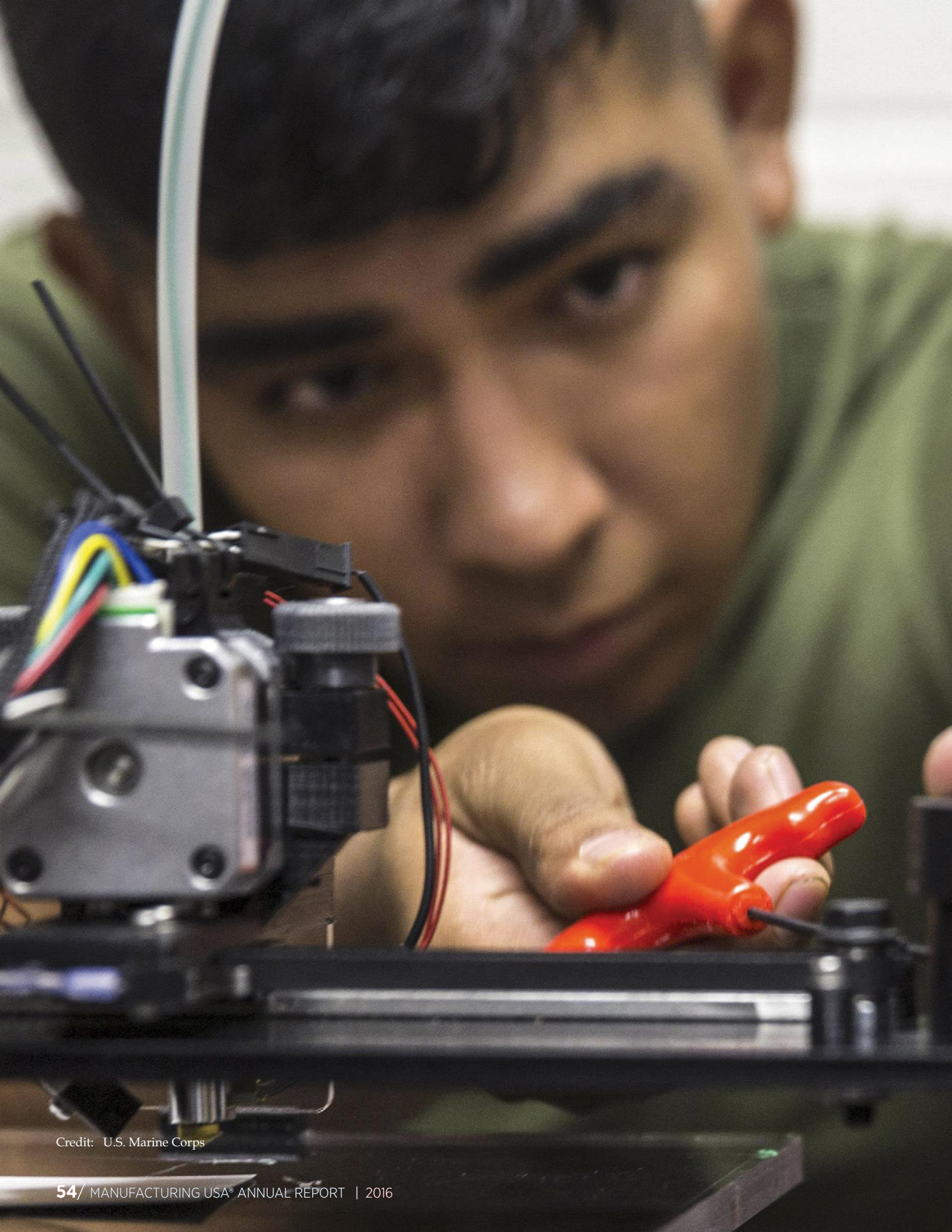
From its Detroit headquarters, LIFT is creating a manufacturing ecosystem in the Midwest and changing the use of metals throughout the country for years to come.

State Manufacturing Association Partnerships – LIFT launched partnerships with three state manufacturing associations in FY 2016, The Kentucky Association of Manufacturers, the Ohio Manufacturers Association, and the Indiana Manufacturers Association. With more than 325 years of combined experience serving the industry and reaching more than 3,200 companies, the partnerships mark a new era for understanding the needs of the manufacturing industry in those three states, as well as the benefits for manufacturers of LIFT and Manufacturing USA.

Sustainability

After LIFT's cooperative agreement completes, the institute's sustainability will rely on an engineering services model for cooperative research and development, including the following revenue sources:

- **Research and development equipment usage fees:** LIFT is building out its 87,000-square-foot high bay at its Detroit facility to hold large-scale manufacturing equipment for use by members on research and development work. The facility is slated to open in 2017. Equipment use will be billed by the project or time used on the machines.
- **Proprietary project work:** With its Detroit high bay facility in place, LIFT will be able to undertake proprietary project work for member companies in-house. This work will yield revenue for LIFT to support sustainability.
- **Membership dues:** With 21 percent growth in FY 16, LIFT's membership continues to expand and evolve across the manufacturing industry, with members from the automotive, aerospace, shipbuilding, and defense sectors. These members will continue to pay membership dues to stay engaged with LIFT and its R&D projects.
- **Engineering and consulting services:** LIFT experts and engineers are available to provide engineering and consulting services to provide solutions for members and non-members.
- **Additional government project work:** With LIFT's expertise in defense-related work across industry, the institute expects to continue to competitively bid and win government project financing in the future as a source of post-cooperative agreement revenue.



Credit: U.S. Marine Corps

AIM Photonics

American Institute for Manufacturing Integrated Photonics

aimphotonics.com

Credit: U.S. Air Force

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

Established: July 2015

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

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

Members: 49

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 on the performance and reliability of electronic integrated circuits while significantly reducing size, weight, and power consumption.

Growth of the integrated photonic circuit industry has been impeded by the lack of open and easy-to-use design tools and standardized, accessible manufacturing platforms. The American Institute for Manufacturing Integrated Photonics (AIM Photonics) is creating the infrastructure in the United States to rapidly develop, use, and assimilate advanced tools for the manufacturing of photonic integrated circuits. Concurrently, AIM Photonics is working with industry to establish manufacturing standards and methods and to develop programs to train a U.S. photonics workforce.

Technology Advancement

"Sensors represent the interface between the real world and data. Developing a universal set of protocols to design, manufacture, modify, and integrate sensors into photonics systems will not only advance this technology, but also present a tremendous economic opportunity—integrated photonics sensors represent a large and rapidly growing market, potentially reaching more than $15 billion globally by 2020."

— Professor Benjamin Miller, University of Rochester

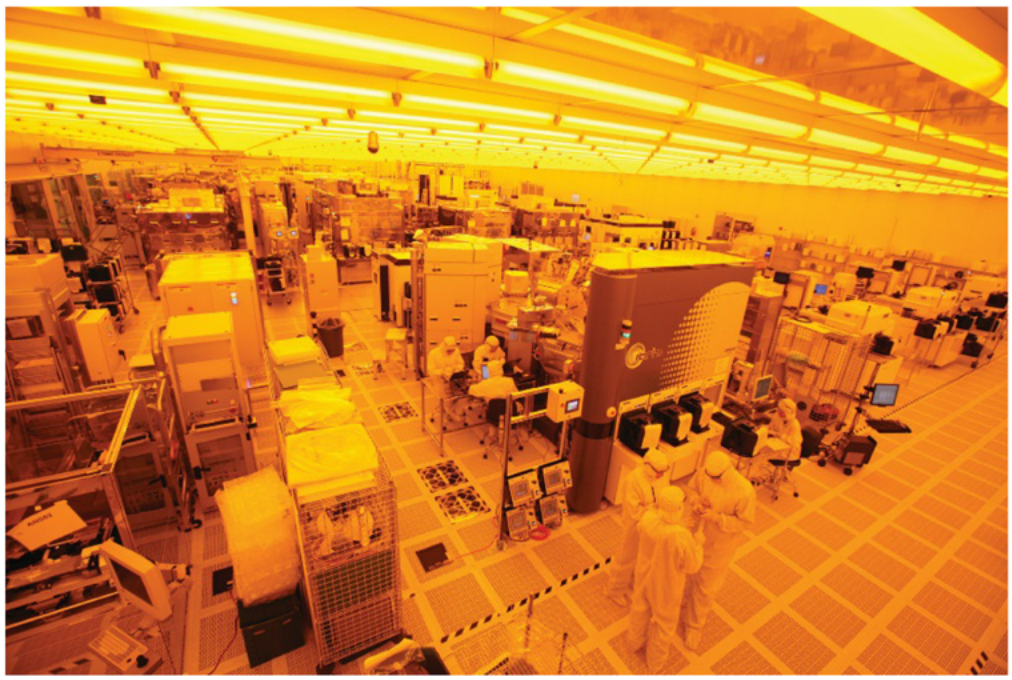


Figure 15. SUNY Poly's Albany NanoTech Complex is the site of some of the world's most advanced nanoscale research and development, including 135,000-square-feet of Class 1 capable cleanroom, a portion of which is shown above. Credit: SUNY Poly

AIM Photonics is creating an innovation ecosystem that integrates efforts of researchers, technology developers, and manufacturers in pre-competitive collaborative, as well as proprietary, programs that enable technological innovations and accelerate the commercialization of cost-competitive technologies. Traditionally, photonic systems comprised separate devices that needed to be mechanically assembled to achieve the desired output. The assembly of separate systems is costly, time consuming, often results in bulky systems, and has high failure rates. AIM Photonics is disrupting this approach, leveraging the successful model implemented in the semiconductor industry by integrating fiber, lasers, and photodetectors onto a wafer to improve productivity and stimulate exciting new applications.

Road-mapping

The Integrated Photonics System Roadmap 2016, which will be released in February 2017, is based on the contributions of more than 700 individuals from 254 organizations. Industry experts and start-ups gave their input at AIM-hosted roadmapping workshops in the spring and fall (100-250 attendees), at technical working group meetings in California and Massachusetts, and during monthly webinars (each with 80-125 attendees). Potential AIM members value the opportunity to participate on the roadmap.

Projects Completed in FY 2016

For FY 2016, 17 total projects were awarded—16 in research and technology development and one in education and workforce development. Some highlights from these projects that address items in the technology roadmap include:

- The Silicon Photonics Process Design Kit (PDK) Project, led by State University of New York Polytechnic Institute (SUNY Poly) in Albany, NY, resulted in the first U.S.-based integrated photonics PDKs being made available to members of the consortium. These PDKs empower AIM Photonics Members and others with access to leading edge silicon photonics component libraries. This allows users to quickly generate their own designs that can be realized using the Multi Project Wafer and Assembly (MPWA) fabrication process. This kind of system-level design methodology is critical for realizing large-scale integrated photonic designs with lower cost and shorter schedules.

Left Credit: U.S. Army
Top Credit: U.S. Army

TAKING "AIM" ON A LEAP FORWARD

Precision Optical Transceivers (Precision OT), an industry-leading manufacturer of optical transceivers and related optical components based in Brockport, NY, had never attempted to create a photonics chip. Pursuing a concept for a new, proprietary product, the company leveraged its membership in AIM Photonics and access to the new integrated photonics PDK to support its internal research and development efforts.

In just three months, by relying heavily on the PDK component library, Precision OT designed a clean layout. Absent access to the PDK, which represents an aggregation of many engineer-years of design effort specifically tailored to the SUNY Poly fabrication process, it is unlikely that the company could have completed the design that quickly.

Access to the multi-project wafer run and the resultant hardware gives companies like Precision OT the opportunity to produce prototypes of innovative products at dramatically lower cost and increases the potential for such companies to expand into new industry segments.

Because Precision OT completed its design in time for a production deadline, the company will be able to participate in a multi-project wafer run in early 2017. The shared PDK and multi-project wafer platforms enable efficient and economical component and device prototyping and the opportunity for rapid transition to high-volume manufacturing.

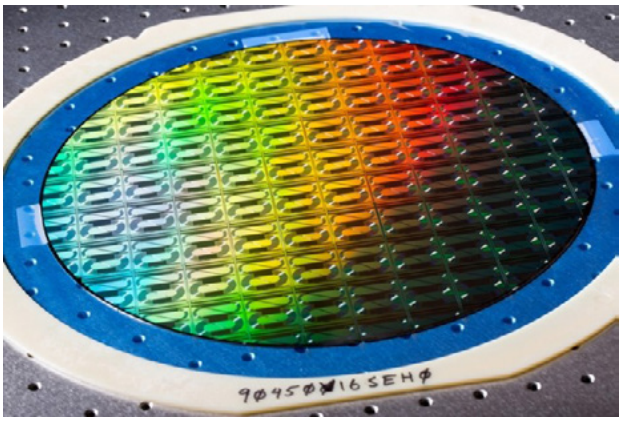


Figure 16. SiPh 300mm Wafer. Credit: SUNY Poly

- The MPWA pilot project leveraged the advanced foundry capabilities at the State University of New York Polytechnic Institute (SUNY Poly) to implement a world-class 300 mm silicon photonics process with 3D integration. The first multi-project wafer fabrication runs were completed in 2016. The project has emphasized process maturation to improve yield and repeatability. To limit costs and increase efficiency, AIM engaged a third party, known as an MPWA aggregator, to aggregate multiple designs, generate final layout,

and transmit designs to the foundry. These activities set the stage for future runs, which will be open to industry, academia, and government, affording a broad spectrum of market participants access to a leading edge manufacturing process that would otherwise be beyond their means.

What is Multi-Project Wafer and Assembly?

Because integrated circuits are expensive to fabricate, it is advantageous to share mask and wafer design space to produce devices in low quantities. AIM Photonics provides multi-project wafer and assembly (MPWA) services to integrate several photonic integrated circuit (PIC) designs onto device wafers, allowing institute members to share space and reduce design costs.

Designs are submitted for fabrication using non-proprietary layout design rules. Designs with similar process steps are then pooled and undergo expensive microfabrication manufacturing process steps together, which reduces manufacturing costs. The wafers are diced and completed chips (packaged or unpackaged) are returned to members.

- The University of California at Santa Barbara (UCSB) is leading a project to develop a sensor to quickly detect a wide variety of chemical and biological agents. Work in FY 2016 led to design improvements that will enable the fabrication of the silicon photonic chip at SUNY Poly. The initial focus is on defense applications for chemical detection capability distributed over tens of meters of coverage, with subsequent work expected to emphasize the extension of the system to detection of biological agents such as circulating cancer cells for point-of-care medical applications.

New Projects Launched in FY 2016

In September 2016, AIM Photonics selected 22 total new projects (16 research and technology development; 6 education and workforce development) for FY 2017. These new projects address key problems in photonic circuit manufacturing such as:

- High Capacity Photonic Interconnected Systems – The project, led by UCSB, is pursuing data center enhancement with emphasis on high capacity communications and high efficiency switching. Large data centers consume two percent of the nation's energy and, due to the cost of electricity, it now costs more to operate a data center than to construct one. The goal of this project is to replace cables, which heat up and consume power, with fibers that transmit data faster and are more energy efficient. The project plans to develop scalable optical switching and to interconnect chips optically rather than electrically to increase data processing and decrease expensive power consumption.
- High Dynamic Range Radio-Frequency Photonics for Wideband Systems – Led by Lockheed Martin, this project uses the SUNY Poly Silicon Photonic (SiP) manufacturing process to develop high-volume packaging of photonic systems for radio-frequency applications. Defense systems deployed in the field will benefit from higher communication bandwidth and extended range by implementing optical methods to communicate between land-based systems and aerial or space systems. The project will permit design and optics problems to be solved in less time and at lower cost, make design cycles faster, and reduce costs.
- Common open access building blocks for photonics systems are readily available to AIM members, thereby facilitating the refinement of designs; and enable the creation of building block photonic circuits with extensive reductions in size, weight, and power for specific radio-frequency applications, such as long-distance optical antenna remoting.

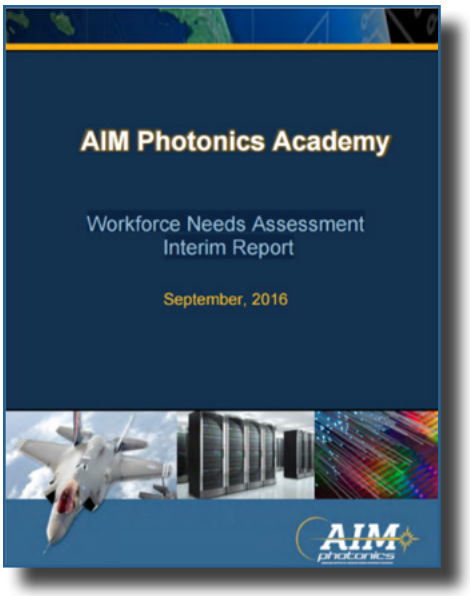


Figure 17. AIM Photonics Academy Workforce Needs Interim Assessment Report. AIM Academy's workforce team developed this interim report to help align academic curricula with industry demands. Credit: AIM Photonics

Figure 18. Engineers Working on AIM Photonics projects at SUNY Poly's Albany NanoTech Complex. Credit: SUNY Poly

Workforce Development

AIM Photonics Academy (AIM Academy) is the unified education knowledge, technology, and workforce program dedicated to advancing integrated photonic circuit manufacturing technology. One of the primary missions of AIM Academy is to create an adaptive portfolio of integrated photonics education and workforce development products capable of meeting industry needs and further increasing national and domestic competitiveness.

