

HIGHLIGHTS REPORT



2022



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MANUFACTURING USA

Highlights Report

A Summary of 2021 Accomplishments and Impacts

October 2022



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MESSAGE FROM THE INTERAGENCY TEAM

As domestic and international challenges continue to affect U.S. public health, the economy, and national security, the advanced manufacturing sector is responding. Innovative, resilient and sustainable manufacturing systems are transforming the U.S. to become stronger, smarter, greener, and more secure.

Manufacturing USA[®], a national network of public-private partnerships, supports this work through collaboration in technology, supply chain, and workforce development to secure U.S. global leadership in advanced manufacturing. The network includes the U.S. Departments of Commerce (DOC), Defense (DoD), and Energy (DOE), their 16 sponsored manufacturing innovation institutes, and six other federal partner agencies – the National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), Health and Human Services (HHS), and the Departments of Agriculture, Education, and Labor. This brings together vast resources and expertise from across the U.S. government to collaboratively support and strengthen U.S. advanced manufacturing.

The public-private manufacturing network enables a robust response to challenges to public health, national security, and global competitiveness. This past year the institutes pivoted to build awareness and access to high-paying quality jobs via flexible models of curricula delivery and even more internships, credentials, and apprenticeship opportunities. Institutes banded together with leading advanced manufacturing companies to develop the technology and robust supply chains that ensure our nation can predict and provide the manufacturing capabilities to guide us through current and future events.

In addition to addressing the urgent issues associated with the pandemic, in FY 2021 the institutes conducted more than 700 applied research and development projects of high priority to industry and collaborated with more than 2,300 member organizations to execute them. Among the institutes' members, 63% are manufacturing firms and 72% of those are small or medium manufacturers – critical components of the U.S. supply chain. More than 90,000 workers, students and educators engaged with advanced manufacturing through workforce efforts of the institutes and their partners.

Finally, the institutes attracted \$354M in funds from state, federal/pandemic, and private funds in addition to \$127M in base federal funding. This 2.8 to 1 investment match exceeds the program design of a 1-to-1 match and represents the catalyzing effect of federal investment.

We are proud to share this report highlighting the Manufacturing USA network's collective efforts to secure U.S. global leadership in advanced manufacturing.



Michael F. Molnar
Department of Commerce



Tracy G. Frost
Department of Defense



Steven McKnight
Department of Energy



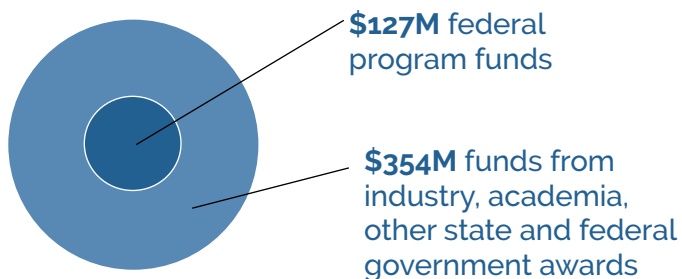
Credit: NIST/AIM Photonics

SECURING U.S. GLOBAL LEADERSHIP IN ADVANCED MANUFACTURING

Advanced manufacturing is essential to our economic and national security. American manufacturers contribute more than \$2.27 trillion to the U.S. economy which on its own would represent the eighth-largest economy in the world.¹ Every dollar spent in manufacturing results in an additional \$2.68 added to the economy, making it the highest multiplier effect of any sector.² This leads to jobs and economic opportunities in local and regional communities.

Manufacturing today employs over 12.85 million people and provides rewarding, living-wage jobs that pay \$92,832 annually on average, including benefits.³ Advanced technology and automation are changing the nature of manufacturing work, and more technical and digital-skilled positions are created every day. More than half of those new jobs—as many as two million—could go unfilled without training programs to prepare new graduates and current workers with the skills these roles will require.

Investments



FY 2021 Funding for Institutes. Credit: NIST

There are countless benefits to embracing innovation and technology. The nation that capitalizes on these new manufacturing industries and develops a diverse and skilled workforce first will dominate the global marketplace and lead the world. By leveraging more advanced manufacturing technologies, the U.S. can ensure that manufacturing remains a strong source of our economic and national security.

Large-scale Public-Private Partnerships: The Manufacturing USA Network

Manufacturing USA exists to secure U.S. global leadership in advanced manufacturing. The nine federal agencies involved with Manufacturing USA establish and deploy a whole-of-government approach to innovation, one that springboards U.S.-based inventions to the forefront of advanced manufacturing technologies, created and utilized by a skilled American workforce.

MISSION: Connecting people, ideas, and technology to

- solve industry-relevant advanced manufacturing challenges
- enhance industrial competitiveness and economic growth
- strengthen our national security

VISION: U.S. global leadership in advanced manufacturing

¹ *Facts About Manufacturing*, National Association of Manufacturers, U.S. Bureau of Economic Analysis, International Monetary Fund.

² *Facts About Manufacturing*, National Association of Manufacturers.

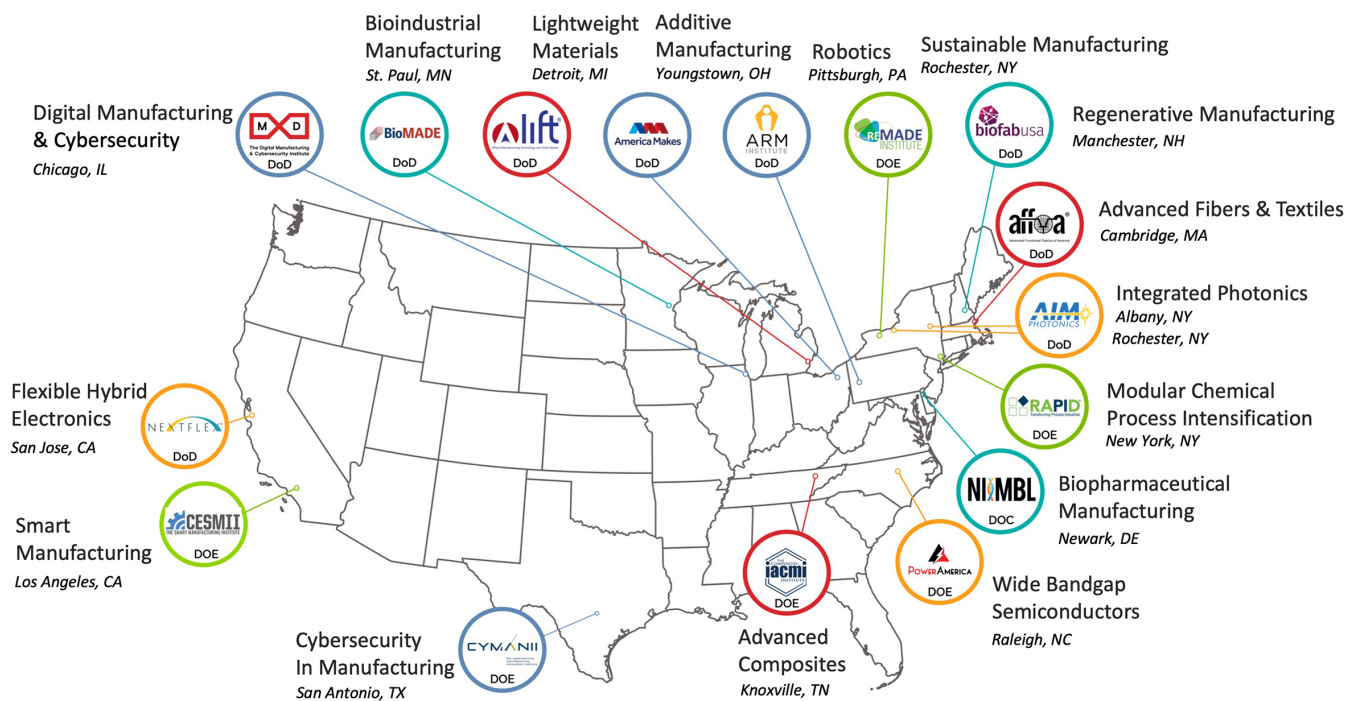
³ *Facts About Manufacturing*, National Association of Manufacturers, U.S. Bureau of Labor Statistics, U.S. Bureau of Economic Analysis.