- AIM Academy's workforce team collaborated with technical membership organizations to develop the Workforce Needs Survey 2016. The survey was used to interview more than 100 stakeholders, three quarters of whom were from industry.
- Results from this work, which were published in the Workforce Needs Assessment Interim Report, defined the skills and education levels most needed in the industry and will assist in aligning the curriculum of academic institutions and training with the demands of industry.
- AIM Academy created integrated photonics teaching packages that include teaching materials for faculty to use to teach courses and typically contain a syllabus and blueprint, materials, instructor notes, assessments, and solutions.
- AIM Academy is creating online courses in automated design with practical hands-on training for students and engineers to learn how to create and assemble photonic device elements to build higher-order circuit functions.
- AIM Academy is developing integrated photonics certificate content, an apprenticeship program, and credentialing criteria.

Innovation Ecosystem

"Precision plans to utilize AIM infrastructure to further push the envelope of our technical offerings. We believe that by working with AIM Photonics and its partners we will be able to significantly advance our transceiver product line and offer adjacent components to meet our customer's needs. Our partnership with AIM Photonics will ultimately provide better services, systems, and cutting edge technologies for our end users."

– Bryce Tenant, CTO, Precision Optical Transceivers

Top Credit: University of California, Santa Barbara.
Left Credit: Air National Guard

PUTTING STUDENTS ON AN EN"LIGHT"ENED PATH

As part of the AIM Academy Workforce Development Project, UCSB piloted a two-unit undergraduate course, "Workforce and Internship Skills." The class trained 28 STEM students on topics essential to workplace success, but rarely taught in college.

Course topics included communications, working in teams, project planning, and time management. The syllabus was developed jointly by faculty from the UCSB Mechanical Engineering Department and the UCSB Technology Management Program, with input from industry collaborators:

- Raytheon - Goleta, CA
- FLIR Systems - Goleta, CA
- NuSil - Carpinteria, CA
- Procore - Carpinteria, CA
- AOL - Los Angeles, CA

The course consisted of a combination of guest lectures and classes, with industry professionals providing real-world perspectives on the material presented. Students were graded in part on a poster competition, where they presented to a panel of industry judges. The event provided students with the opportunity to create meaningful links with industry managers. Many said that the experience contributed to their next career step. As one student put it, "I will be interning for Microsoft.. I credit my successful interview experience to the workshops we did in your class. I remember when you brought in several industry people to mock interview us. ...I felt much more comfortable pitching myself afterwards, and the constant reminders on how be a great intern, time management tips, and our final project was INCREDIBLY helpful."

Overall, 83 percent of the students rated the course as "very good" or "excellent" and it will be offered again in 2017 in the fall quarter to better align with the hiring cycle for industry internships to maximize its benefit to the students.

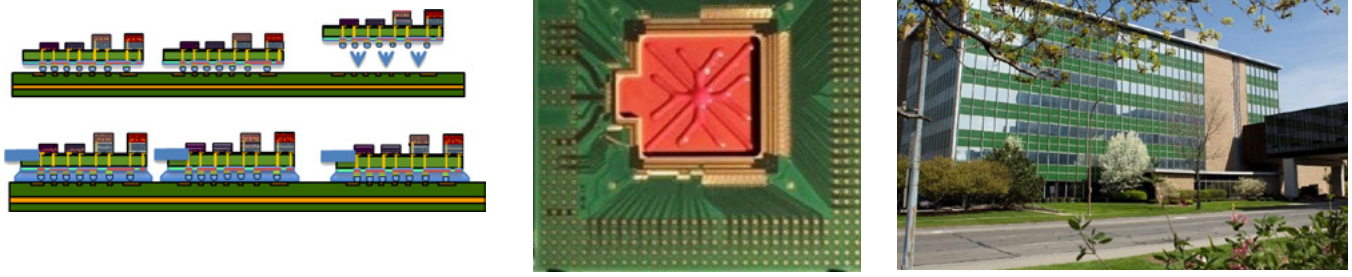


Figure 19. The planned AIM Photonics Test, Assembly, and Packaging facility will support the development of packaged photonic devices. Left: Schematic of the chip-scale testing, assembly and packaging of a silicon photonics system, including attaching an optical fiber and laminating the device on a substrate; Middle: A packaged photonics-based device mounted on a printed circuit board; Right: Location of the future AIM Photonics Test, Assembly, and Packaging facility in Rochester, NY. Credit: AIM Photonics and the State of New York

The ecosystem being created by AIM Photonics harnesses the combination of the nation's leading talent from both industry and academia in indium phosphide and silicon photonics integration. SUNY Poly's fully-functional, best-of-class, U.S.-based design tools and manufacturing facilities are designed for continuous upgrade to support the photonics-manufacturing infrastructure of the future. Driven by industry needs, projects awarded in 2016 focused on capacity building that will address the broadest range of challenges. These focus on processing, packaging, assembly, and testing, which represent a significant portion of the cost of integrated photonics. In 2017, capacity building will accelerate with the opening of the Test, Assembly, and Packaging Facility in Rochester, NY.

The facility will provide increasingly standardized design and manufacturing resources that will enable academics, large and small manufacturers, and government agencies to pursue innovative projects that address photonic integration needs. As different market application segments advance, AIM Photonics will respond by targeting additional resources to achieve maximum impact to the U.S. photonics manufacturing ecosystem.

In 2016, AIM Photonics pursued a robust engagement strategy with workshops and conferences to educate partners and potential partners about the AIM Photonics program. At multiple events in California, New York, and Massachusetts, AIM Photonics promoted its resources and projects while collecting feedback on industry needs. This effort increased response rates to the call for project proposals issued in April 2016, with 68 entities submitting 27 joint project proposals. In addition, the existence of AIM Photonics and its resources have drawn the attention of the National Science Foundation, which is generating additional interest and funding for projects.

AIM Academy is working closely with large U.S. companies, including IBM and Raytheon, while also attracting smaller companies that build and design integrated photonics. AIM Academy is bringing together companies, community colleges, and political leaders to explore possibilities for creating an I-90 Corridor for integrated photonics companies from Boston through Western Massachusetts to Albany and Rochester.

Sustainability

Consistent with the goals established in its cooperative agreement, AIM Photonics is regularly assessing its structure and activities to ensure that the institute becomes financially sustainable. It is expected that the AIM Photonics structure will support its own sustainability as well as develop a sustainable domestic integrated photonics supply chain feeding back into AIM Photonics, thereby creating an ongoing cycle of growth. At this juncture, the sustainability plan is, in addition to potential membership dues, relying on the

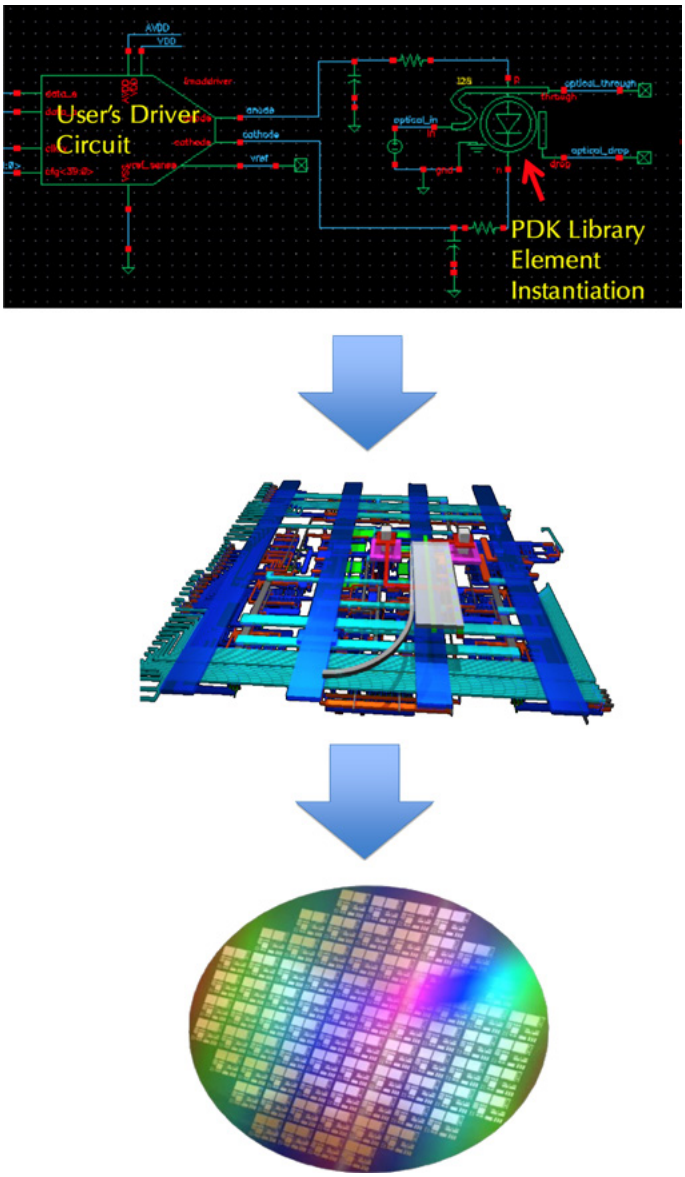


Figure 20. Top: The AIM Photonics process for design and manufacture of integrated photonics begins with members designing their devices, relying on the Silicon Photonics Process Design Kit, a growing library of advanced silicon photonics component designs; Middle: Using facilities in the SUNY Poly's Albany NanoTech Complex, the designs are fabricated into working devices; Bottom: The devices are fabricated on multi-project wafers, which are diced, with working components returned to the AIM Photonics members.
Credit: AIM Photonics

following tactical strategies to increase revenue over time and achieve long-term sustainability:

- Provide open access to infrastructure – Using foundry economies-of-scale to reduce costs will allow small, mid-sized, and large companies to prototype, develop, assemble, test, package, and demonstrate devices at the manufacturing scale and commercialize immediately.
- Provide a single entity for integrated photonics manufacturing innovation – Creating a center of gravity in the United States that is the first choice for companies, Federal agencies, universities, and other entities to leverage for their own PIC needs.
- Attract funding from Federal agencies outside the cooperative agreement– Since the needs of Federal agencies do not have the same volume demands as industry, AIM Photonics can provide integrated photonics circuits in the small volumes they require.

"I…wanted to thank you for admitting me into TMP 191IN; I doubt I would have gotten the offer without going through your course…I would love for future students to take advantage of the material you cover."

— Undergraduate student, in the AIM Photonics-sponsored "Workforce and Internship Skills" class

Credit: U.S. Army

NextFlex

America's Flexible Hybrid Electronics Manufacturing Institute

www.nextflex.us

Credit: NextFlex

NEXTFLEX

Mission: Pioneer a new era of advanced Flexible Hybrid Electronics (FHE) manufacturing in the United States

Locations: San Jose, CA

Established: August 2015

Consortium Organizer: FlexTech Alliance

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

Members: 53

Background

NextFlex is a public-private partnership founded to mature flexible hybrid electronics (FHE) manufacturing by combining electronics printing techniques with thinned semiconductors. Modern electronics are typically fabricated using packaged semiconductor chips on rigid circuit boards, resulting in devices that are bulky and rigid. Through innovative manufacturing processes, FHE integrates electronic systems, sensing elements, communication devices, and power into paper-thin, conformable, flexible, and stretchable electronics platforms. The results are devices with dramatically reduced size and weight that can continuously receive and communicate information and conform to complex or irregular shapes (Fig. 21). FHE will become the new standard in a range of electronics applications, unlocking new ways to make lives safer, healthier, more efficient, and sustainable.

NextFlex will achieve its mission by 1) catalyzing a U.S. FHE ecosystem; 2) providing new manufacturing capability to the Department of Defense and industry partners; 3) demonstrating FHE manufacturing through relevant technology demonstration platforms; and 4) educating and training current and future advanced manufacturing talent.

Technology Advancement

"There are multiple areas that FHE can touch—such as structural health monitoring, taking small sensors and integrating them into composite structures, such as aircraft wings, and enabling self-diagnostics and real-time monitoring. That is a big win and a big goal. Also, eliminating wires in aircraft dramatically reduces weight."

— Erick Seltmann, Manager, Communications & Sensors, Advanced Electromechanical Technologies, The Boeing Company (Huntsville, AL)

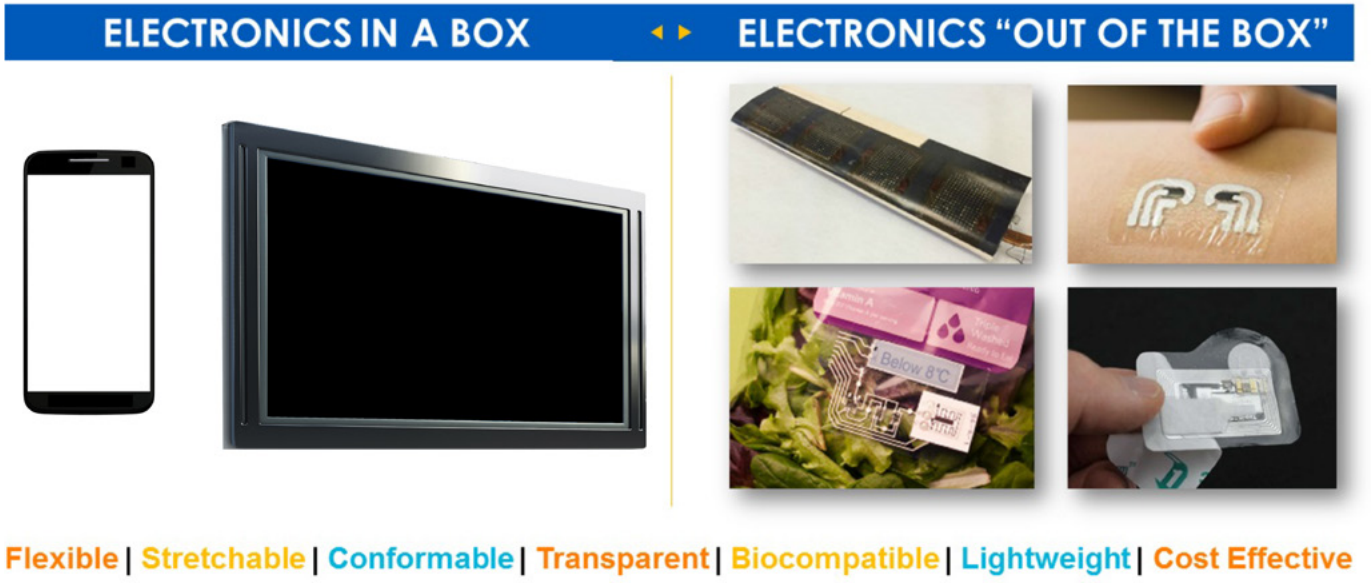


Figure 21. Taking electronics "out of the box" will usher in new ways to improve health and safety such as by (clockwise): strain and temperature sensors embedded into wings; smart tattoos that can measure blood alcohol or glucose; discrete, wireless EKG patches; or smart labels to keep foods fresh. Credits: United Technology Research Center and Stanford University—wing, University of California San Diego—glucose-monitoring tattoo, GE—wireless patch, Thin Film Electronics—salad smart label. Credit: NextFlex

NextFlex brings together companies, government entities, and academia to transition technology from concept to scalable manufacturing. By bringing intelligence out of the box and, literally, onto everything, NextFlex is ushering in an era of electronics on everything. NextFlex members are transforming day-to-day life, from the familiar, such as wearable performance monitoring devices for athletes, to the formerly unimaginable, such as wearable robotics (exoskeletons and smart, pliable prosthetics) for people with disabilities. These devices provide sensor solutions and system intelligence that improve the health and safety of, and increase the effectiveness of, U.S. warfighters and workers alike. Whether focused on next-generation consumer devices, national security or defense and aerospace innovation, NextFlex membership is at the forefront of delivering a new breed of products and solutions. The NextFlex pilot manufacturing line will catalyze FHE commercialization through the integration of best-in-class processes, technical expertise, and collaborative learning.

Road-mapping

In August 2016, NextFlex released its first Flexible Hybrid Electronics Technology Roadmap. The roadmap included input from more than 150 subject matter experts across 70+ participating organizations, from start-ups to Fortune 500 companies, universities, and non-profits. It is designed to be used for member strategy alignment, as well as technology planning and investment decisions by the institute, industry members, and participating government agencies. Nine roadmap segments were developed, five of which are manufacturing-focused, supporting four technology demonstration areas: Human Monitoring, Asset Monitoring, Soft Robotics, and Integrated Array Antennas.

Figure 22. The flexible hybrid electronics behind a new EKG system that will free patients of wires and improve their mobility. Top Credit: GE

Left Credit: NextFlex

FLEXIBLE HYBRID ELECTRONICS GET PATIENTS OUT OF HOSPITAL BEDS

According to the Centers for Disease Control and Prevention (CDC), there are 27.6 million patients in the U.S. diagnosed with heart disease, and in 2014, 614,000 deaths were recorded as a result of it. Current electrocardiogram (EKG) technology requires patients to remain stationary in a hospital bed, tethered by wires. A NextFlex project team has developed a wireless EKG system (Figure 22) that can be applied by first responders and remain with patients throughout the duration of a hospital stay. It can then travel with patients when they return home, allowing for remote monitoring, improved mobility, and shorter recovery times. The project is being led by GE Global Research (Niskayuna, NY), Binghamton University (Binghamton, NY), i3 Electronics (Endicott, NY), and Rochester Institute of Technology.

Product and manufacturing engineering teams developed a functional prototype that obtains clinical-quality heart rate measurements and heart electrical activity. The device can transmit vitals wirelessly to hospital monitors. The next version of the device will be further miniaturized and improved until the form factor is unobtrusive, new electronic components are fully reliable, and it is market-ready. This breakthrough will enable an entirely new class of wireless clinical monitoring devices that can significantly change the efficiency, efficacy, and costs of healthcare, with this early example focused on helping people with heart disease.

New Projects Launched in FY 2016

Electronics on Everything: Making a Safer, Healthier, More Efficient World

2016 was the first full year of operation for NextFlex and 25 new projects were launched to address critical manufacturing challenges for flexible hybrid electronics, including:

- **Smart Bandage:** Purdue University is partnering with Plainsboro, NJ-based Integra Life Sciences to develop a bandage that can both measure and manage oxygen levels in a wound (Figure 23). These features are designed to promote faster wound healing compared with an ordinary bandage.
- **Wearable Connectivity:** The current generation of technology-embedded clothing contain bulky "pucks"—thick, removable, plastic-enclosed electronics that are sewn into performance-monitoring products, such as shirts, gloves, and socks. A cross-disciplinary development team comprising Jabil Circuit, Inc. (San Jose, CA), DuPont (Wilmington, DE) and California State Polytechnic University, San Luis Obispo, are developing a method to directly attach silicon chips to stretchable textiles. This approach will enable a new class of sleek, puck-free high-tech clothing, making technology-enhanced clothing feel as comfortable as traditional clothing.
- **Mouth Guard Monitor:** Engineers from PARC (Palo Alto, CA) and the University of California, San Diego, are creating a smart mouth guard that can non-invasively and continuously monitor health by detecting substances in saliva that indicate exhaustion, glucose levels, and organ distress. The device will communicate these conditions in real-time to a smart watch, phone, or to a monitoring doctor. Even with the latest technology, electronic components break down from exposure to moisture and are too rigid and bulky to be practical (Figure 24) for many applications. The FHE-enabled device will completely encapsulate sensitive electronics

Figure 23. A smart bandage designed to accelerate wound healing. Credit: M. Ochoa, on behalf of Purdue University

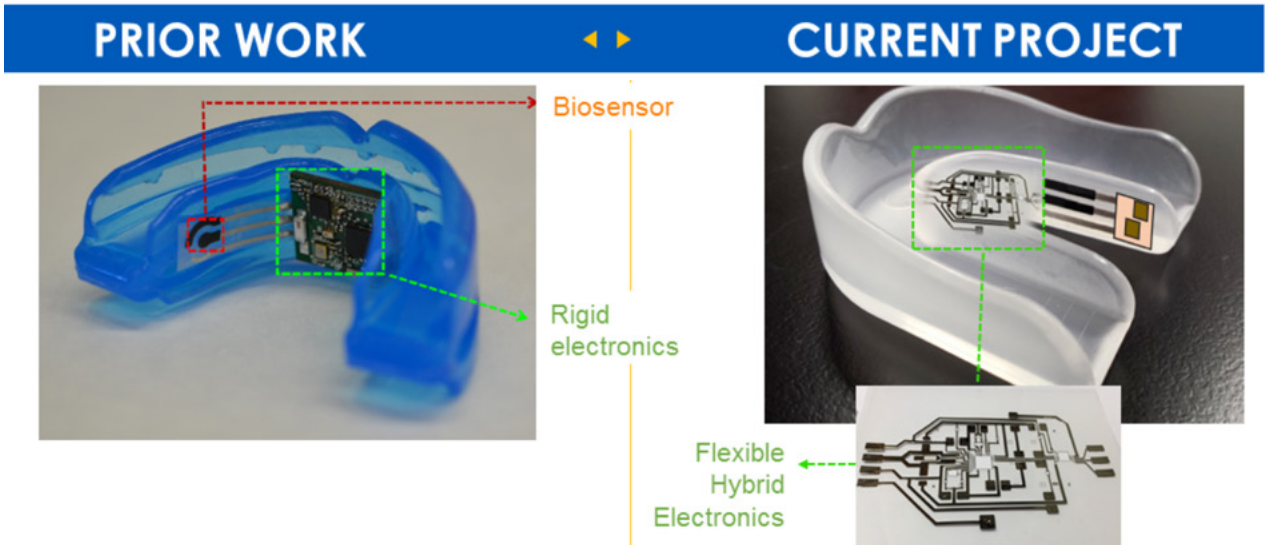


Figure 24. FHE breakthroughs will increase resiliency and reduce size of electronic components. Credit: University of California San Diego and PARC, a Xerox Company. Credit: NextFlex

to withstand a moist environment, reduce the component sizes, and operate for up to eight hours.

Many NextFlex projects contribute to additive electronics manufacturing processes that reduce waste and cost, enabling high-mix production, which is key for manufacturing in the U.S. Contributors to these projects are leading companies, such as Lockheed Martin (Owego, NY), GE Global Research (Niskayuna, NY), The Boeing Company (Huntsville, AL), Universal Instruments (Conklin, NY), Uniqarta (Cambridge, MA), Jabil (San Jose, CA), Flex (Milpitas, CA), DuPont (Wilmington, DE), American Semiconductor (Boise, ID), Sensor Films (Victor, NY), and Analog Devices (Wilmington, MA). Work will be conducted through funded projects at the NextFlex hub and pilot manufacturing line using staff and partner engineering resources.

Workforce Development

Growing Tomorrow's Advanced Manufacturing Workforce from School to Production Floor

"Our work with NextFlex and the Manufacturing USA network exemplifies the level of innovation needed to help our local companies develop the talent they need to succeed, gives our students hands-on training that is integrated seamlessly with their education, and helps them complete their degrees while working, with little to no debt."

— Terri Sandu, Director of Talent and Business Innovation, Lorain County Community College

NextFlex education, workforce development, and training activities are focused on facilitating and enabling the outreach, education, and employment of the FHE talent pipeline through collaborative initiatives with partnered companies, schools, government, and non-profit organizations. In our first year, some high-impact activities have included:

- A detailed supply and demand analysis of FHE-related jobs to gather data on employment, education, wages, skills, and demographics in order to ensure future areas of NextFlex resource investments are data-driven and focused on specifically identified labor market shortfalls.
- Exploratory pilot programs at the high school, community college, and university levels to attract, recruit, and educate the next generation of FHE manufacturing talent.
- Project-based learning activities with SRI International (Menlo Park, CA) and Jabil Circuit, Inc. (San Jose, CA), in Silicon Valley high schools. Through this pilot program, promising students gained first-hand experience with advanced manufacturing prior to post-secondary education. NextFlex plans to reach thousands more young people in communities across the country within the next 18 months.
- Developing a "learn and earn" program with Lorain County Community College in Cleveland, OH. This pilot program is designed to be replicated in other communities to meet the needs of local employers.
- Mentoring and prototyping support for university-level Hacking for Defense project teams at Stanford University that solved real national security technology challenges while teaching college students about information technology and manufacturing. This program is currently in the process of scaling to dozens of universities across the country, and NextFlex will continue to provide mentoring and prototyping support as it does so.

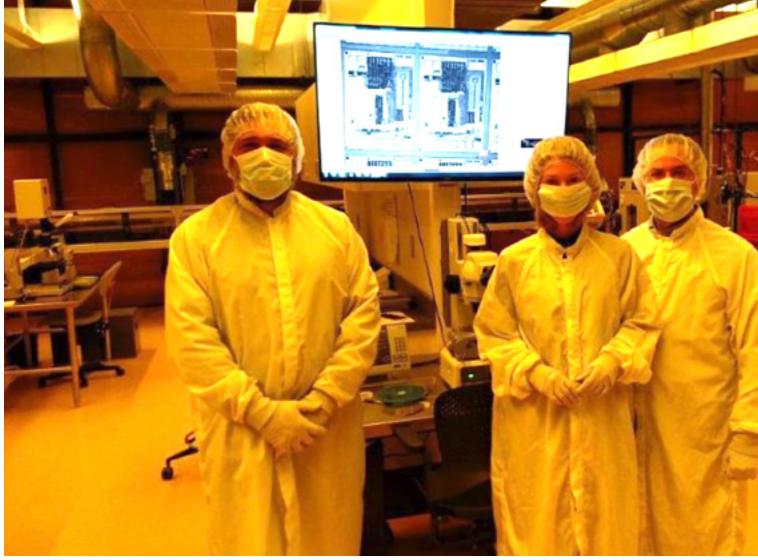


Figure 25. Three potential students touring the Lorain County Community College MEMS training lab to gain insight into the field of microelectronics. They are excited to hear that the NextFlex-supported program is actively tailored by Ohio industries such as SMART Microsystems Ltd, Rockwell Automation, and Valtronic and providing each of them an educated, trained and experienced workforce. Top Credit: J. Vanderford, on behalf of Lorain County Community College. Left Credit: NextFlex

TRAIN OHIO PROGRAM LETS STUDENTS LEARN WHILE THEY EARN

This initiative is designed to help regional employers connect with students in a combined education and career pathway. A pilot program for this initiative is in Northeast Ohio where Lorain County Community College and a dozen area manufacturers have joined together.

In this program, students are recruited by both the school and a sponsoring company, attending classes two days a week and working for three. At the end of the two-year period, each student will receive a degree in microelectromechanical systems (MEMS) and have two years of work experience. MEMS sensors are widely used in electronics products such as mobile phones. Upon graduation, the sponsoring companies hire the students.

- Utilizing FabLabTV, a multimedia STEM outreach production reaching nearly 2 million viewers weekly, raising awareness of the opportunities in advanced manufacturing.
- Supporting the "America's College Promise" outreach forum, which increases access to community college education.

Innovation Ecosystem

Connecting a Nascent Supply Chain

"We are working closely with GE [Niskayuna, NY], Corning [Corning, NY], Lockheed-Martin [Owego, NY], Universal Instruments [Conklin, NY], i3 Electronics [Endicott, NY], and start-ups like Sensor Films [Victor, NY] to build a manufacturing infrastructure in New York State. NextFlex gives us the opportunity to collaborate on developing technology important to our corporate partners and catalyzed with the support of both Federal and New York State resources."

— Mark Poliks, Professor, Binghamton University

Credit: U.S. Navy

NextFlex is driving the growth of an emerging flexible hybrid electronics industry in the United States through strategic funding for innovative ideas. Institute projects include all sectors of the supply chain, from printed electronics to semiconductors to electronics manufacturing services. They involve universities, non-profits, and government agencies in improving processes through manufacturing on the NextFlex pilot line to scalable manufacturing and commercialization. Examples include:

- Supported by $20 million in matching funds from New York State for FHE manufacturing and catalyzed by a NextFlex project, an industry supply chain cluster has formed in New York connecting equipment, materials, system integration, and academic partners.
- A NextFlex project led by the University of Massachusetts at Amherst to establish a pathway to integration and manufacturing of a fully-capable wearable human health monitoring sensor platform has brought together partners Uniqarta, Inc. (Cambridge, MA), and E Ink (Billerica, MA), who met through the project call process, and are now working on a new application for thin chips that will go into the final product that can track heart rate and oxygen levels in people.
- A partnership between Boeing (Huntsville, AL), and start-up Sensor Films (Victor, NY) is leveraging Sensor Film's manufacturing equipment capability to enable rapid prototyping and economical on-demand production of flexible hybrid electronic devices. Major manufacturers, such as Jabil, Boeing, and GE, will use this to mass customize products for end users.
- Stanford University, Uniqarta (Cambridge, MA), Eastman Chemical (Palo Alto, CA), UTRC (East Hartford, CT), and Acellent Technologies (Sunnyvale, CA) are leveraging their unique, complementary expertise, facilities, materials, and processes to create a fly-by-feel sensor system that optimizes fuel efficiency and mechanical stress monitoring to improve the lifespan of aircraft wings. The partners are developing engineered approaches that reduce or eliminate manufacturing process gaps and overcome technical challenges.

Sustainability

NextFlex's sustainability plan has six key elements:

1. Membership: Membership fees create a predictable and growing revenue stream for the institute. Membership fees vary, but all active members have an obligation to provide annual dues. NextFlex membership reached 53 on September 30, 2016, and continues to grow.

2. Consulting Services: NextFlex is developing commercial services for industry and other organizations. These services include testing, reliability, and prototype assessments to help clients lower costs and improve quality. NextFlex also offers assessments of manufacturing maturity for FHE processes and technology and evaluation of target metrics roadmaps, including helping industry define the specific challenges in achieving the next level. During FY2016 discussions were initiated with DoD that may result in 2017 revenues.

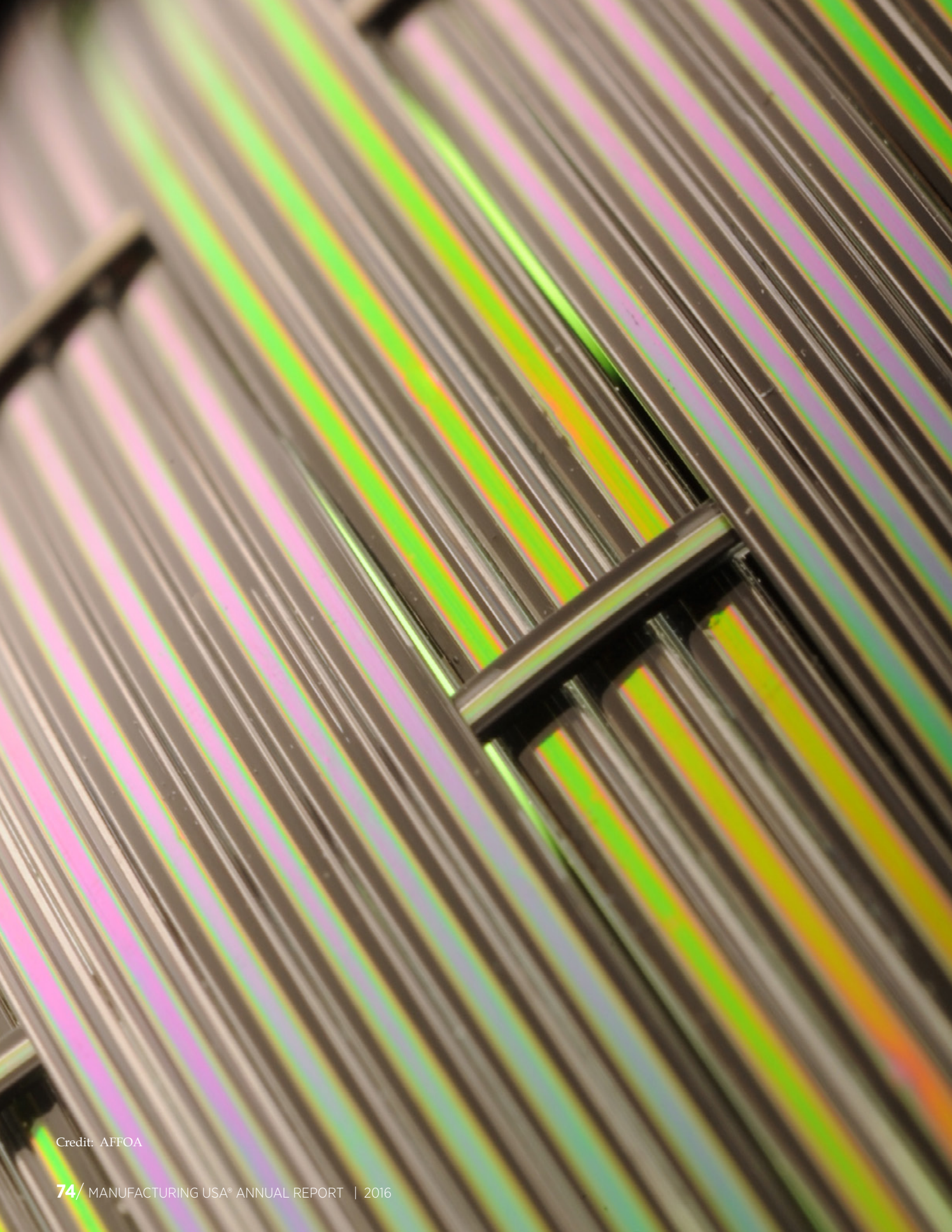
3. Manufacturing Services: A primary element of the sustainment plan is to leverage investments in the NextFlex pilot manufacturing line facility and technical staff to develop prototyping services, pilot production for FHE devices, and training services for manufacturing. Using the facility, NextFlex will offer prototyping and low volume production of FHE products under contract, as well as training members and others to use NextFlex-developed process technology and in-house training of member company personnel. Manufacturing capability is in the process of being created, using outputs of development projects as well as in-kind contributions and donations.

4. Sponsored Research: NextFlex intends to compete for grants, cooperative agreements, and other forms of contracts from industry, government agencies, and other groups that have interest in FHE-related research or evaluation. Beyond the activities supported by the cooperative agreement, NextFlex can attract funding from other sources that use its world-class FHE manufacturing capabilities and manufacturing support services.

5. Project Management: NextFlex has been asked to provide project management services for Federal agencies and plans to expand this activity. NextFlex works with client organizations to define their needs before using competitive processes to select appropriate organizations that will implement the projects. Three agency projects initiated in FY2016 were underway.