Ensuring American Inventions are Made in America

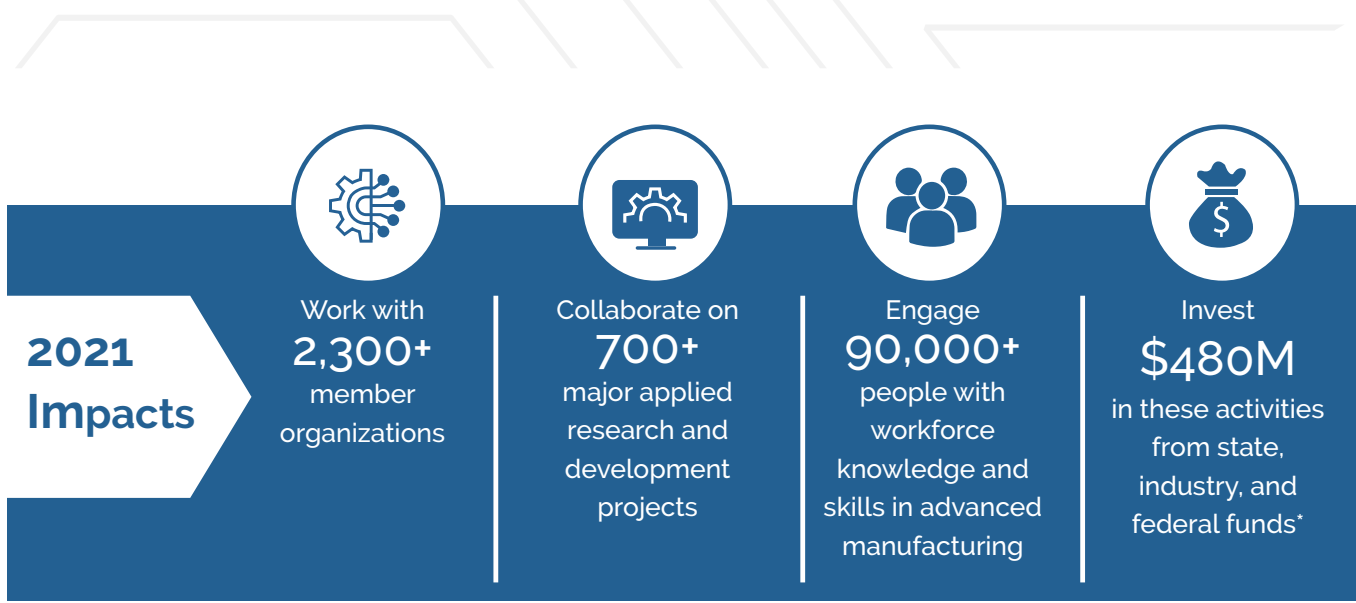
The members of each institute collaboratively engage in the pre-competitive development of technologies within their specific field of focus. They test applications for the technology, share capital-intensive infrastructure, and create training programs to develop a workforce with the skills needed for today's manufacturing—and that of tomorrow.

From AIM Photonics' chip fabrication facility in Albany, NY to flexible hybrid electronics workforce development programs at NextFlex in San Jose, CA, and MxD's role in a national project to advance racial equity in manufacturing, the institutes continue to demonstrate the value of Manufacturing USA.

In the pages that follow, samples of each institute's projects and initiatives illustrate their work in building successful and productive innovation ecosystems that are delivering industry-changing results from collaboration.



Map of Manufacturing USA institutes. Credit: NIST



Improving Our Way of Life
 Innovating products that assist workers, make buildings safer, consume less energy, and save lives. Today's research will improve tomorrow's reality.

Strengthening Our Economy
 Leading research and development on critical manufacturing technologies to strengthen U.S. global competitiveness, ensuring our country will reap the rewards of American innovation at scale.

Ensuring Our National Security
 Supporting a strong advanced manufacturing sector, critical for our cyber, economic, energy, food, and health security. The network's emphasis on domestic manufacturing and technology will secure American prosperity.

Empowering the Current and Next Generation
 Partnering with educational organizations to teach advanced manufacturing technologies via workshops, courses, internships, and apprenticeships. With this investment in skills, we will create the workforce of the future.

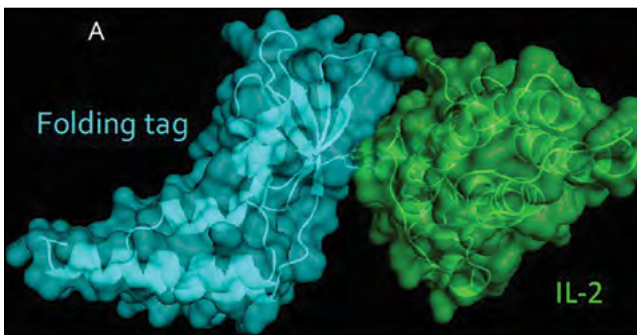
**The institutes attracted \$354M in funds from state, federal/pandemic, and private funds in addition to \$127M in base federal funding.*

DEVELOPING ADVANCED MANUFACTURING TECHNOLOGIES

The institutes and their member organizations collaborate on pre-competitive applied research and development projects (R+D) in their respective area of advanced manufacturing technology. These projects lead to innovations in products and processes that have broad application potential throughout the industry. Collectively, this work helps propel leadership by the U.S. manufacturing industry in the global race to develop new advanced manufacturing technologies. **Examples of the 708 ongoing R+D technology advancement projects include:**

90% Cost Reduction in Growing Cells for Biopharmaceuticals

NIIMBL, Commerce-Sponsored Institute



Cytokines. Credit: NIIMBL

Potomac Affinity Proteins teamed with the University of Maryland College Park to reliably scale the manufacturing of cytokines, a critical growth component in cell cultures. Using its *Escherichia coli* expression system, the team was able to produce and validate cytokines at a 90% cost reduction (from a range of \$1,000 to \$50,000 per milligram to just \$100 per milligram). The process allows for greater scale-up potential at a reduced cost, while expanding flexibility for the industry to adopt the novel purification process for other critical cytokines or proteins to improve cell therapies involved in immune responses.