Education and Workforce Development: NextFlex is working with Federal agencies and private sector employers to execute education (including internships) and workforce training programs, as well as with state education agencies, local governments, and public education institutions to provide student training and internship opportunities. These activities have attracted funding to cover costs.

Credit: U.S. Air Force



Credit: AFFOA

AFFOA

Advanced Functional Fabrics of America

www.affoa.org

Credit: Kayana Szymczak

Manufacturing USA®

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.

Locations: Cambridge, MA

Established: April 2016

Consortium Organizer: Massachusetts Institute of Technology

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

Members: 53

Note: This institute was launched in the second half of FY 2016. As such, a basic overview and early activities are provided.

Institute Overview

"Our future depends on how we can innovate with fabrics."

— Norman Chapman, President of Inman Mills (Inman, South Carolina), a company founded by his grandfather in 1901.

Our clothes help define us, yet the fabrics we wear haven't seen the rapid evolution demonstrated in our electronic devices. 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." For the first time, technology's basic ingredient—semiconductors—has made it into the fibers themselves, creating extraordinary leaps in fiber performance. These new fiber materials enable visually inconspicuous yet highly functional capabilities in fabrics. These advancements will transform the textile industry from a low-tech, low wage, offshore industry to a high-tech, value-added, innovation-driven manufacturing ecosystem located in the United States.

What are Functional Fibers and Fabrics?

Fibers that have the functionality of semiconductor devices yet are produced at fiber lengths, uniformity and cost. These fibers can be woven into fabrics that see, hear, sense, communicate, store and convert energy, regulate temperature, monitor health and change color.

A key element in Advanced Functional Fabrics of America's (AFFOA) investment and operational strategy is to accelerate exciting, advanced, internet-connected textile products that introduce new business models. With highly functional fabric device systems, the ability to offer consumers "fabrics as a service" creates value in the textile industry—moving it from producing commodity goods in a price-competitive market to practicing recurring revenue models with rapid innovation cycles that are now characteristic of high-margin technology business sectors. It is a premise of the institute that there is little room to lower the bottom line in the textile industry, as offshore labor rates and currency manipulations have stymied U.S. competitiveness. However, there is significant opportunity to raise the top line, leveraging Federal, academic, and private sector investment in basic and applied science that is now ripe for scaling and manufacturing.

Product Focus

Products provide the volume and margin context for manufacturing. AFFOA therefore has a strategic position in helping industry define exciting new high margin products that will help drive high value-added manufacturing and investments in advanced manufacturing processes, establishing a virtuous high-margin innovation cycle.

Fibers and fabrics are ubiquitous forms that appear across diverse markets and products—from apparel and upholstery to wound dressings and composites. Therefore, AFFOA's product focus is expected to yield results and progress across markets as diverse as fabric products. AFFOA's nonproprietary roadmap projects deliver product prototypes that excite follow-on industry investment through proprietary projects funded by industry members and executed through the Fabric Innovation Network, described below. These projects lead to revolutionary fibers and textiles (RFT) products to meet market needs and demands and grow the domestic supply chain for these products.

Applications

AFFOA is transforming traditional fibers, yarns, and fabrics into highly sophisticated, integrated and networked devices and systems. AFFOA leads the convergence of advanced technology into fiber and textile production to commercialize fabric products that deliver value added services to the user – enabling fabrics to become the new software. Through AFFOA's activities fabrics that see, hear, sense, communicate, store and convert energy, regulate temperature, monitor health and change color will soon be possible to benefit the consumer and warfighter.

The Fabric Innovation Network

AFFOA is building a sustainable, high-tech prototyping ecosystem, the Fabric Innovation Network (FIN), to benefit U.S. manufacturers. FIN is made up of small, medium, and large manufacturers that rapidly execute prototypes and pilot production of integrated fabric products, decreasing time-to-market and helping accelerate product innovation. The institute is also building a national network of Fabric Discovery Centers (FDCs). These functional fabric startup incubators connect with market-facing companies to accelerate the development and introduction of exciting advanced fabric products. FDCs are "fab-less" incubators that lower the activation barrier to innovation by allowing start-ups to use the FIN to prototype and scale their inventions, thereby minimizing the initial startup time and financial investment.

"Made in America" Strategy and "One-Stop Licensing" Initiative

A core element in AFFOA's approach is to facilitate a domestic "Made in America" manufacturing capability in advanced fabrics based on U.S. innovation. To that end, AFFOA is aggregating existing U.S. university intellectual property (IP) in the field of revolutionary fibers and textiles. AFFOA seeks to fund research projects that will address scaling challenges to make this IP more valuable to domestic manufacturers.

AFFOA has created the first of its kind "One Stop Licensing Initiative" to facilitate the commercialization of this aggregated, underused university IP in revolutionary fibers, fabrics, and textiles. Companies seeking to commercialize university IP can come to AFFOA as a one-stop broker to license IP from member universities. IP licensed through the initiative is licensed on a non-exclusive basis on streamlined, business-friendly terms to help achieve the goals outlined above.

Early Activities

"Your innovation in fostering collaboration is already sowing seeds for technology advancement, to the benefit of society."

— Shandon Hart, Corning

Governance

AFFOA established a governance structure with clear responsibilities and roles for the various participants that promotes communication and participation by AFFOA stakeholders across the ecosystem through representative bodies. The governance structure enables efficient and rapid decision making and operations.

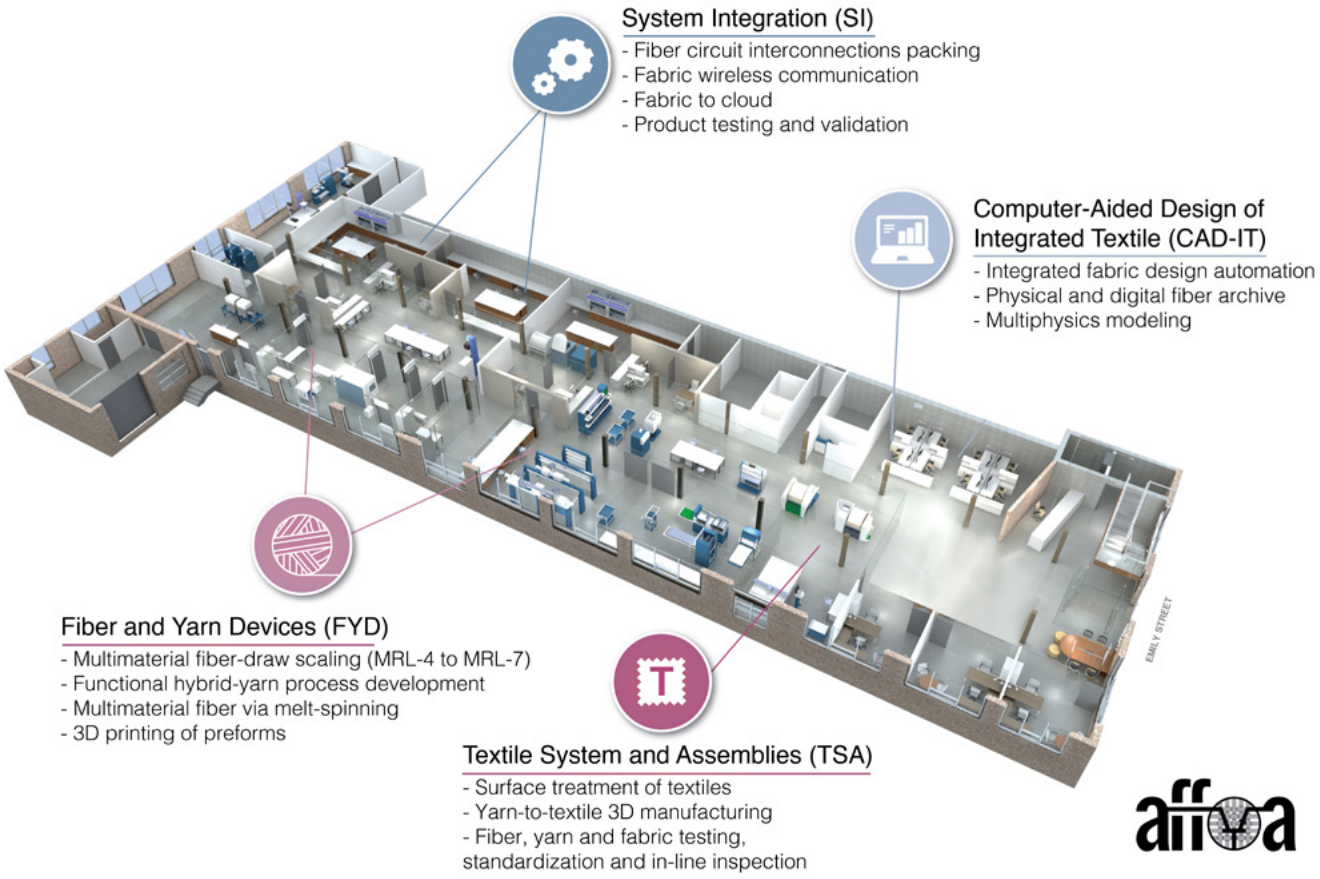


Figure 26. Proposed AFFOA Prototype Facility. Credit: AFFOA

In June 2016, AFFOA established its board of directors. The nine men and women comprising the board include representatives from academia and industry, including SMEs.

AFFOA also established its Technical Advisory Committee (TAC) and the Education and Workforce Development Committee (EDWC). Committee members are senior leaders and subject matter experts from industry, academia, and government. AFFOA's committees are populated on a merit basis with membership in the institute not required. As with the board of directors, members serve in a fiduciary capacity to the institute and do not represent their organizations' interests.

Membership

AFFOA opened membership at the end of July 2016. Concurrent to establishing world-class operating capabilities, AFFOA has successfully recruited diverse and high-quality members. In an unconventional approach to contracting, it offered two-page member agreements with simple and clear terms.

AFFOA's membership structure does not have tiers but offers categories, depending on the type of institution:

- University members provide technologies and IP and participate in technology transfer projects;
- Fabric Innovation Network members execute products and prototypes;
- Startup members drive the commercialization of exciting RFT products; and
- Industry members fund proprietary projects through the institute.

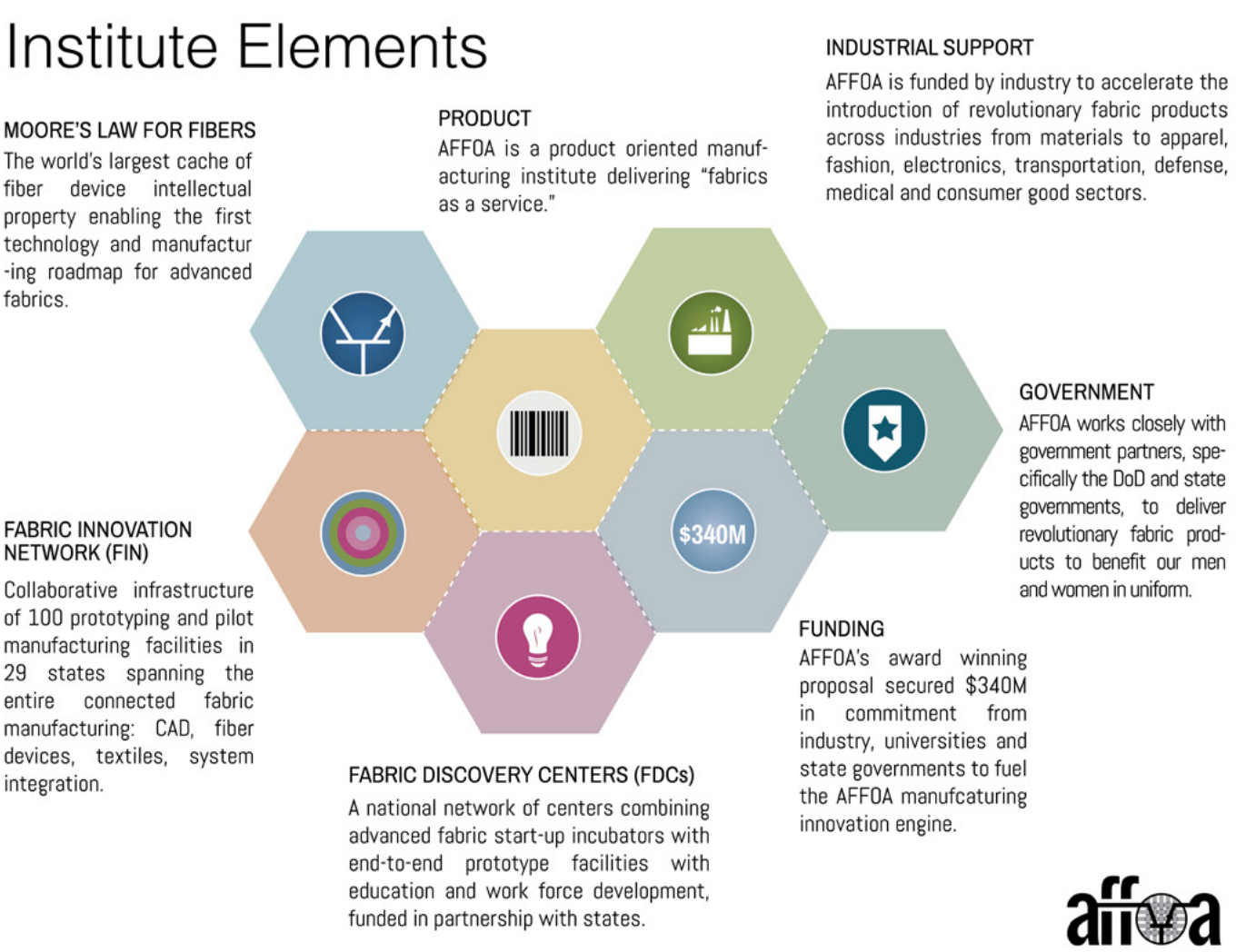


Figure 27. AFFOA Institute Elements for Creating a U.S. Based Ecosystem for Manufacturing Functional Fibers. Credit: AFFOA

To launch membership, an Industry Day and Membership Meeting was held in July 2016 in Cambridge, MA. The event attracted more than 100 organizations and 240 attendees with 95 percent of exit-survey respondents stating AFFOA's plans were clearly communicated and their expectations had been met. By the end of FY 2016, more than 50 members had signed membership agreements, approximately half by small and mid-sized manufacturers.

Roadmapping

Based on industry input, the institute has introduced the first-ever fiber and fabric technology capability and manufacturing roadmaps. The roadmaps are based on IP that exists domestically today in order to provide a cornerstone for AFFOA's Made in America Strategy. AFFOA will direct investment through technology programs to materialize this roadmap, to accelerate the development, scaling, and commercialization of RFT products that are IP protected and domestically manufactured.

Workforce Development

AFFOA's workforce development program began with a metrics-based analysis of current national workforce needs and existing education and training capabilities. The survey's goal was to refocus existing training resources to address current workforce needs. To train the RFT workforce of the future, workforce development was integrated into AFFOA's technology

programs. Infrastructure to capture and disseminate lessons learned from existing resources and technology programs was designed, including a learning portal and learning capture framework. The first Fabric Discovery Center was also designed with the goal of collocating startup incubation and end-to-end prototyping with learning and training resources.

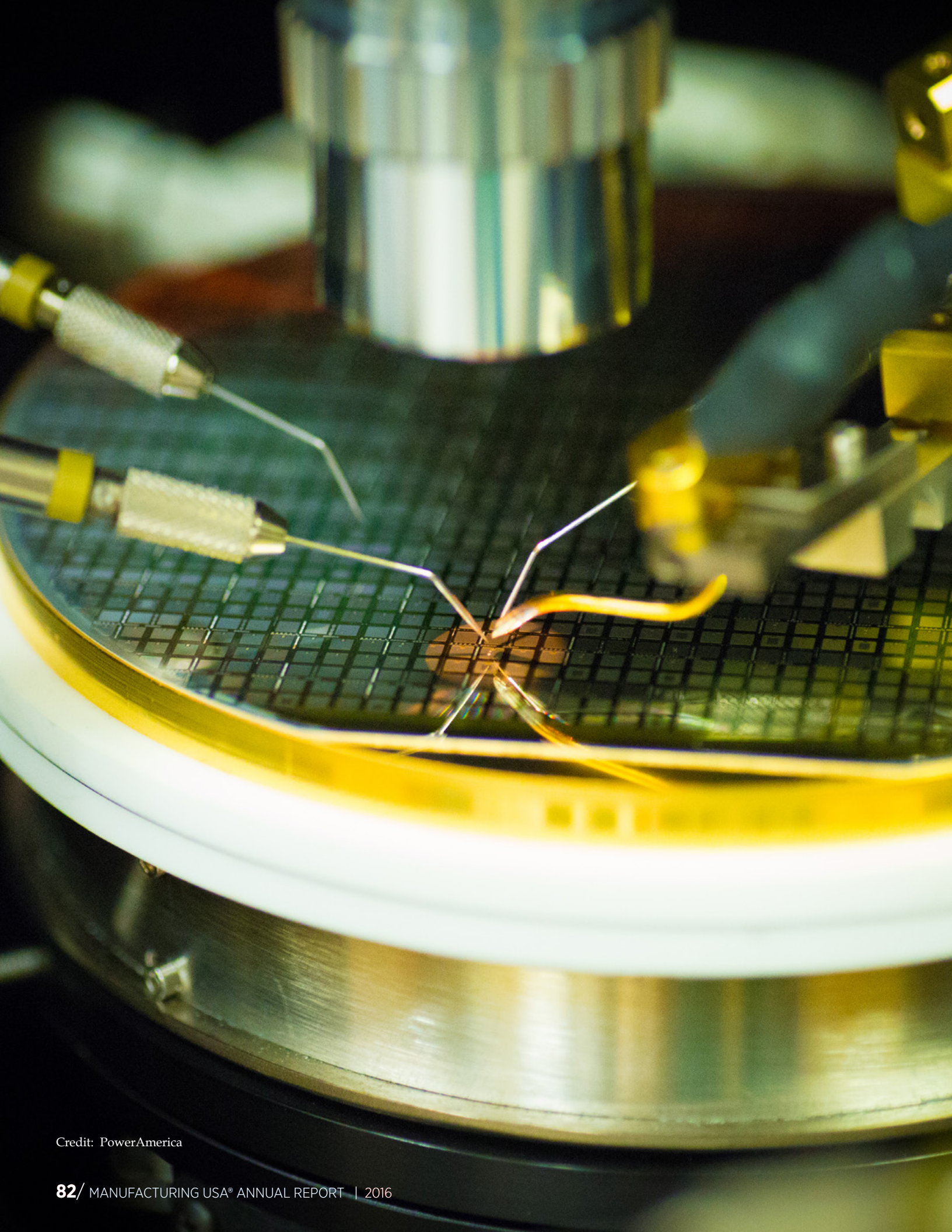
The Future

AFFOA's organizational infrastructure and operational strategy was formed with several distinct elements, including fabrics as a service, One Stop Licensing Initiative, IP-based roadmaps and technology programs, and a streamlined and accountable governance structure. These elements set a strong foundation for the future activities of the institute. Immediate upcoming activities include the issuance of Project Call 1.0 in the first quarter of FY 2017 along with the announcement of Fabric Discovery Centers in FY 2017.

Figure 28. Fibers drawn from a preform that contains semiconductors. By adding computer properties to fabrics, a whole new world of devices could emerge. Credit: M. Scott Brauer; courtesy of AFFOA

Department of Energy

Credit: PowerAmerica



Credit: PowerAmerica

PowerAmerica

PowerAmerica

The Next Generation Power Electronics Manufacturing Innovation Institute

www.poweramericainstitute.org

Manufacturing USA®

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.

Locations: Raleigh, NC

Established: January 2015

Consortium Organizer: North Carolina State University

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

Members: 32

Background

PowerAmerica is working to accelerate the development and adoption of advanced semiconductor components made with silicon carbide (SiC) and gallium nitride (GaN) 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.

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

Technology Advancement

"Through our collaboration with PowerAmerica, we believe our silicon carbide technology work has been advanced by five years."

— Brij Singh, John Deere

PowerAmerica's technology advancement efforts have ranged from technology road-mapping, to specific projects that bring companies and universities together, to scale-up of emerging power electronics technologies for factory production, to the creation of the country's first "open-foundry" SiC-based semiconductor fabrication facility.

Road-mapping

PowerAmerica released its second member-led *Technology Roadmap*[26] in May of 2016 in order to help U.S.-created wide bandgap technologies reach their potential in reducing energy consumption and emissions in a variety of industries, while also creating manufacturing jobs across the United States. This roadmap offers a strategy for making wide bandgap semiconductor technologies cost competitive with silicon-based power electronics and for accelerating the adoption of these technologies in new markets and applications. The roadmap thrusts—reducing cost, improving reliability, enhancing performance capabilities, and strengthening the power electronics ecosystem—form an integrated, collaborative strategy for advancing U.S.-created power electronics technologies.

[26] PowerAmerica Strategic Roadmap for Next Generation Wide Bandgap Power Electronics, The PowerAmerica Institute, May 2016, https://www.poweramericainstitute.org/wp-content/uploads/2017/01/PowerAmerica_Roadmap_Final-Public-Version-January-2017.pdf

Projects Completed in FY 2016

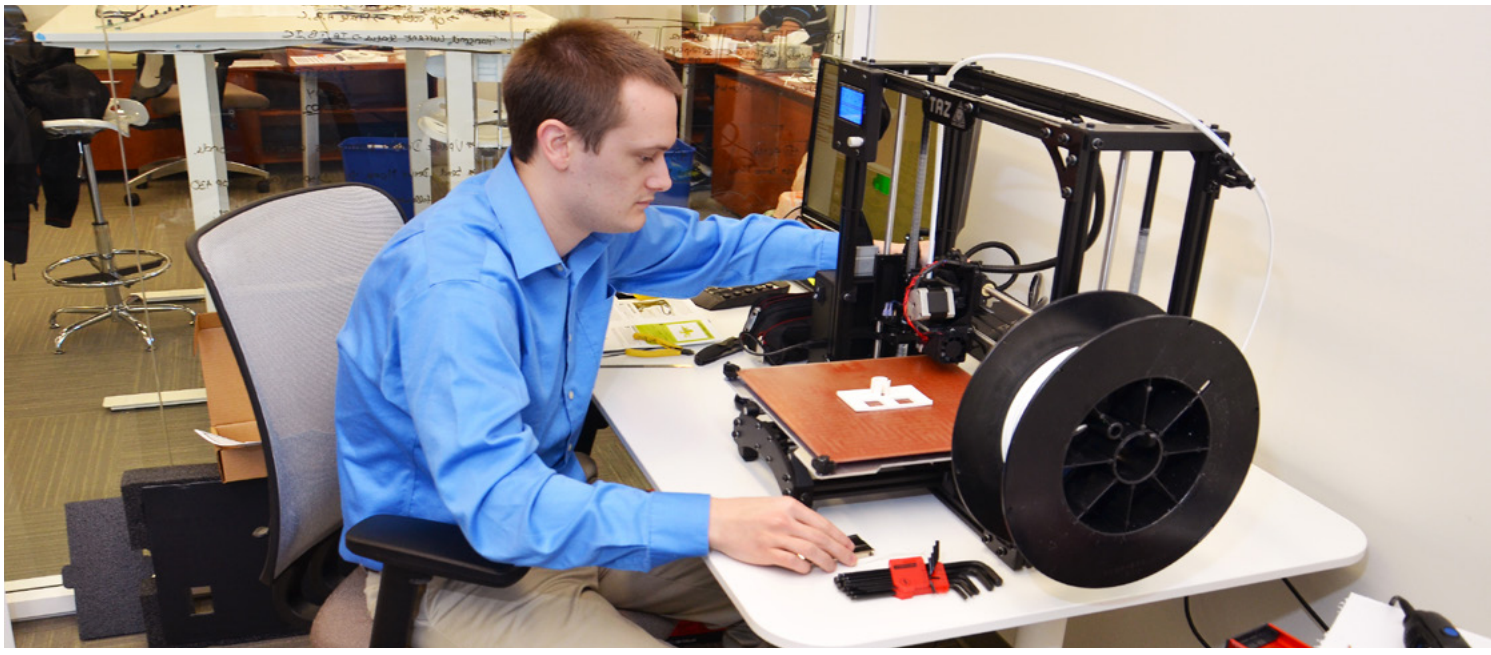
PowerAmerica has 36 ongoing projects, with all members making significant progress. In FY 2016, 25 projects were completed. Some highlights from these projects are:

- John Deere, working with researchers from the Department of Energy National Renewable Energy Laboratory, has developed a high-power silicon carbide-based inverter to convert battery power into the alternating current needed for hybrid motors in heavy duty construction vehicles and trucks. Compared with traditional transformer-based inverters, this device increases efficiency and decreases heat-related breakdowns. With a working prototype installed in under a year, Moline, IL- based Deere plans to hire American production workers in Fargo, ND, to manufacture and sell inverters starting in 2019.
- With support from PowerAmerica, Virginia Tech researchers developed a high-density AC adapter for laptop computers that will reduce the size of wall adapters by more than 50 percent, making this technology more transportable. The adapter increases efficiency so less energy is consumed during the charging process. PowerAmerica is now helping the researchers find U.S. industry partners to scale up development for manufacturing in the United States.
- PowerAmerica and X Fab have developed baseline fabrication processes that can be used at the X Fab foundry. These processes lower the barrier to market entry by allowing companies without production cleanrooms to rapidly make their innovations ready for manufacturing by using a shared set of manufacturing recipes in the X Fab cleanrooms to produce their wide bandgap products.

New Projects Launched in FY 2016

In FY 2016 PowerAmerica launched 11 new projects. They address key challenges in the manufacturing of SiC and GaN such as:

- Arc flash and short circuit malfunctions are electrical safety hazards within building power systems, contributing to one death per day in the United States. With support from PowerAmerica, Charlotte-based startup AtomPower has scaled up the manufacturing processes for its high-speed, safer circuit breakers, and in the process increased the current and voltage capacity of what it claims to be "the world's fastest circuit breaker." Through an association facilitated by PowerAmerica, the company is now working to incorporate the fast circuit breakers into products made by a large manufacturer, Lockheed Martin.



Credit: PowerAmerica

Figure 29. X-FAB employee showing a SiC wafer processed at their facility. Top Credit: X-FAB

Left Credit: X-FAB

POWERAMERICA HELPS BREATHE NEW LIFE INTO FACTORY, PRESERVING HUNDREDS OF JOBS AND HELPING POWER ELECTRONICS COMPANIES MOVE PRODUCTS FORWARD

In 2015, PowerAmerica partnered with X-FAB Texas in Lubbock, TX, to transform its silicon wafer fabrication facility. Before this partnership, silicon fabrication requirements had moved beyond what could be supported by the X-FAB Texas equipment set and the 400 highly-skilled manufacturing jobs at the facility were in jeopardy unless new lines of business could be created.

X-FAB and PowerAmerica partnered to create the world's first "open foundry" capable of supporting 6-inch silicon carbide (SiC) wafers. This capability enables semiconductor companies without their own fabrication facilities to produce silicon carbide products and compete in new ways.

- Companies need to ensure critical new technologies are reliable before they are brought to market. Wolfspeed, a Cree company based in Durham, NC, is using PowerAmerica support to have its silicon carbide metal–oxide–semiconductor field-effect transistors (MOSFETs) JEDEC-certified for reliability. The certification will help enable these smaller, lighter, and more efficient wide bandgap power electronic components to be accepted for large-scale adoption by industry.
- Florida State University researchers have used PowerAmerica support to develop a prototype photovoltaic inverter that has already achieved world record power density at very high efficiency in just one year. The device reduces both costs and energy losses when solar energy is converted into electrical energy that can be used on a traditional electric grid. As part of the next phase of the project, with assistance from PowerAmerica, the team is now pursuing further development with a large multinational electronics manufacturer.
- Data storage centers, such as those used by Google and Amazon, are projected to use as much as 10 percent of all U.S. electricity by 2020. Researchers at Virginia Tech, working on a PowerAmerica project, are using silicon carbide parts to create more efficient data centers, translating to a 1 percent improvement in efficiency—which would be equivalent to 4.6 nuclear power plants in energy savings.

Workforce Development

"Through PowerAmerica, we've had the opportunity to interact extensively with U.S. universities and use their capabilities to explore applications of wide bandgap semiconductors, as well as great access to qualified students and interns."

— Iulian Nistor, ABB

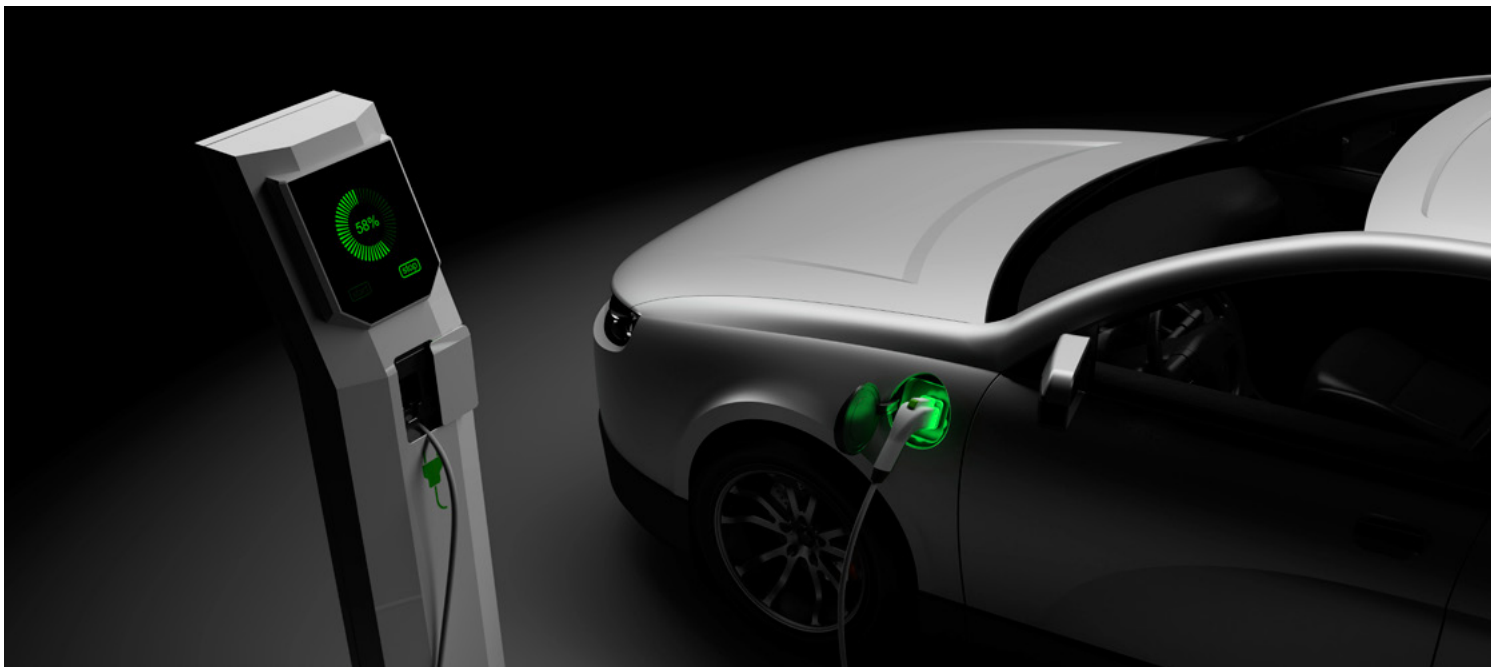
The PowerAmerica Education and Workforce Development team acts as a catalyst in building a wide bandgap semiconductor-centric education ecosystem that enables individuals to attain the skills required to enter the "career pathways" of design, development, and manufacturing of new and innovative WBG-enabled technologies and products. Toward that end, in FY 2016:

- Eight new courses were offered in wide bandgap semiconductors in graduate programs at university member institutions;
- More than 650 graduate and undergraduate students enrolled in power electronics courses;
- 31 graduate students engaged in hands-on research;
- 17 undergraduate students engaged in hands-on research through PowerAmerica's unique Undergraduate Research Scholars program, which provides undergrads the opportunity to work alongside faculty on cutting-edge applied research in wide bandgap technologies and wide bandgap-enabled product prototyping;
- 24 high school teachers and community college instructors completed courses at Train-the-Trainer Summer Institutes; and
- More than 5,000 students were reached through on-campus career fair and classroom introductions.

Innovation Ecosystem

"PowerAmerica has accelerated our research by providing us access to the end users, so we can apply their feed-back to our technology to ready it for commercialization."

— Ty McNutt, Wolfspeed



Credit: PowerAmerica

Figure 30. Computer-aided design of an electric vehicle charger designed by NC State University as part of a PowerAmerica project. Credit: NC State University

A FASTER, CHEAPER, MORE EFFICIENT CHARGER FOR ELECTRIC VEHICLES

Researchers at North Carolina State University (NCSU) have developed a SiC-based fast charger for electric vehicles that is cheaper, more compact, and more efficient than its silicon-based counterparts. The U.S. is projected to have 3.2 million electric vehicles on the road by 2023 and NCSU believes that its advanced charger, developed as a PowerAmerica project, will meet a critical need in this evolving market.

While current fast chargers are the size of a vending machine and require the use of a separate large transformer, the NCSU units are the size of a microwave and do not require an additional transformer. They cut the final cost of installed vehicle charging systems from about $90,000 to under $50,000, making charging stations more affordable. The systems deliver power with a stunning 96 percent efficiency, resulting in significant operating cost savings while reducing energy losses by half. The design can also be used in aerospace and military systems where weight reduction is critical, in industrial AC to DC power converters, in power supplies for energy-efficient data centers, and in other high-power electric applications.

NCSU plans to install the prototype charger on its campus in Raleigh for field demonstration in 2017, and to use the device to attract industrial partners to bring the product to market.

PowerAmerica is driving the growth of a globally competitive wide bandgap semiconductor industry in the United States through strategic funding for innovative ideas. PowerAmerica projects span all aspects of power electronics manufacturing, from foundry and device design, through module development and manufacturing, to commercialization applications and education and workforce development.

PowerAmerica projects create supply chains that include a wide array of industry members, from start-ups of a few people innovating with emerging technology to huge multinational corporations with large research departments, marketing teams, and factories. The projects bring students who will form the future workforce together with teachers, professors, and industry experts to exchange ideas and technical expertise, build relationships and business partnerships, form industry collaborations, and build a common future vision.