Sustainable Infrastructure Solutions with Composite Bridges

IACMI, Energy-Sponsored Institute



Fiber-Reinforced Polymer Vehicle Deck Bridge. Credit: IACMI

IACMI and academic and manufacturing collaborators built the first fiber-reinforced polymer vehicle deck bridge in Tennessee. It decreases installation time and reduces energy costs during construction. Engineered for high strength, the composite bridge deck has a 100-year lifespan and is 90% lighter than concrete. The deck is also embedded with smart sensors to monitor its health and performance.

Next-Generation Health Status Monitoring

AFFOA, Defense-Sponsored Institute

AFFOA, in collaboration with the Defense Fabric Discovery Center at MIT Lincoln Laboratories, successfully developed and tested a headband that can detect hypoxia (insufficient oxygen at the tissue level), enabling a response prior to impairment,

battlefield conditions, or future treatment for individuals with fluctuating blood oxygen levels (asthma, for example). The fabric contains embedded microelectronic components that measure and wirelessly transmit key physiological conditions, including temperature, heartrate, and blood-oxygen levels for 40 hours continuously.



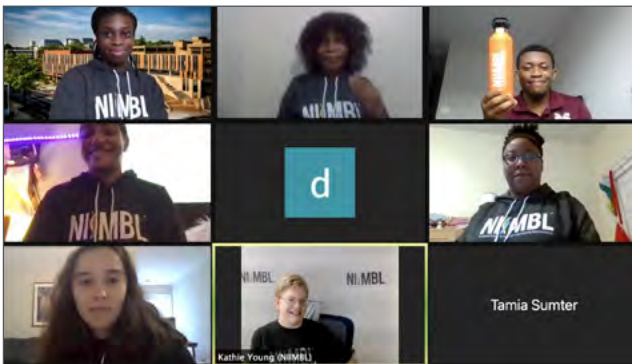
PSM headband developed by AFFOA and the Defense Fabric Discovery Center at MIT Lincoln Lab. Credit: AFFOA

EMPOWERING THE ADVANCED MANUFACTURING WORKFORCE

Institutes and their members and workforce development partners are targeting diverse and underserved populations to bring opportunities to all Americans interested in manufacturing careers. While also developing curricula and certificate pathways in specific technology fields in response to and in collaboration with industry needs. **In FY 2021, more than 90,000 workers (including veterans and those impacted by the pandemic), students, and educators participated in institute workforce programs – either virtually or through a hybrid approach.** A few examples include:

Inspiring Diversity and Interest in Biopharmaceutical Manufacturing

NIIMBL, Commerce-Sponsored Institute



NIIMBL eXperience virtual meeting. Credit: NIIMBL

In June 2021, a group of select college freshmen and sophomores from across the country participated in the NIIMBL eXperience program and received a jumpstart on careers in the biopharmaceutical industry. The program gives African American/Black, Latinx, and Native American students a chance to explore biopharmaceutical careers through direct interactions with industry professionals. The 2021 eXperience included the most expansive and diverse group of host institutions yet, from large biopharma manufacturers and small innovative companies to leading academic and non-profit institutions. Since the program's inception in 2019, students have secured internships at leading companies such as Merck & Co., Genentech, Millipore Sigma, and Eli Lilly.

Collaborating to Inspire High Schoolers

NextFlex + America Makes, Defense-Sponsored Institutes



Students testing circuits in the NextFlex Technology Hub. Credit: NextFlex

America Makes launched the Additive Edge project in collaboration with another institute, NextFlex, to introduce youth to advanced manufacturing and provide students with valuable work experience. This national outreach program inspires high school students in the U.S. to explore additive manufacturing (i.e., 3D printing) and entrepreneurship and will distribute 3D printers to secondary schools that successfully recruit female students into additive manufacturing courses.

Increasing Smart Manufacturing Adoption Aptitude

CESMII, Energy-Sponsored Institute

CESMII and the Society for Manufacturing Engineering (SME) announced a partnership to advance education and workforce development toward smart manufacturing. SME's training organization, Tooling U-SME, the industry's leading learning and development solutions provider, works with more than half of all Fortune 500 manufacturers as well as 800 educational institutions across the country. CESMII has in-depth training content on smart manufacturing technology, business practices, and workforce development that increases access for underrepresented groups. Leveraging Tooling U-SME's extensive reach into industry and academia, the combined CESMII and Tooling U-SME training portfolios will expedite smart manufacturing adoption and drive transformational and diverse workforce development.



Smart Manufacturing Lab. Credit: CESMII

BUILDING INNOVATION ECOSYSTEMS

Innovation in American manufacturing today is reliant on strong and robust manufacturing supply chains and the collaboration of a wide array of entities within and related to them. Academia, manufacturing companies large and small, member organizations, training and educational organizations, and many others must work together to advance and strengthen U.S. manufacturing. These innovation ecosystems are making great advances to strengthen our supply chain and ensure our nation's discoveries become products here in the U.S.

This whole-of-America approach is catalyzed and led by the Manufacturing USA institutes. Institutes' public-private partnerships include all the components of the U.S. industrial base. Last year, the institutes collectively had 2,320 members. Sixty-three percent are manufacturers, nearly two-thirds of which are small and medium-sized companies. Other members include community colleges, major research universities (representing 22% of members), and state and local economic development entities (15% of members).

Institutes and their members:

- develop and accelerate advanced manufacturing technologies
- share facilities, expertise, state-of-the-art equipment, and funding
- collaborate on applied R&D and workforce projects deemed most valuable by stakeholders.

The work they do lays the foundation for new products, processes, and workforce skills.



Credit: NIST

Developing Sustainable Biopharmaceutical Manufacturing for the Future

NIIMBL, Commerce-Sponsored Institute



Staff working in the NIIMBL lab. Credit: NIIMBL

NIIMBL's ambitious 10-year process intensification program intends to transform biopharmaceutical manufacturing. Across 15 major companies and through six distinct workstreams, thought leaders are collaborating on an integrated approach to add flexibility, improve control and security of the supply chain, foster sustainability, and reduce costs. The program establishes carbon-neutral bioprocessing with the combination of technological innovation, new materials, recycling, and new practices. These elements will address critical barriers to designing rapid, sustainable, and cost-effective biomanufacturing.