Already, an innovation ecosystem is forming around Lubbock-based XFAB, described above. In addition to jobs created at the foundry itself, the facility substantially

reduces the economic barriers to market entry for power electronics companies across the U.S. Because U.S. companies can now economically fabricate silicon carbide devices domestically rather than having to offshore production, they can more easily enter and compete within the rapidly growing global power electronics market.

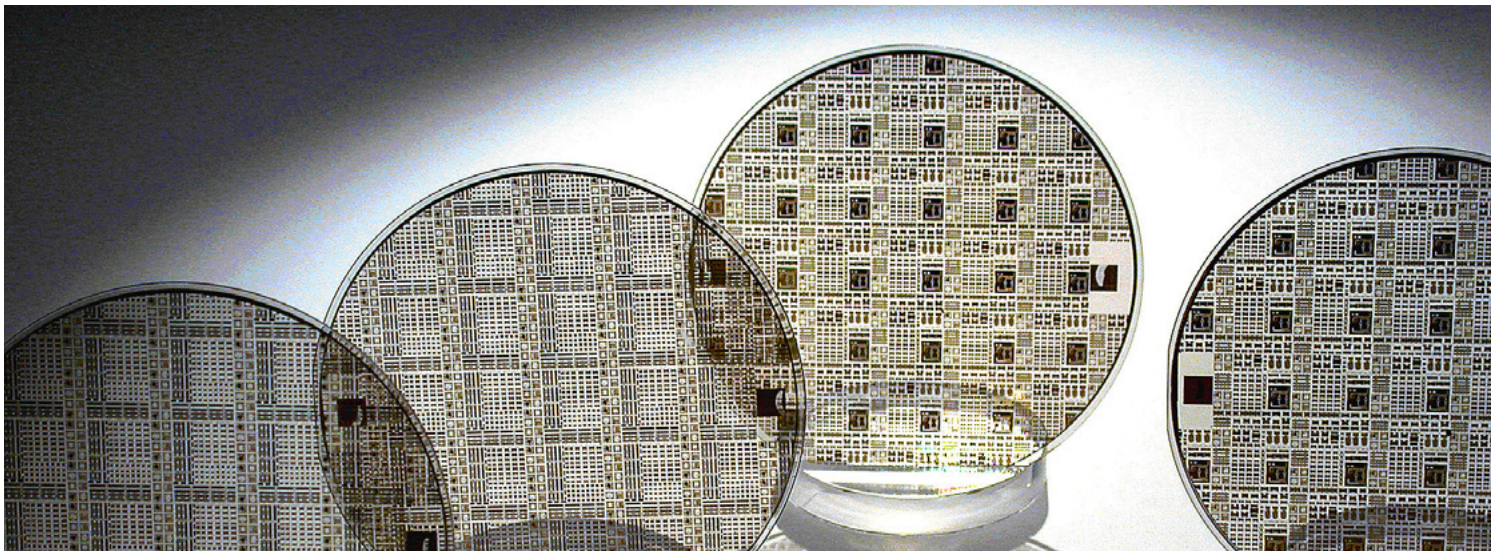
Through PowerAmerica, smaller U.S.-based companies fabricating wide bandgap devices at the XFab foundry are creating strategic supply relationships with the large companies that use these devices in their systems. The technologies developed there are allowing large companies to find new technology opportunities and design new products that are more compact and energy efficient. This makes U.S. manufacturing companies more competitive internationally, fulfilling the Manufacturing USA goal of strengthening manufacturing in this country.

Sustainability

Once PowerAmerica's initial Federal funding ends, the institute will rely on support from the university and the state of North Carolina; membership fees; and education and consulting services; among other revenue sources, as detailed below:

- **University support:** With plans to bring at least five new faculty members on board, PowerAmerica will have additional expertise to go after new research grants. Additional university support, such as access to endowments and support for the masters of science in Electric Power Systems Engineering, will also assist the institute.
- **Membership dues:** PowerAmerica is creating an ecosystem that offers extensive value for industry and academia, even without Federal funding. Industry will continue to pay membership dues to stay on the cutting edge of wide bandgap commercialization and development.
- **Consulting services:** These include low-cost manufacturing at XFab using processes developed by PowerAmerica; development of packaging and module solutions; custom reliability testing; and prototype demonstration/validation.
- **User Facility Revenue:** Income from the use of XFab and PowerAmerica's cost-shared tools for commercial production.
- **Device Bank:** A collection of power devices and modules is available for purchase, to shorten the time to acquire them and thereby accelerating commercialization of new products.
- **Short courses and training programs:** Tailored to the needs of working professionals.

Today, PowerAmerica members such as Monolith Semiconductors (Ithaca, NY), United Silicon Carbide, Inc. (Monmouth Junction, NJ), and GeneSiC Semiconductor (Sterling, VA), as well as non-members, are using X-FAB Texas' production facility to create leading-edge U.S. products.



Credit: PowerAmerica

Credit: IACMI

The Institute for iacmi Advanced Composites Manufacturing Innovation

THE COMPOSITES INSTITUTE

IACMI

Institute for Advanced Composites Manufacturing Innovation

www.iacmi.org

Credit: IACMI

Manufacturing USA®

IACMI

Mission: To research and advance knowledge that will accelerate advanced composites technology development by combining industry-driven expertise with strategic regional research capabilities to catalyze manufacturing innovations that enable robust supply chains and a skilled workforce, thereby advancing U.S. manufacturing competitiveness.

Locations: Headquarters: Knoxville, TN; Technology Area Locations: East Lansing, MI; Detroit, MI; Dayton, OH; Lexington, KY; West Lafayette, IN; Denver, CO; Knoxville, TN; Nashville, TN

Established: June 2015

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

Funding: Federal, $70M; Non-Federal, $180M (both planned funding over five years)

Members: 126 as of September 30, 2016

Background

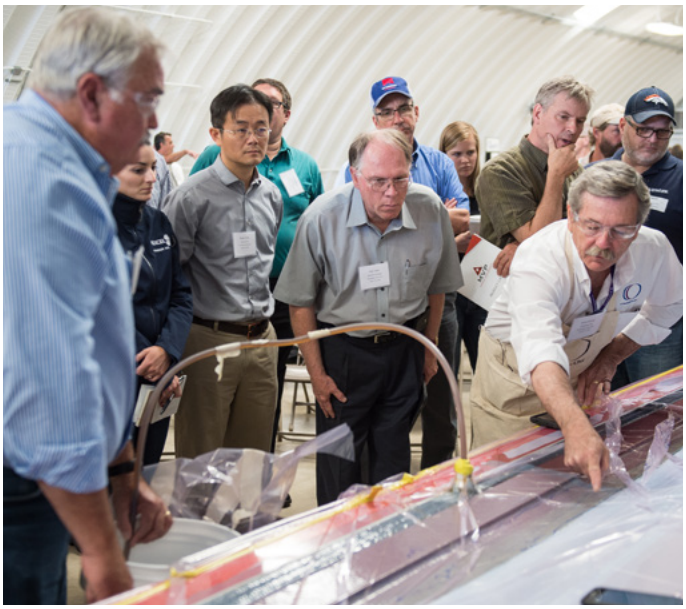
The Institute for Advanced Composites Manufacturing Innovation, IACMI, and its partner organizations work to benefit the nation's energy and economic security by sharing existing resources and co-investing to accelerate development of advanced composites. This diverse public-private partnership develops manufacturing technologies that respond to the need for faster and more cost-, material-, and energy-efficient composite manufacturing, including recycling at the end of product life. IACMI broadly engages educational, economic development, trade, and professional organizations to build the skills and workforce critical to the growth of composite industry companies of all sizes.

The U.S. DOE Clean Energy Manufacturing Initiative has identified advanced composites as a key cross-cutting technology with high potential to enable increased energy efficiency in transportation and energy production while creating new economic opportunity for U.S. manufacturers. IACMI closely aligns with the initiative and leverages existing facilities and capabilities, creating focused centers to support the specific advanced composites needs in targeted vehicles, wind energy, and compressed gas storage applications. The technology area locations are close to their respective manufacturing and end-user bases to enable rapid growth of regional manufacturing clusters to meet supply chain needs.

Technology Advancement

"To make a real impact in the composites industry, we have to all come together as one group. Innovation and working together is key, and IACMI helps enable that. Without the collaboration of an entire team, this project would not have been successful."

— Dana Swan, Business Development Scientist, Arkema



Credit: IACMI

IACMI co-funds collaborative projects that address member needs and IACMI technical goals to significantly lower the carbon fiber-reinforced polymer (CFRP) cost, reduce CFRP embodied energy, and improve composite recyclability into useful products.

Road-mapping

To ensure the institute conducts research aimed at solving industry's needs, IACMI solicits industry input in the development of the IACMI Technology Roadmap. The roadmap targets the five- and 10-year technical and economic objectives of reducing the cost of composites by 25 percent in five years and 50 percent in 10 years, reducing embodied energy by 50 percent in five years and 75 percent in 10 years, and increasing recyclability to 80 percent in five years and 95 percent in 10 years. The roadmap will provide a sound technical basis for future IACMI projects.

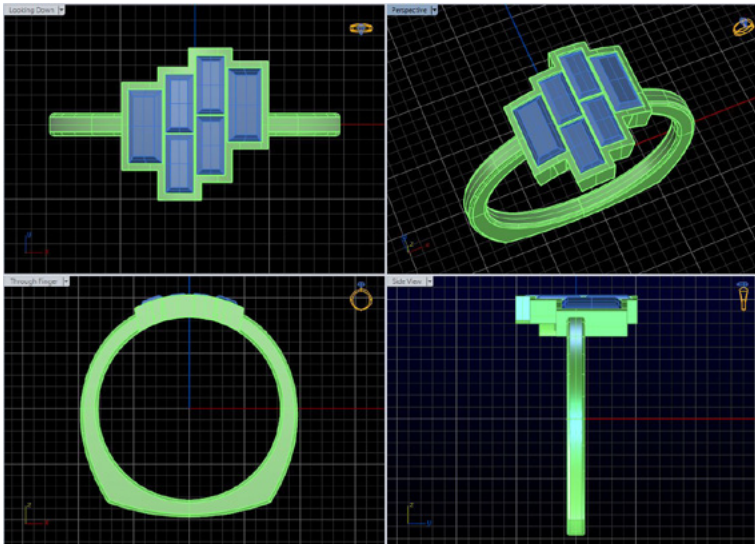
IACMI partnered with Nexight Group, a technical and management consultancy specializing in technology road-mapping, in August 2015 to build a Phase 1 Roadmap. This accelerated, preliminary roadmap priority identification was based on literature review, expert interviews both within and outside of IACMI membership, an online survey of more than 800 IACMI partners and interested parties, and two in-person road-mapping meetings at IACMI headquarters in Knoxville. The Phase 1 Roadmap was released in January 2016. The roadmap features five major research focus areas: vehicles, wind energy, compressed gas storage, materials development, and design, modeling, and simulation.

Phase 2 of the roadmap development kicked off in FY 2016. This phase focuses on developing the road-mapping process, incorporating stakeholder engagement throughout because the resulting roadmap is a living document that will require updating as member needs evolve. Two workshops were held in FY 2016, one in March in Knoxville and a second in May in Detroit. The Phase 2 roadmap is scheduled to launch in February 2017.

Projects launched

In its first full year of operations, IACMI launched three new projects with more than 10 projects in the pipeline expected to launch in early FY 2017.

- **Thermoplastic Composite Development for Wind Turbine Blades**—Thermoset composites reinforced by fiber are the current material of choice for large-scale wind turbine components; however, they face challenges in manufacturing costs, performance, and recyclability. IACMI and Denver-based Johns Manville will lead a team of seven industry partners to investigate new developments in thermoplastic materials to lower production costs and improve recyclability of wind turbine blades. The long-term impact could additionally improve reliability in composite structures, which would allow for process improvements on a larger scale and increase energy efficiency.
- **Rapid Carbon Fiber Prepreg Molding Technology for Automobile Structural Parts**—IACMI, in partnership with Tacoma, WA-based Toray Composites (America), Inc., announced the launch of a strategic project to decrease the cost of carbon fiber automotive structural parts by 15 percent for target components. Currently, high cost and long cycle times limit the use of carbon fiber in automotive structural parts. Toray Composites is leading a team of eight manufacturing and university collaborators, taking a supply chain, ecosystem-based approach to integrate material selection, molding methods, and preform design patterns with waste stream utilization.



Credit: IACMI

Credit: IACMI

IACMI-THE COMPOSITES INSTITUTE HANDS-ON WORKFORCE EVENTS PROVIDE TRAINING FOR OVER 400 IN 2016

A series of workshops delivered at IACMI's partner locations across the United States were dedicated to training manufacturers in energy reducing technologies, materials, and processes in closed mold and other advanced processes.

April 2016 – IACMI HQ, Knoxville, TN

150 Attendees, Representing 25 states

Attendees included GE & BASF

June 2016 – NREL, Boulder, CO

155 Attendees, Representing 28 states

Attendees included 3M & MVP

August 2016 – Purdue University, W. Lafayette, IN

114 Attendees, Representing 19 states

Attendees included Owens Corning & SikaAxson

- **Thermoplastic Composite Parts Manufacturing Enabling High Volumes, Low Cost, Reduced Weight with Design Flexibility**—IACMI, in partnership with DuPont Performance Materials (Wilmington, DE), Fibrtec Inc. (Atlanta, TX), and Purdue University (West Lafayette, IN) are conducting a project with a dual focus on decreasing the cost of manufacture and increasing design flexibility for automotive composites. Advancements in both areas are needed to open new opportunities for composite parts.

- **Reduction of CO_2 Emissions Through Lightweight Body Panel**—Carbon-composite-metal Carbon-metal composites show promise for drivetrain components, but costs and cycle time inhibit their applications in high-volume automotive components. This IACMI project led by Volkswagen Group of America will explore material, component design, and production methods to achieve cost and cycle time requirements for large-scale production, resulting in similar weight savings as metal alternatives but lower cost.

Figure 31. Over 400 attendees received training at IACMI workforce events in FY 2016. Credit: IACMI

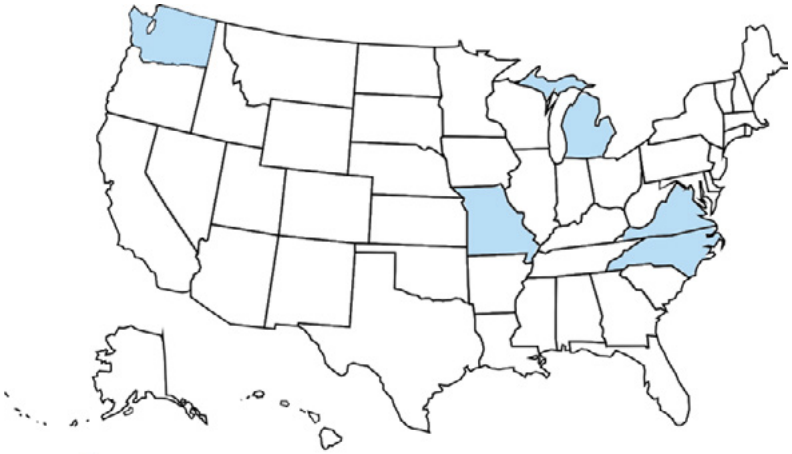
Workforce Development

Our participation in IACMI provides hardworking Hoosiers with the tools they need to create high-paying jobs and develop a skilled workforce critical to the growth and competitiveness of manufacturing in Indiana and the U.S.A."

— Ian Steff, Chief Innovation Officer, State of Indiana

One of IACMI's goals is to identify the workforce that is likely to be directly affected by new composites technologies and develop the talent pipeline before new materials come to market. By creating relationships with education and workforce partners and increasing the workforce capacity now, world-class composites talent will be ready to work when new technologies are fully integrated into industry.

- IACMI and the American Composites Manufacturers Association (ACMA) entered an agreement in the fall of 2015 to partner on workforce development efforts including the support and promotion of the ACMA Certification Composites Technician Program (CCT) and memberships in each other's organizations.
- In the fall of 2015, IACMI teamed with Composites One, the nation's leading distributor of composite materials, to announce their new partnership. IACMI and Composites One, along with the Closed Mold Alliance and Magnum Venus Products, designed curricula and hosted three training workshops between April and August 2016 designed to educate the composites workforce in the latest processes and advanced technologies. The three workshops drew a national audience of more than 400 technicians and students from more than 30 states.
- IACMI's Summer Internship Program received several hundred applications from 116 students attending colleges and universities across the country—with 15 participants selected and awarded a paid 10-week internship at one of five IACMI partner locations. The program provided undergraduate and graduate students with national exposure to industry experts, hands-on access to state-of-the-art manufacturing equipment, and academic interactions with high-level scientists and engineers in advanced composites and manufacturing. By exposing students to cutting-edge composites technology research, the internship helps create an enthusiastic, skilled new generation of the composites workforce and expands the composites industry for future career growth.



Credit: IACMI

IACMI, THE COMPOSITES INSTITUTE TECHNICAL PROJECT: RAPID CARBON FIBER PREPREG MOLDING TECHNOLOGY FOR AUTOMOBILE STRUCTURAL PARTS (SEAHAWKS)

Challenge: High costs and cycle times limit the use of carbon fiber composite (CFC) in automotive structural parts.

Approach: A supply-chain centric (ecosystem-based) approach that integrates material selection, molding methods, preform design patterns, together with waste stream utilization will decrease costs and cycle times.

Impact: Integrated supply chain-based improvements to materials selection, component design, form set-up, process, and scrap management will decrease costs by 15 percent for target components.