Evolving the Factory Floor

MxD, Defense-Sponsored Institute



Demonstrating HoloLens on MxD factory floor. Credit: NIST/MxD

Siemens and Dow are leveraging MxD's process industry testbed to showcase the future of automation. This new testbed offers a hands-on demonstration of how innovative software and the Internet of Things (IoT) come together with hardware to accelerate digitalization for process industries.

Companies can see firsthand how to design, monitor, and maintain products more effectively, securely, and even remotely, using data and digital tools to collaborate in real-time.

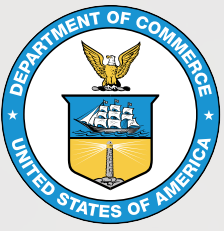
Modeling for Sustainable U.S. Fiber Recycling

REMADE, Energy-Sponsored Institute



Paper bale. Credit: Shutterstock

A REMADE project team developed a technology systems model to increase domestic fiber recycling and establish a profitable domestic recycling ecosystem. The team identified new process pathways for the U.S. fiber recycling industry to expand domestic capacity, improve profitability, and increase environmental benefits. The Paper Recycling Integrated System Model (PRISM) allows fiber recyclers and Institute of Scrap Recycling Industries members to modify process parameters, technologies, and operating practices at material recovery facilities and reprocessing mills to identify specific technology and enable additional pathways to achieve energy and emissions goals. To broaden the potential benefits of this project, PRISM was built around a user-friendly public interface that fiber recycling users can access through a web-based platform. Initial beta tests identified pathways to reduce process energy use (by 37% to 83%) and greenhouse gas emissions (by 15% to 60%).



DEPARTMENT OF COMMERCE INSTITUTE HIGHLIGHTS







The National Institute for Innovation in Manufacturing Biopharmaceuticals

Established: March 2017

Headquarters: Newark, DE

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

Consortium Organizer: University of Delaware

Members: 186

Funding: \$70M Federal
\$129M Non-Federal (planned from 2017 - 2022)

www.niimbl.force.com

OVERVIEW

NIIMBL enhances patient access to medicines by accelerating biopharmaceutical manufacturing innovation, workforce training, and supporting standards development. Biopharmaceuticals are medicines made from biological sources, including therapeutic proteins, vaccines, and cell and gene therapies. These medicines improve and save lives by treating debilitating conditions including cancer, diabetes, autoimmune disorders, and bacterial and viral infections. The institute's work supports the needs of the industry by creating a qualified workforce, and it supports the needs of the nation by ensuring leadership in biopharmaceutical manufacturing innovation, leading to economic prosperity and our public health security.

TECHNOLOGY ADVANCEMENT

“Before the NIIMBL project, our business model had been to license technology. Now, we may become a manufacturer. Being involved with people who live, eat, and breathe manufacturing has been transformative for us.”

– Phil Bryan, Potomac Affinity Proteins

Reducing Costs for Critical Cell Growth Components:

Potomac Affinity Proteins teamed with the University of Maryland College Park to develop a process that increased the production of cytokines nearly 2,000% beyond initial estimates and at a 90% cost reduction compared to traditional methods. Cytokines are proteins used in cell culture to support cell growth, survival, and differentiation. While they are a vital component of cell therapy manufacturing, they are also the most expensive, ranging from \$1K to \$50K for a single milligram. The team used Potomac Affinity Proteins' *E. coli* expression system to create a platform process for production and purification that integrates molecular machinery into traditional manufacturing technologies. The results exceeded expectations, dramatically cutting costs to less than \$100 per mg. This method can be scaled-up to manufacture significantly higher quantities at only dollars per mg, providing significant manufacturing cost savings.



Improving Lentiviral Vector Products. Credit: NIIMBL

Improving Biomanufacturing for Cell and Gene Therapy Applications:

The University of Massachusetts Medical School, Johns Hopkins University, Rensselaer Polytechnic Institute, and their collaborators developed an integrated and optimized process to reduce the cost and complexity of manufacturing lentiviral vector (LV) products such as cell and gene therapies, while simultaneously aiding in the national response to COVID-19. This project de-risked technology development and provided the industry with a blueprint for enhanced LV operations upstream and downstream. Through the project, Johns Hopkins University played a vital role in COVID-19 response by using the same biomanufacturing platform established for lentiviral vectors to pivot to producing SARS-CoV-2 spike proteins within two weeks. The ability to make crucial proteins in-house saved significant time and assured the availability of quality materials. Additional project participants included: Massachusetts Life Sciences Center, Artemis Biosystems, Inc., and Repligen Corporation.

Improving Trace Metal Measurement for Better Process Control:

Clemson University and partners advanced trace metal testing in cell culture to improve process control. The level of trace metals (zinc, copper, manganese, and selenium) found in cell cultures may impact the health, growth rate, and productivity of cells used to manufacture therapeutic products. First, the team demonstrated precise analysis transfer between the FDA and University of Massachusetts Lowell. Then, the team designed and tested a small-scale mass spectrometer for more rapid trace metal quantification. The compact mass spectrometer reduced measurement time from approximately four hours per sample to only 10 minutes, a 96%-time savings. The approach and time-savings will allow manufacturers to measure trace metals more frequently for better process control. Additional project partners included Massachusetts Life Sciences Center and Merck & Co., Inc.

Developing a New Test for Safe, High-throughput COVID-19 Antibody Testing:

MassBiologics of the University of Massachusetts Medical School and the Wadsworth Center developed a flexible, high-throughput Polyvalent Microbead Immunoassay (MIA) for SARS-CoV-2 antibody-based diagnostics. During the onset of the COVID-19 pandemic, healthcare workers used live virus assays to measure antibodies, increasing exposure risk. With its high correlation to live virus tests, the MIA assay serves as a safe high-throughput surrogate. It has the capacity to screen nearly 100 samples within four hours, compared to days with live virus assays. The MIA provides an efficient method of antibody testing to screen quarantined workers before returning to work, identify recuperating patients for potential antibody therapy research, and serve as a benchmark to test vaccine efficacy.

WORKFORCE DEVELOPMENT

NIIMBL builds a national capacity of skilled talent to meet the acquisition, training, and workforce development needs of the biopharmaceutical manufacturing ecosystem. Through industry and academic collaboration, NIIMBL has established a diverse portfolio of projects and programs aimed at building a world-leading biopharmaceutical workforce to meet rapidly growing industry needs.

"This project was a fantastic experience. It was rewarding working with industry partners who were so engaged in what we were trying to do."