Project Length:

Phase I - April 19, 2016 – October 18, 2016

Phase II – Component study (18 months – Start date TBD)

Toray Composites (America), Inc., Zoltech, Reichhold, Janicki Industries, Globe Machine Manufacturing Co., CRTC, ACMA, MSU

IACMI Vehicles Technology Area

Innovation Ecosystem

"The integration of design within the materials selection and manufacture process optimizes vehicle production by reducing cycle time. 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

The innovation ecosystem fostered by IACMI is a major focus and strength of the institute. Its partner locations are each a hub of activity for one of the five major technology areas:

- IACMI's Vehicles Technology Area in Michigan, where 70 percent of all U.S. automotive research and development (R&D) occurs at more than 370 R&D centers, is led by Michigan State University and is focused on reducing the weight of vehicle structures.
- IACMI's Compressed Gas Storage Technology Area, led by the University of Dayton Research Institute in Ohio, features full-scale manufacturing work cells in addition to supporting small business incubation and workforce development. The university's institute serves as the portal within IACMI to Ohio's extensive composites industry, which includes more than 24,000 employees serving all aspects of the composites industry.
- IACMI's Wind Turbines Technology Area, located at the National Renewable Energy Laboratory (NREL) in Colorado, capitalizes on the long and productive history of collaboration between NREL and the major wind industry OEMs, including Vestas, GE, Siemens, TPI Composites and LM Windpower.
- IACMI's Composite Materials and Process Technology Area, located in Tennessee and led by Oak Ridge National Laboratory and the University of Tennessee, Knoxville, focuses on development and characterization of energy-efficient, high-rate, and low-variability manufacturing processes from constituent materials through composite structures.

Credit: IACMI

- IACMI's Design, Modeling & Simulation Technology Area, located in Indiana and led by Purdue University, offers modeling and simulation tools to help address the need to shorten the development cycle and decrease the cost of composites manufacturing while allowing more time for innovation throughout the entire supply chain.

These core partners provide open access to state-of-the-art facilities and technologies through IACMI projects.

IACMI's membership base includes a collection of SMEs and large multinational companies. They represent complementary areas of nondestructive evaluation, inline monitoring for process control, modeling and simulation for process and component design and optimization, and product testing and certification. Collectively, these member organizations represent the entire supply chain and cover the material life cycle through small, medium, and large volume applications, with an emphasis on high-volume manufacturing.

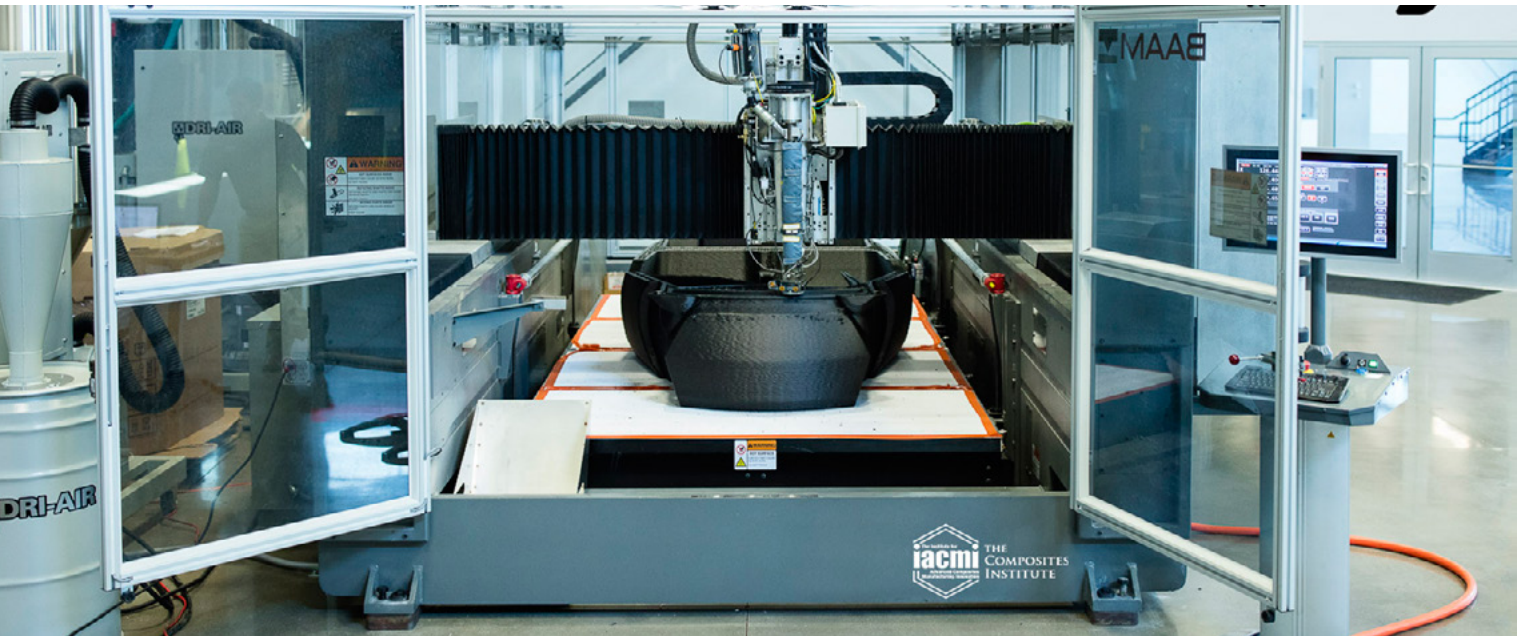
Together, IACMI's people and physical infrastructure deliver unparalleled capabilities to accelerate the development of innovative composite materials technologies.

Sustainability

"The Composites Institute's impact is larger than the project research and development work taking place at our facilities. Collaboration amongst IACMI members spans the entire industry supply chain from material suppliers, BASF and Techmer, to design and manufacturing with Local Motors. Commercialization of new innovations is resulting in the creation of new jobs, expansion of manufacturing facilities and an overall economic development impact benefitting the entire ecosystem of composites manufacturers."

— Bryan Dods, IACMI-The Composites Institute CEO

As IACMI-The Composites Institute progresses through the five-year award period of Federal funding, increased emphasis will be placed on core state and industry partner engagement, which is expected to result in continued funding streams for the organization.



Credit: IACMI

CESMII

Clean Energy Smart Manufacturing Innovation Institute

www.cesmii.org

Credit: CESMII

CESMII

Clean Energy Smart Manufacturing Innovation Institute

Note: This institute was announced in the second half of FY 2016 and did not commence operations during the reporting period of this report. Therefore, a basic overview of the institute is provided here.

In September 2015, the Department of Energy announced a funding opportunity for its next institute focused on smart manufacturing.

Smart manufacturing enables all information about the manufacturing process to be available when it is needed, where it is needed, and in the form it is needed across the entire manufacturing value-chain to power smart decisions. Islands of efficiency become interoperable, networked, and resilient solutions to drive transformational manufacturing enterprise performance for any size, level of technical sophistication, or resource availability at lower cost.

In June 2016, the competition ended with the announcement that the Smart Manufacturing Leadership Coalition (SMLC) will lead the new Clean Energy Smart Manufacturing Innovation Institute (CESMII). The winning coalition, headquartered in Los Angeles, CA, brings together a consortium of nearly 200 partners — hailing from more than thirty states — with over $140 million in public-private investment to spur advances in smart sensors and digital process controls that can radically improve the efficiency of U.S. advanced manufacturing.

CESMII also will launch five regional manufacturing centers across the United States, each focused on local technology transfer and workforce development. UCLA will lead the California regional center, in partnership with the city of Los Angeles, harnessing the ability to tap the largest manufacturing base in the United States. Texas A&M University will lead the Gulf Coast center — a region anchored in the chemical, oil, and gas sectors — and Rensselaer Polytechnic Institute (RPI) will lead the Northeast center, where glass, ceramic and microelectronic manufacturing has a strong presence. Pacific Northwest National Laboratory will lead a hub in the Northwest and NC State will spearhead a regional hub for the Southeast.

To ensure that all American businesses, regardless of their size or potential resource limitations, can benefit from the institute's progress, CESMII will use an open-source digital platform and technology marketplace to integrate advanced sensors, controls, platforms, and modeling technologies into smart manufacturing systems. The institute will also provide the manufacturing communities with easy and affordable access to real-time analytic tools, infrastructure, and industrial applications.

CESMII is expected to launch in FY 2017.

CLEAN ENERGY SMART MANUFACTURING INNOVATION INSTITUTE™

INSTITUTE COMPETITIONS

The lead sponsoring agencies of Manufacturing USA initiated a new phase of growth in FY 2016. DOC, DoD, and DOE all announced competitions for new Manufacturing Innovation Institutes. These institutes will all be awarded in early FY 2017, with full details to follow in the FY 2017 Annual Report.

Department of Commerce

In February 2016, NIST announced a competition for the formation of at least one Manufacturing Innovation Institute with the possibility of more based on available funding to join the growing Manufacturing USA program. This competition was the first Manufacturing USA solicitation in which proposals were accepted on any advanced manufacturing topic.

As an open-topic competition, NIST accepted applications for proposed institutes in any area of advanced manufacturing so long as it was not duplicative of any existing institute or of any announced competition. There could be one or multiple submissions on a particular advanced manufacturing topic, and many submissions were particularly strong because proposing teams could be formed from members of an entire U.S. industry sector, rather than compete against other teams in the same technical space.

All proposals, regardless of advanced manufacturing topic, competed and were ranked against each other. The criteria for evaluation were developed to be consistent with the RAMI Act[27] and independent of technology. The competition selected an institute that best addressed the published evaluation criteria.[28]

Department of Energy

In May 2016, DOE announced a funding opportunity to support the establishment of a Manufacturing Innovation Institute on Modular Chemical Process Intensification for Clean Energy Manufacturing.[29] Modular chemical process intensification represents an emerging opportunity for processing industries in the U.S. manufacturing sector to improve energy efficiency, reduce feedstock waste, and improve productivity by merging and integrating separate unit processes (mixing, reactions, separation) into single modular hardware elements of reduced size, with higher efficiency and inherent scalability. Modular chemical process intensification is a set of technologies that brings significant reduction in equipment size, and improvement in energy efficiency, for the manufacturing of products requiring chemical processes. Through modularization, parallel integration, and combination of processes, process intensification approaches lead to significant benefits in energy efficiency, capital and operating expenses, quality, waste reduction, and process safety. Process intensification frequently involves combining separate unit operations (such as reaction and separation) into a single piece of equipment, resulting in a more efficient, cleaner, and more economical manufacturing process. At the molecular level, process intensification technologies significantly enhance mixing, which improves mass and heat transfer, reaction kinetics, yields, and selectivity. At the core of process intensification is the optimization of process performance by focusing on molecular level kinetics, thermodynamics, and heat and mass transfer. These improvements translate into reductions in: complexity, equipment requirements, and facility footprint, and thereby, minimize risk and uncertainty of construction and operation in chemical manufacturing facilities, for both existing and new products.

In June 2016, DOE requested proposals for a new Clean Energy Manufacturing Innovation Institute focused on improving technologies and processes to achieve cost parity of recycled and waste materials with primary feedstocks, while improving material efficiency in manufacturing processes. Through the funding opportunity titled "Reducing EMbodied energy And Decreasing Emissions (REMADE) in Materials Manufacturing," the REMADE in America Institute will enable the development of key industrial platform technologies that will dramatically reduce life-cycle energy consumption and carbon emissions associated with materials production and processing by creating new technologies for reuse, recycling, and remanufacturing of materials.[30] Solving this enormous and currently

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[27] Revitalize American Manufacturing and Innovation Act of 2014, 15 USC 278s(d).

[28] In December 2016, DOC announced that the University of Delaware will lead the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL).

[29] In December 2016, DOE announced that the American Institute of Chemical Engineers (AIChE) will lead the Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute.

[30] In January 2017, DOE announced that the Rochester Institute of Technology (RIT) will lead the REMADE in America Institute.

unmet challenge could reduce energy usage in the U.S. manufacturing sector by up to 6 percent, saving billions in energy costs, lowering greenhouse gas emissions, and improving U.S. manufacturing competitiveness. U.S. manufacturing accounts for nearly a third of the nation's total energy use annually, with much of that energy embodied in the physical products made in manufacturing. Analysis shows that the development of cost-effective new technologies to slash the life-cycle embodied energy and carbon emissions for materials production in the U.S. economy relative to the use of primary feedstocks could offer energy savings on the order of up to 1.6 quadrillion BTU annually across four classes of waste materials: metals, fibers, polymers, and e-waste.

Department of Defense

In June 2016, the U.S. Army Contracting Command, on behalf of the DoD ManTech Program, announced its intent to solicit proposals for an Advanced Tissue Biofabrication institute.[31] Significant breakthroughs in stem cell biology, tissue engineering, and materials science over the past decade have laid the foundation for this institute. Advances in cell biology and computer modeling, as well as in cell material sourcing and manufacturing, have provided ready access to, and a better understanding of, the basic building blocks of living and functional tissue and organs. Breakthroughs in biofabrication have occurred over the past decade, representing coordination between the material, biology, and engineering communities. These breakthroughs now enable three-dimensional constructs or tissues to be built with controlled cellular interfaces. Advances in micro- and nano-fabrication and microfluidic technologies now enable cell-cell and cell-material interactions to be engineered and controlled at unprecedented levels. Bioprinting technologies are being used to improve the scale, throughput, automation, and reproducibility of engineered tissues and real-time assays. To be successful, this institute must bring together, engineering, computer science, materials science, and biology-related research and manufacturing expertise from universities, research organizations, and established industrial businesses, along with local, state, and Federal government.

In July 2016, DoD announced an opportunity for a Manufacturing Innovation Institute focused on Robots in Manufacturing Environments.[32] The cost of labor drives low-skilled manufacturing jobs to low-wage nations around the world. The insertion of agile, collaborative robotics into U.S. manufacturing has the potential to alter the current paradigm by changing the cost, quality, and efficiency equations. The vision of this institute includes robots working collaboratively with humans on the assembly line and in material handling, increasing productivity and precision while freeing humans from low-value added activities. The integration of advancements in collaborative robotic capabilities could create new opportunities to U.S. manufacturers. This opportunity is designed to help reverse the global manufacturing trend of off-shoring production of innovative products, based primarily upon the lowest labor cost. This institute is envisioned to bring together a diverse collection of engineering, computer science, materials science, and human-machine behavioral research and manufacturing expertise to help ensure that robotics is a fully deployed and effective tool in strengthening U.S. manufacturing competitiveness in the global market.

Credit: DMDII

[31] In December 2016, DoD announced that Advanced Regenerative Manufacturing Institute will lead the Advanced Tissue Biofabrication Manufacturing Institute. The institute name was subsequently changed to BioFabUSA.

[32] In January 2017, DoD announced that Carnegie Mellon University will lead the Advanced Robotics Manufacturing (ARM) Innovation Institute.

CONCLUSION

In only its second year, Manufacturing USA has established a network of institutes for manufacturing innovation to address our nation's pressing manufacturing technology and competitiveness needs. The program is successfully fulfilling the goals laid out in the RAMI Act and the institutes have differentiated themselves as premiere public-private partnership innovation models for industry, academia, government, and other non-profit entities.

The Manufacturing USA program's second year also benefitted from two third-party program evaluations. The reports provided critical assessments of the program, including key findings on network membership. Highlights of the reports include:

- The network of institutes has fostered more than 9,000 relationships between organizations.
- Manufacturing USA institutes collectively represent more than 750 members, including two-thirds of Fortune 50 U.S. manufacturers, 270 small manufacturers, and eight of the ten top-ranked research and engineering universities.
- The program's active institutes are supporting a diverse portfolio of technology development projects, transitioning innovative technologies into scalable, cost-effective, and high-performing products and processes.
- Institutes are providing a substantial return on R&D spending to their membership.

The network is providing value to the institutes and helping the program better accomplish its purposes. The Manufacturing USA Secure Collaboration Site provided by the AMNPO is being used to share information among institutes and network working groups; one institute is already hosting its own shared services work on the site and others are likely to do the same as new institutes begin operations in FY 2017. The institutes all share the goal of building the next generation of manufacturing workforce, and together they use the network to find synergies and more efficiently accomplish this goal.

The program added two new institutes in FY 2016:

- Advanced Functional Fabrics of America
- Clean Energy Smart Manufacturing Innovation Institute

Five additional institutes were announced after the reporting period of this document that will expand the Manufacturing USA network to a total of fourteen institutes in FY 2017. Including the NIST open topic institute competition, these institutes will address: modular chemical process intensification; advanced tissue biofabrication; advanced robotics; reducing embodied energy and decreasing emissions; and biopharmaceutical manufacturing.

By providing regionally grounded innovation infrastructure while maintaining national connectivity, the Manufacturing USA network of institutes is able to successfully leverage and increase the collective talent and capabilities of U.S. global leadership in advanced manufacturing.

The Manufacturing USA institutes are progressing rapidly by actively supporting collaborative projects developed in partnership with their respective public and private-sector memberships. The institutes are offering their members clear value, as evidenced by membership growth, breadth, and commitment; and the institutes have laid the foundations for sustainability that will ensure Manufacturing USA provides lasting positive impacts on U.S. manufacturing.