– Guy Hamilton, Shoreline Community College

Establishing Academic Pathways for Biopharmaceutical Careers: Shoreline Community College, in collaboration with Juno Therapeutics (now Bristol-Myers Squibb) and Life Sciences Washington, developed a series of courses that address skills gaps identified by the industry. The new courses focused on aseptic technique, cleanroom dynamics and introduction to bioreactors, quality systems, and regulatory affairs. Shoreline began to offer the courses in Fall 2021. All four modules can be completed in 10 weeks. The program provides a pathway for students to receive necessary training for entry-level jobs, as well as re-training for career changers or those seeking employment.



Credit: NIIMBL

Expanding Diversity in the Biopharmaceutical Industry: In June 2021, 14 college freshmen and sophomores from across the U.S. participated in the NIIMBL eXperience program and received a jumpstart on careers in the biopharmaceutical industry. The program gives African American/Black, Latinx, and Native American students the opportunity to explore biopharmaceutical careers through direct interactions with industry professionals. The 2021 eXperience included the most expansive and diverse group of host institutions yet, including large biopharma manufacturers, small innovative companies, and leading academic and non-profit institutions. Since the program's inception in 2019, students have secured internships at leading companies such as Merck & Co., Genentech, Millipore Sigma, and Eli Lilly.

Preparing Service Members for Careers in the Biopharmaceutical Industry: Led by Texas A&M University, the Military Service Members in Biopharmaceutical Manufacturing program prepared 41 veterans, transitioning service members, and military spouses for careers in biopharmaceutical manufacturing through targeted technical training. The team worked with Merck & Co., Inc. and Pfizer to harmonize and align current training programs at Texas A&M, Durham Technical Community College, and Central Carolina Community College. Through coordinated messaging and marketing materials, the team leveraged the North Carolina Biotechnology Center's Veterans Outreach Program to drive industry awareness and build relationships with North Carolina and Texas military communities. Additional project participants included the North Carolina Biotechnology Center.

INNOVATION ECOSYSTEM

"One of the great things about the project was building our network and building the skillset in each of our labs that are really complementary."

– David McNally, University of Massachusetts Medical School

Big Data Analysis for Biomanufacturing:

The analysis and interpretation of data can take biomanufacturing processes to the next level. NIIMBL's newly-launched program will enable biomanufacturers to harness the power of big data analytics to make informed decisions before conducting longer term analysis. Fueled by the collaboration of this community, this highly-integrated, synergistic program focuses on five key areas: standardization and contextualization, end-to-end automated control of critical quality attributes, multivariate sensors and analytics, advanced control strategies, and bioprocess modeling and simulation.

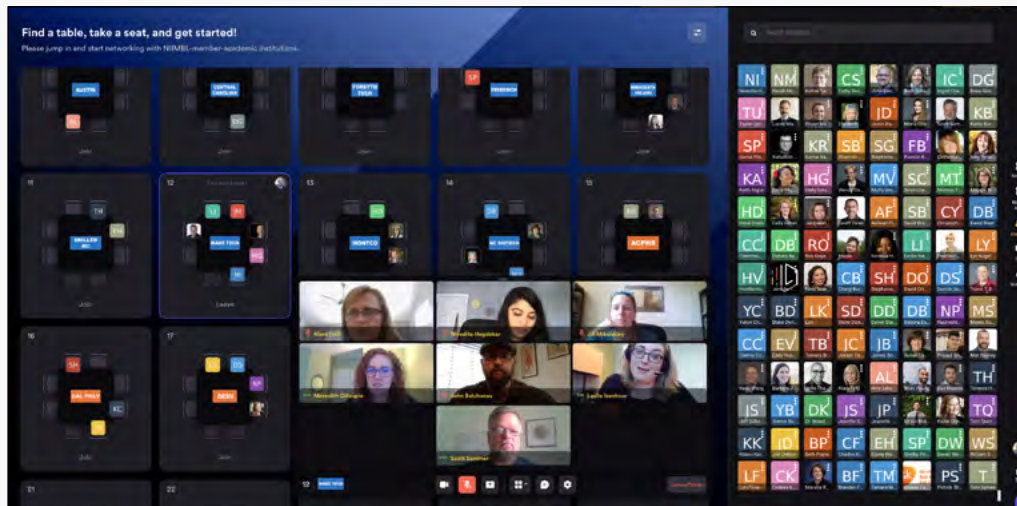
Developing Sustainable Bio-pharmaceutical Manufacturing for the Future:

NIIMBL's process intensification program intends to transform biopharmaceutical manufacturing by 2029. Across 15 major companies and through six distinct workstreams, thought leaders within the NIIMBL community are collaborating on an integrated approach to create flexibility, improve control and security of the supply chain, foster sustainability, and reduce costs.

Goals addressing sustainability include establishing carbon-neutral bioprocessing by combining new innovations of technologies, new materials, and recycling, with new practices to address challenges in carbon-neutral manufacturing, sustainability design, and circular economies for raw materials, and consumables.

SUCCESS STORY

Connecting the Right People at the Right Time



NIIMBL Virtual Education and Resource Fair. Credit: NIIMBL

One of NIIMBL's core goals is to forge connections between key industry leaders, whose paths otherwise may not cross, to solve common challenges. As hiring demands continue to grow in the biopharmaceutical industry, NIIMBL members seek to broaden early talent recruitment from more schools. Currently, however, they face a lack of time, bandwidth, and connections to do so efficiently.

At a time when COVID-19 had drastically impacted the ability to network face-to-face, NIIMBL hosted in April 2021 a Virtual Education and Resource Fair. Attended by more than 230 members, the event connected companies with key contacts at academic institutions to broaden, and in some cases secure, job opportunities for more students across the country.

Twenty-eight participating academic institutions hosted virtual tables. Employers from 28 industry companies moved from table to table to learn about each institution and establish an immediate contact with an academic resource lead.

"By networking with academic institutions, I was able to build new relations and find out about resources I did not know existed to help draw in more talent to our company."

– Industry member

"We met people from a range of companies and are excited to follow up with them. I do not know how we would have connected with them so easily otherwise."

– Academic member



DEPARTMENT OF DEFENSE INSTITUTE HIGHLIGHTS







America Makes

The National Additive Manufacturing Innovation Institute

Established: August 2012

Headquarters: Youngstown, OH

Mission: Accelerate the adoption of additive manufacturing (AM) by convening, coordinating, and catalyzing the AM industry to help advance U.S. manufacturing competitiveness and security.

Satellite Locations: The W.M. Keck Center for 3D Innovation at The University of Texas at El Paso (El Paso, TX); Texas A&M Engineering Experiment Station at Texas A&M University (College Station, TX) National Institute for Aviation Research at Wichita State University (Wichita, KS)

Consortium Organizer: National Center for Defense Manufacturing & Machining (NCDMM)

Members: 240

Funding: \$83M Base Federal Funding
\$153.3 M Base Non-Federal Cost Share

www.americamakes.us

OVERVIEW

America Makes is the nation's leading public-private partnership for additive manufacturing (AM) technology and education. America Makes members from industry, academia, government, workforce, and economic development organizations work together to accelerate AM adoption and the nation's global manufacturing competitiveness, focused on three areas: developing AM technology, developing an AM workforce, and maintaining a collaborative AM ecosystem.

TECHNOLOGY ADVANCEMENT

America Makes convenes technical expertise to build teams with capabilities beyond those of any single organization to address the specific needs of the Department of Defense. By fostering this collaborative mindset, America Makes accelerates the development and deployment of additive manufacturing solutions to enhance military readiness, strengthen alliances, and improve business performance and overall manufacturing affordability.

"America Makes provides the AM industry with the people, data, and supply chain so that we can use new technologies faster."

– Michael Hayes, Technical Lead Engineer, Boeing

Leveraging Artificial Intelligence/Machine Learning for Directed-Energy Deposition 3D Printing: America Makes, working with General Electric Aviation, Edison Welding Institute (EWI), Raytheon, and Youngstown State University, developed and successfully demonstrated the accuracy of a qualification framework for Ti64 Directed-Energy Deposition 3D printing build. This framework is based on probabilistic artificial intelligence/machine learning (AI/ML). The approach offers the potential for 60% to 85% savings in fabrication and characterization costs compared to traditional qualification approaches.

Maturation of Advanced Manufacturing for Low-Cost Sustainment:

America Makes officially completed the US Air Force-sponsored Maturation of Advanced Manufacturing for Low-Cost Sustainment (MAMLS) project in November 2020. A collaborative effort among 40 organizations on 45 projects with \$27M in funding impacting more than a dozen platforms, MAMLS provided America Makes members with a variety of best practices, new manufacturing processes, implementation options, business case examples, and knowledge on additive manufacturing. The objective of the project was to explore the relationships between powder bed fusion additive manufacturing processes, the generation of stochastic flaws, and the subsequent impact such flaws have on fatigue properties through process monitoring with high-speed video.

Preparing the Nation for Future Crises:

America Makes' Additive Manufacturing Crisis Production Response (AMCPR) program's mission is to advance U.S. manufacturing supply chain resiliency and responsiveness, while simultaneously preparing the nation for future and unknown crises. AMCPR conducted and completed scenario planning workshops, testing the system in a variety of national crisis scenarios. The seven scenarios workshopped to date are: shortage of three dimensional (3D) printed medical swabs; development of a polymer facemask through a collaboration of designers, reviewers and suppliers; response and repair of a water main break; 3D production of a fuel elbow component for a downed Blackhawk helicopter; rapid response to a power shutdown by providing a critical piece to repair a gas turbine; sand molding for a t-joint to reduce manufacturing time; and response to limited syringe availability in rural areas where supply chains are limited.

WORKFORCE DEVELOPMENT

The America Makes portfolio contains numerous education and workforce development programs, from outreach in communities to K-12 engagement, post-secondary courses, and warfighter training. It also includes many DoD and veteran training programs, assistance in building multiple apprenticeship frameworks, and validation of a variety of industry-recognized credentials. America Makes is dedicated to building career pathways in additive manufacturing and community engagement through a variety of stakeholders. The institute executes projects, builds scale and scope, sets strategy, identifies, and creates programs to meet new requirements, and establishes best practices through an advisory committee.

“These programs are awesome and exactly what schools need right now.”

– Robert Eggleston, Career Coach, East Ohio Educational Service Center

Collaborating to Inspire High Schoolers: In FY 2021, America Makes launched the Additive Edge program in collaboration with NextFlex to introduce high schoolers to additive manufacturing and entrepreneurship. The program will distribute 3D printers to secondary schools that successfully recruit female students into AM courses while providing valuable resume-building experience to each participant.

Developing New Additive Manufacturing Training Curriculum:

America Makes successfully launched a Manufacturing Engineering Education Program after three years of development and a \$1.9M investment. The project focused on creating new training content in advanced manufacturing specific to enabling technologies, included a credential landscape audit, and an educational landscape assessment across several regions. The program was developed after assessing the needs of underserved and veteran populations through national and regional workshops with workforce, community, and economic organizations. In addition, the credential audit examined over 68 national industry-recognized credentials and 2,000 competencies to align, map, and identify gaps across the industry. The resulting education program features 33 new blended eLearning courses and two new instructor-led trainings. This new eLearning content has already impacted more than 8,000 learners in academia and in nearly 500 companies.

Supporting Americans Toward Careers in Advanced Manufacturing:

America Makes member-companies in Chicago, led by 3Degrees, leveraged educational and training assets from America Makes to recruit, reskill, and/or upskill individuals in underserved communities with limited experience in technical fields or higher education. 3Degrees and America Makes partnered with the West Side Forward Organization to deploy institute-created educational tools in a boot-camp style curriculum. America Makes member companies (including EOS, Impossible Objects, Renishaw, and others) hosted student visits and pledged to hire participants for full-time or part-time roles upon completion of the four-week program. Participants were qualified to receive America Makes-vetted industry-recognized credentials. The first pilot cohort successfully completed training in September 2021.

Advancing Education and Workforce Development during COVID-19: Funding from NIST and the Coronavirus Aid, Relief, and Economic Security (CARES) Act enabled America Makes to establish a wide range of eLearning assets when in-person training was not an option. The institute provided eLearning training across two dozen in-demand focus areas in 48 states, impacting nearly 1,000 individuals from 100 companies, and reskilling and upskilling 200 independent participants for manufacturing. The project also produced new credentials in AM and 11 new middle school micro-learning modules to introduce students to 3D printing and future career opportunities.

INNOVATION ECOSYSTEM

America Makes is a critical part of the manufacturing ecosystem in Youngstown, Ohio, and through that to a larger national network that provide members access to additive manufacturing capabilities and expertise. America Makes further expands that network through three satellite centers at the University of Texas El Paso, Texas A&M Engineering Experiment Station at Texas A&M University, and the National Institute for Aviation Research at Wichita State University. Each satellite center mirrors and enhances the efforts of America Makes to foster a collaborative infrastructure for the open exchange of additive manufacturing information and research, engaging with local companies and educational institutions to supply education and training in additive manufacturing technologies, and focusing on the transition of additive technology from the research lab to commercialization.

“We would never be able to work with major OEMs or receive follow-up funding without the connections we gained through America Makes.”

– **Stephanie Gaffney, Director of Additive Manufacturing Programs, Youngstown Business Incubator**

Organizing the Advanced Manufacturing Olympics: America Makes facilitated the first-ever U.S. Air Force (USAF) Advanced Manufacturing Olympics Innovation Challenge for the Air Force Rapid Sustainment Office, Air Force Research Laboratory, University of Dayton Research Institute, and Wright Brothers Institute. The success of the event left a lasting footprint for the USAF and the future of AM technology advancement and education and workforce integration, as the USAF explores and integrates new organizations into the DoD supply chain.