Credit: AFFOA

Credit: DMDII

APPENDIX A

FEDERAL AGENCIES PARTICIPATING IN THE MANUFACTURING USA PROGRAM

U.S. Department of Agriculture

Worldwide, the bioenergy and bioproducts are emerging as new and rapidly growing sectors of the highly productive agricultural and forest industry. Manufacturing biobased products (e.g. biofuels, industrial chemical intermediates, performance polymers, and finished higher value products) represents a significant opportunity for the United States to support growth of a bioeconomy. Expansion of the bioeconomy has the potential to sustainably harvest and use one billion tons of renewable biomass in the United States annually without affecting existing farm and forest product markets, growing the current market five-fold over the next 15 years, adding to the bioeconomy, and creating thousands of jobs, many in rural areas.

The agricultural and forest sectors are essential for ensuring sustainable, reliable, and accessible production of bioenergy and biobased 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 bioenergy production into existing U.S. agricultural and forest systems without disrupting existing markets for food, feed, or fiber.

The USDA recognizes manufacturing plays an important role in maximizing the benefits of a sustainable, rural economy. Areas of interest include bioproduct development and enabling bio-manufacturing to: 1) establish processes and chemical platforms leading to high-value intermediate and end-use products; 2) support commercialization of products developed from fundamental building blocks of new technological advances through 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. The growth of the bioeconomy also depends upon understanding and addressing the entire supply and value chain of the bioeconomy, rural America's role in the bioeconomy, and the role of research and development.

The USDA invests in early-stage, innovative technologies that show promise in harnessing American resources safely and efficiently by using appropriate approaches to address the research needs of a diverse portfolio of bioenergy and biobased product systems. The bulk of research is focused on producing and biorefining, cellulosic (e.g. grasses, crops, woody biomass) and oil seed feedstocks that are regionally adaptable and sustainable. Proteins from processed plants and animals from agricultural systems and lignocellulosic fiber feedstocks from processed woody biomass are emerging as having the potential to enable new bio-manufacturing opportunities. Cellulosic nanomaterials from U.S. forests and agricultural plants also have enormous promise to bring about fundamental changes in and significantly benefit from our nation's forestry and agricultural production systems. Cellulose nanomaterials derived from trees and agricultural feedstocks: 1) are renewable and sustainable; 2) are produced via photosynthesis from solar energy, atmospheric carbon dioxide, and water; 3) store carbon; and 4) are carbon negative or carbon neutral dependent upon how long cellulose-based products remain in service. Cellulosic nanocrystals, for example, are predicted to have strength properties comparable to Kevlar, have piezoelectric properties comparable to quartz, and can be manipulated to produce photonic structures. Current global research directions in cellulose nanomaterials indicate that this material could be used for numerous innovative new products, including lighter and stronger paper and paperboard products; lighter and stronger building materials; wood products with improved durability; barrier coatings; body armor; lightweight automobile and airplane composite panels; electronics; biomedical applications; and replacement of petrochemicals in plastics and composites.

Department of Commerce

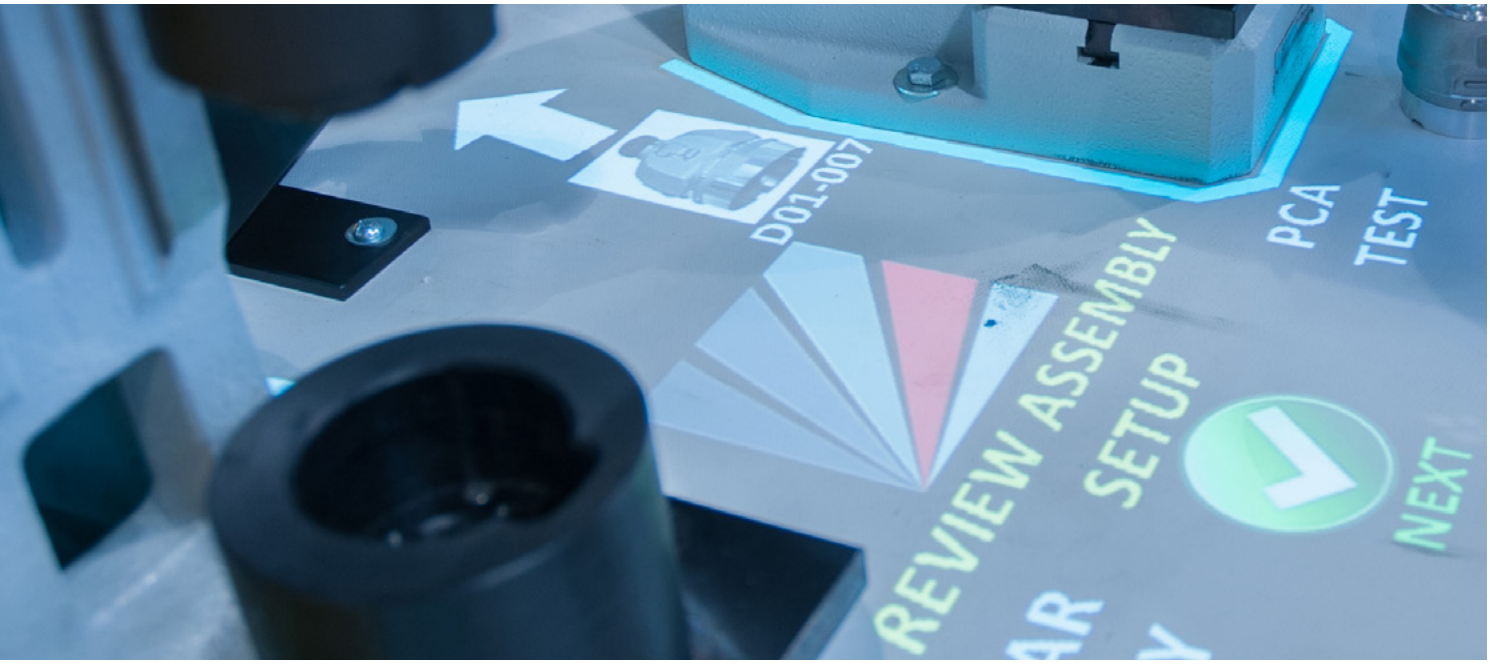
As part of its mission to create the conditions for economic growth and opportunity DOC supports the work of the Manufacturing USA program by establishing industry-led manufacturing innovation institutes. The Department hosts the Advanced Manufacturing National Program Office (AMNPO), an interagency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

Under its authority in RAMI,[33] 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. While the government does not steer which new technologies get developed or how universities undertake research, the government does have a critical role to play as a catalyst and a convener. 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 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



Credit: DMDII

[33] Section (d) of the Revitalize American Manufacturing and Innovation Act of 2014, 15 USC 278s(d).

manufacturers to develop new products, expand into global markets, and adopt new technologies, such as those in development at the Manufacturing USA institutes.

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 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 Department of Education supports education at all levels with across-the-board relevance to the knowledge and skill needs of the economy. Particular programs and initiatives focus on science, technology, engineering, and mathematics (STEM) fields, which are especially important in building the technically skilled workforce needed by the advanced manufacturing industry. Most significantly, the Department administers funds that support career and technical education programs in local education agencies and community colleges across the nation. The Department conducts leadership and technical assistance activities to promote quality career and technical education programs that are well articulated between secondary and post-secondary levels, and lead to successful careers. A particular focus for leadership and assistance programs is on advanced manufacturing. The Department is supporting Federal efforts to revive this sector through its support for the technical skills agenda.

The Department has been active in helping develop Manufacturing USA from its formation, and collaborates with other Federal agencies, in particular in those areas that focus on the knowledge and skill needs of the economy and efforts related to student success.

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, the 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% of total industrial energy use. The 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.

The DOE uses manufacturing innovation institutes to develop advanced manufacturing technologies to support these initiatives. At the end of the fiscal year 2016, the DOE

has awarded two 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. Since the beginning of the latest fiscal year, i.e. FY2017, three additional institutes have been solicited, selected and awarded. These additional institutes include; Smart Manufacturing: Advanced Sensors, Controls, Platforms and Modelling for Manufacturing, Process Intensification: Rapid Advancement in Process Intensification Deployment (RAPID) and Reducing Embodied Energy and Decreasing Emission (REMADE) in Materials Manufacturing.

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 through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise. By investing in bold, broadly applicable, disruptive technology that industry cannot tackle today, STMD seeks to mature the technology 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.

Advanced manufacturing research and development at NASA is focused in several areas: in-space manufacturing, materials for extreme environments, additive manufacturing (3D printing), polymer matrix composites, metals processing/joining, robotics, computational physics-based modeling, non-destructive evaluation, and other highly specialized areas. This 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 plan.

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 particular focus to develop technology testbeds within its research facilities and 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. An estimated $256.3 million was invested in CEMMSS in FY 2016, with an estimated $175.74 million of that in advanced manufacturing. Programs in CEMMSS support fundamental research leading to transformative advances that address nanoscale to macroscale manufacturing. These include process modeling, advanced sensing and control techniques (encompassed by cybermanufacturing), 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.

Credit: NIST

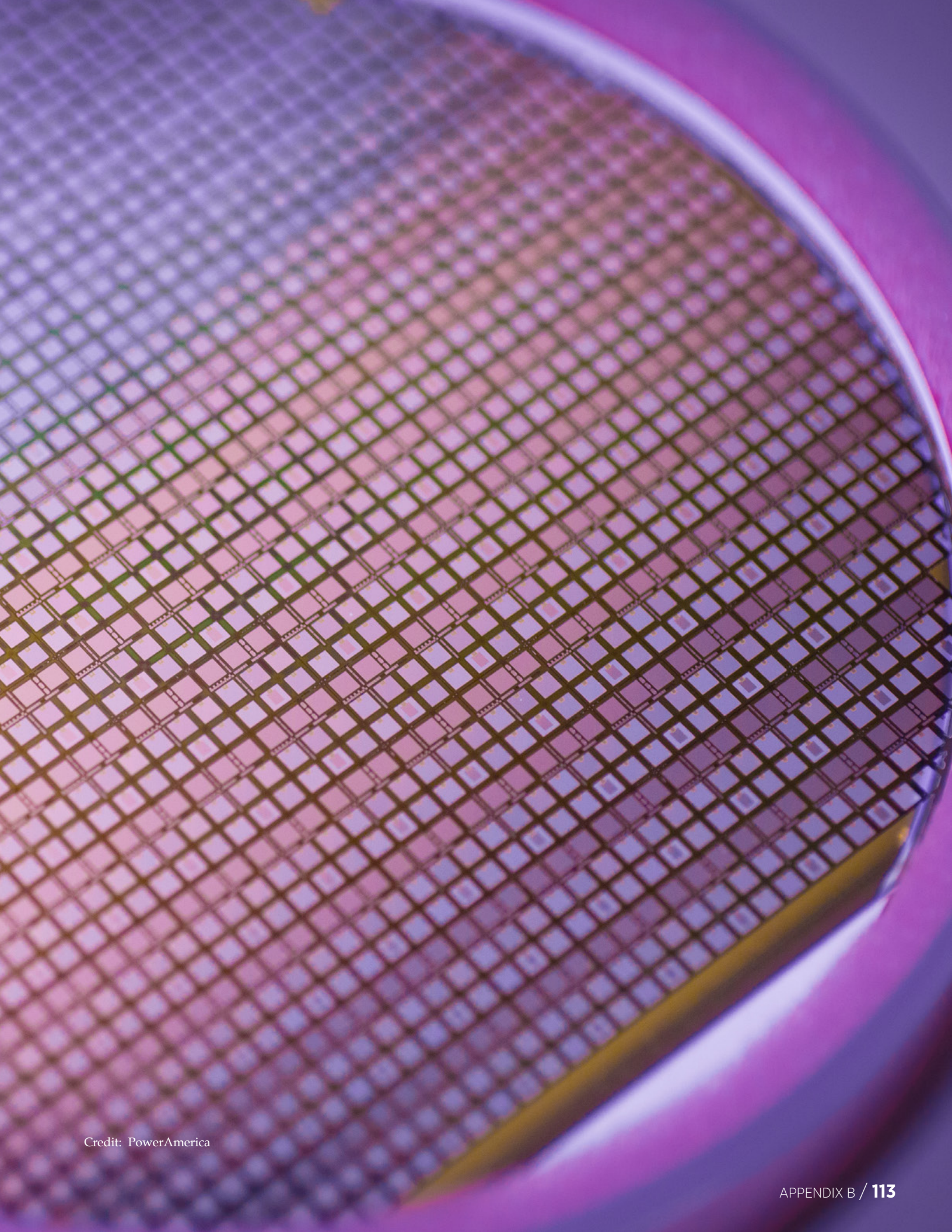
Credit: AFFOA

APPENDIX B

ABBREVIATIONS

ACADEMI	Advanced Curriculum in Additive Design, Engineering and Manufacturing Innovation
ACMA	American Composites Manufacturers Association
AFFOA	Advanced Functional Fabrics of America Institute
AIM Academy	AIM Photonics Academy
AIM Photonics	American Institute for Manufacturing Integrated Photonics
AL-Li	Aluminum-Lithium
AM	Additive Manufacturing
AM4MC	AM for Metal Casting
AMP	Advanced Manufacturing Partnership
AMNPO	Advanced Manufacturing National Program Office
AMSC	Additive Manufacturing Standardization Collaborative
AMTech	Advanced Manufacturing Technology Consortium
ANSI	American National Standards Institute
APICS	Association for Supply Chain Management (formerly the American Production and Inventory Control Society)
ARM	Advanced Robotics for Manufacturing Institute
ARMI	Advanced Regenerative Manufacturing Institute
ATE	Advanced Technological Education (NSF)
AWS	American Welding Society
BAAM	Multi-functional Big Area Additive Manufacturing
CAD	Computer Aided Design
CCT	Certification Composites Technician Program
CDC	Centers for Disease Control and Prevention
CEMI	Clean Energy Manufacturing Initiative (DOE)
CEMMSS	Cyber-enabled Materials, Manufacturing and Smart Systems (NSF)
CESMII	Clean Energy Smart Manufacturing Innovation Institute
CFC	Carbon Fiber Composite
CFRP	Carbon Fiber-Reinforced Polymer
DCL	Dear Colleague Letter
Deloitte Report	Manufacturing USA: A Third-Party Evaluation of Program Design and Progress
DMC	Digital Manufacturing Commons
DMDII	Digital Manufacturing and Design Innovation Institute
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOEd	Department of Education
DOL	Department of Labor
EBM	Electron Beam Melting
EDWC	Education and Workforce Development Committee
EKG	Electrocardiogram
ERC	Engineering Research Center (NSF)
EOP	Executive Office of the President
FDC	Fabric Discovery Center
FEA	Finite Element Analysis
FHE	Flexible Hybrid Electronics
FIN	Fabric Innovation Network
FY	Fiscal Year
GaN	Gallium Nitride
GAO	Government Accountability Office

GOALI	Grant Opportunities for Academic Liaison with Industry (NSF)
I/UCRC	Industry/University Cooperative Research Center (NSF)
IACMI	Institute for Advanced Composites Manufacturing Innovation
IMCP	Investing in Manufacturing Communities Partnership (DOC)
IMTS	International Manufacturing Technology Show
IP	Intellectual Property
LIFT	Lightweight Innovations for Tomorrow
ManTech	Manufacturing Technology Program (DoD)
MEMS	Microelectromechanical Systems
MEP	Manufacturing Extension Partnership (NIST)
MII	Manufacturing Innovation Institute
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
MOU	Memorandum of Understanding
MPW	Multi-Project Wafer
MPWA	Multi Project Wafer and Assembly
MSSC	Manufacturing Skill Standards Council
NASA	National Aeronautics and Space Administration
NCDMM	National Center for Defense Manufacturing and Machining
NCSU	North Carolina State University
NIIMBL	National Institute for Innovation in Manufacturing Biopharmaceuticals
NIST	National Institute of Standards and Technology (DOC)
NIMS	National Institute for Metalworking Skills
NREL	National Renewable Energy Laboratory (DOE)
NSF	National Science Foundation
NSTC	National Science and Technology Council
OEM	Original Equipment Manufacturer
PCAST	President's Council of Advisors on Science and Technology
PDK	Process Design Kit
PIC	Photonic Integrated Circuit
Precision OT	Precision Optical Transceivers
RAMI	The Revitalize American Manufacturing and Innovation Act of 2014
REMADE	Reducing EMbodied energy And Decreasing Emissions
RD&D	Research, Development, and Demonstration
RFT	Revolutionary Fibers and Textiles
RPI	Rensselaer Polytechnic Institute
SAM	Subcommittee on Advanced Manufacturing
SBIR	Small Business Innovation Research
SEAHAWKS	Rapid Carbon Fiber Prepreg Molding Technology for Automobile Structural Parts
SiC	Silicon Carbide
SiPh	Silicon Photonic
SMEs	Small and Mid-Sized Enterprises
SMLC	Smart Manufacturing Leadership Coalition
STEM	Science, Technology, Engineering, and Mathematics
STMD	Space Technology Mission Directorate (NASA)
STTR	Small Business Technology Transfer
SUNY Poly	State University of New York Polytechnic Institute
TAC	Technical Advisory Committee
TCIE	The Center for Industrial Effectiveness
TSIN	Tennessee STEM Innovation Network
UCSB	University of California at Santa Barbara
UTRC	United Technologies Research Center
WBG	Wide Bandgap
WEO	Workforce and Educational Outreach



Credit: PowerAmerica

Advanced Manufacturing National Program Office

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