America Makes was contracted to execute coordinating activities, event promotion, and challenge events for the USAF Advanced Manufacturing Olympics Innovation Challenge. Credit: America Makes

Renovating for Improved Innovation and Collaboration: In FY 2021, America Makes created a state-of-the-art collaboration facility in its Youngstown, Ohio center. This offers stakeholders the opportunity to innovate, collaborate, and convene around AM technology. Additional space serves as an awareness showcase, providing information about current AM capabilities, the institute's work with DoD, and other institute successes.

Promoting Cybersecurity in AM: America Makes, in collaboration with the American Society for Testing Materials and Auburn University, launched three cybersecurity for AM virtual training courses. These courses examine the risks, needs, and solutions to cybersecurity needs in AM. Key topics include security threats, malicious actors, realistic attacks, defensive responses, and current limitations of these approaches. A corresponding training for executives, “AM Security Overview,” orients decision makers to the challenges of strategically securing AM against a broad variety of threats. A third version of the training for subject matter experts (SMEs), “AM Security Inside-Out,” is oriented to both SMEs in AM who are not familiar with security and to SMEs in cyber security who are not familiar with AM.



Manufacturing Times Digital

Established: February 2014

Headquarters: Chicago, IL

Mission: Provide the government and U.S. manufacturers with the digital tools needed to transform American manufacturing.

Consortium Organizer: MxD

Members: 314

Funding: \$91.5M Base Federal Funding
\$138.1M Base Non-Federal Cost Share

www.mxdusa.org

OVERVIEW

MxD is where innovative manufacturers forge their futures. In partnership with the Department of Defense, MxD provides manufacturers with digital tools and expertise to begin building every part better than the last. Institute members increase their productivity and win more business, powered by a workforce with the digital skills they need for a cybersecure industrial base. MxD also works with DoD manufacturers and contractors to assess and implement digital improvements throughout the industrial base.

TECHNOLOGY ADVANCEMENT

Ensuring the military has the most effective resources is a central driver of MxD's work. MxD partners with manufacturers to harness the power of the digital thread to and drive forward advanced manufacturing technologies, while equipping the workforce (present and future) and the supply chain with the skills and cyber resiliency needed to ensure an innovative, secure, and prepared defense industrial base.

"MxD continues to demonstrate the value of its partner ecosystem and ability to quickly mobilize to provide innovative solutions to the U.S. Government and manufacturing sector. We are proud to have been selected by MxD and the DoD for such a critical project and look forward to our continued partnership with MxD in developing this important capability."

**– Tod Weber, Chief Executive Officer,
Software AG Government Solutions**

Strategizing Future Investment Plans: MxD created a multi-year strategic investment plan outlining the institute's research, development, and demonstration efforts for digital manufacturing, supply chain, cybersecurity, and workforce development. Technical advisors from the Defense Logistics Agency, Office of Naval Research, Air Force Research Lab, and several Department of Energy labs contributed to the effort. MxD drafted the plan to advance domestic manufacturing towards the vision of Industry 4.0 based on information gathered from participants on MxD's Technical Advisory Committee and Executive Council, surveys to members, discussions during webinars and workshops, and subject matter experts.

Advancing Open Automation Testbeds: MxD collaborated with Applied Dynamics International (ADI), Dow, and the University of Michigan to create an open automation testbed designed to provide low-cost plug-and-play connectivity of equipment and software from different vendors. The developed Integration Test Environment testbed located on MxD's factory floor combines off-the-shelf industrial computing components with ADI's ADEPT IoT software platform to provide connectivity across legacy and future interfaces. This enables various applications to have access to real-time data and computing and is enhanced by single-board computers that can emulate new devices or technology in the system. Manufacturers can benefit from low-cost experimentation to develop, test, and evaluate new technologies without interrupting production operations and costly R&D investments. MxD members as well as Defense Logistics Agency supply chain manufacturers are encouraged to use the testbed to explore options for integrating and improving their process and as a model for real-time industrial connectivity. ADI and Dow are now exploring a follow-on project to connect the testbed to another process manufacturing testbed for expanded research.



Tour participants watch a demonstration of the Process Manufacturing test area on MxD's Factory Floor.
Credit: MxD

Automating Supply Chain Alerting: The COVID-19 pandemic exposed fragile aspects of supply chains that can cause widespread disruptions, driving a need to secure U.S. manufacturing supply chains by improving the current structure and increasing resiliency. In response, MxD partnered with Software AG Government Solutions in April 2021 to develop Supply Chain Risk Alerting to the DoD. Seeking new ways to minimize manufacturing production impacts during a crisis, Software AG will provide a rapid hybrid integration solution to deliver a supply chain risk alert framework to policy leaders and supply chain leaders so they can efficiently assess a wide range of value chain designs and optimize supply chain resiliency and agility during an emergency.

WORKFORCE DEVELOPMENT

MxD's workforce development program, MxD Learn, fosters collaboration across industry, academia, government, and non-profit leadership to ensure the current and future workforce is fully skilled for the roles and competencies needed for digital and cybersecurity manufacturing applications.

"Cybersecurity and manufacturing technology are critical to U.S. manufacturing capabilities. The training helps to solidify concepts that I can use in my role as well as in sharing the information with colleagues to create greater awareness of cybersecurity concepts and best practices."

– Cybersecurity Governance, Risk and Compliance Specialist, Boeing

Advancing Manufacturing Cybersecurity Career Pathways: MxD published the *Manufacturing Cybersecurity Systems Operator Success Profile and Career Pathways*, as an update to its *Hiring Guide: Cybersecurity in Manufacturing*. These resources describe new-to-work or transitional roles useful to inform industry job descriptions, workforce training curricula, and apprenticeships. With funding from the Siemens Foundation, MxD Learn partnered with ManpowerGroup and contributors across industry, government, and academia to complete the additional Success Profiles and Career Pathways. The cyber systems analyst role highlights the growing impact of artificial intelligence in manufacturing cybersecurity and workforce development.



Students from the National Defense University tour the MxD Factory Floor to learn more about MxD cyber programs. Credit: MxD

Launching Manufacturing Cybersecurity Curriculum: In partnership with the University of Maryland Baltimore County, MxD piloted a new platform and training curriculum focused on Cybersecurity for Manufacturing Operating Technology (CyMOT). The initial pilot included 25 participants from 10 partner manufacturers. The first course – Cybersecurity Fundamentals for Manufacturing – is one of three courses that the pilot cohort must complete to earn certification as manufacturing cybersecurity systems operators. MxD drew course content and aligned competencies and outcomes from MxD's *Hiring Guide*, which includes a full success profile for the manufacturing cyber systems operator role.

Advancing an Inclusive Future for Manufacturing: MxD Learn was a strategic partner of the Industry and Inclusion Cohort, a national project led by The Century Foundation, Lumina Foundation, Urban Manufacturing Alliance, and seven other urban workforce development organizations. The collaborative effort strategized solutions to the U.S. manufacturing national recruitment challenges, through deepening relationships between employers and communities and developing credential-based training programs to forge a more inclusive future for manufacturing. Two final reports were released from the project: "Manufacturing Workforce Strategies: Building an Inclusive Future" and the "Industry and Inclusion Blueprint for Action."

INNOVATION ECOSYSTEM

Through its robust network of industry, academic, and government partners, MxD supports U.S. manufacturing with workshops, federally funded project opportunities, workforce development tools, and a 22,000 square-foot future factory floor innovation center to advance the digital transformation of U.S. manufacturers, accelerate innovation, and ensure manufacturers produce "every part better than the last."

"Providing hands-on experience is critical for digital transformation in the process industries, showing how digital twins and the connected mobile worker can enable greater productivity, reliability and safety."

– Billy Bardin, Global Digitalization Director, Dow

Collaborating to Support Small and Mid-Size

Manufacturers: MxD launched a partnership with the Philadelphia-regional Manufacturing Extension Partnership Center, Delaware Valley Industrial Resource Center (DVIRC), to provide resources to small and mid-sized manufacturers in Philadelphia. As the recipient of a DoD Office of Economic Adjustment grant, DVIRC established an Advanced Manufacturing Leadership Council and selected MxD's vice president of strategy and engagement to sit on the Council. MxD will advise DVIRC on technology innovation and implementation that will help small and mid-sized manufacturers become more competitive.

Serving as National Leaders:

MxD's Chief Executive Officer participated in the latest Reagan Task Force discussion on investing public and private capital in support of U.S. manufacturing and to advance national security objectives. The Task Force is developing recommendations of critical sources of public and private capital needed in this arena; attracting and allocating long-term investment in American manufacturing; and bridging the gap between interests and risk tolerances of private capital and the needs of a resilient industrial base.

Recognized for Outstanding Manufacturing

Leadership: The Manufacturing Leadership Council presented four awards to MxD initiatives during their annual Awards Gala in May 2021. The awards recognized the outstanding accomplishments of three projects: the MxD Cyber Platform (recognized for Industrial Internet of Things Leadership); the MxD Cyber Box (recognized for Enterprise Integration Technology Leadership); and the MxD Hiring Guide (for Talent Management Leadership). The Cyber Box is a portable demo that can be taken on the road to bring awareness to institutions, manufacturers, and solution providers regarding the benefits of implementing cybersecurity practices at their organizations. Its use cases focus on identifying and protecting from cyber threats. Katia Valenzuela, an associate at MxD, was also awarded for Next-Generation Leadership, the second year in a row that MxD associates have been nationally recognized as emerging manufacturing leaders. MxD's achievements were recognized alongside those of major U.S. manufacturing entities, including Dow, Johnson & Johnson, and Lockheed Martin, elevating the work of the DoD institutes into a globally-recognized community and active peer group.

SUCCESS STORY

Evolving the Factory Floor



*Visitors learn more about the Siemens and Dow process manufacturing testbed on the MxD Factory Floor.
Credit: MxD*

Siemens and Dow are leveraging MxD's process industry testbed to showcase the future of automation. This new testbed offers a hands-on demonstration of how innovative software and IoT come together with hardware to accelerate digitalization for the process industries. Companies can now see firsthand how to design, monitor, and maintain products more effectively, efficiently and, even remotely, using data and digital tools. This system provides operators simple and secure access, making remote operation easier. Maintenance teams benefit from device-independent access, with actionable diagnostic and maintenance information accessible from their tablets, laptops, or multi-monitor stations. For engineering, efficient web-based collaboration opens new possibilities by working in parallel.

Hardware planning, control logic, or operator displays can be engineered in any workflow with flexibility that not only adapts to the availability of staff, but to the location as well. Siemens' smart field instrumentation oversees the operation of the process and provides advanced health, operation, and diagnostic data to ensure reliable and safe operation. The Siemens Xcelerator portfolio of software and services provides the digital fabric that enables the testbed design, simulation, commissioning and process operations, planning, quality, as well as analysis of IoT data. Its Mendix low-code application development platform drives business transformation by leveraging real-time sensor and asset data to provide actionable information. Xcelerator enables workers to gain digital skills as they further innovate the testbed.



Operated by the American Lightweight Materials Manufacturing Innovation Institute (ALMMII)

Established: February 2014

Headquarters: Detroit, MI

Mission: Advancing American manufacturing into the future through technology and talent development and driving rapid implementation of smarter manufacturing by connecting the materials, processes, and systems together with the talent needs of the future.

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

Members: 130

Funding: \$83M Base Federal Funding
\$84.1M Base Non-Federal Cost Share

www.lift.technology

OVERVIEW

LIFT connects materials, processes, systems, and talent needed to drive American manufacturing into the future.

LIFT – Leading Innovations For Tomorrow, the institute's technology program, develops and deploys new advanced materials manufacturing technologies and processes, including light weighting, and multi-material processing in support of our national economy and national defense. The institute's talent program, delivers a new advanced manufacturing curriculum in its immersive Learning Lab environment and to schools across the nation to address the skills gap in the U.S. workforce, providing workers with the skills, knowledge, and abilities required by new innovative technologies.

TECHNOLOGY ADVANCEMENT

LIFT has built an ecosystem of manufacturers and educators collaborating on critical advancements in support of the industrial manufacturing base, our national defense, and the U.S. economy. LIFT's "Fast Forge" technology program brings large industry, small companies, and academic partners together to deliver rapid solutions to manufacturing challenges across industry.

"Working with LIFT and the Army to bring together advanced composites and advanced structural design in a key vehicle subassembly is an important step in advancing vehicle architectures. This pioneering work with LIFT will pave the way for broader adoption of light weighting, and realization of the associated performance, efficiency, and sustainability benefits."

– Ethan Escowitz, CEO, ARRIS Composites

Transitioning Technology to the Warfighter: A LIFT project in collaboration with Ricardo Defense successfully won an \$89M U.S. Army contract to retrofit High Mobility Multipurpose Wheeled Vehicle (HMMWV or 'Humvee') fleets with a combination system which adds antilock braking and electronic stability control to mitigate rollovers commonly associated with specific military vehicles. LIFT funded and managed the initial project, completed in 2017, leading to the successful retrofitting of 10 Michigan National Guard vehicles with the optimized system and making the kit available for purchase by military units worldwide. In FY 2021, Ricardo Defense announced its award for another Army contract to provide up to 9,480 critical safety improvement retrofit kits over the next three years. The initial project team included support from GKN, Michigan Technological University, and the University of Michigan Transportation Research Institute.



Humvee antilock braking and electronic stability control systems retrofit kits are being rolled out across the Army. Credit: LIFT

Re-engineering Critical Parts for Army Technology:

LIFT contracted with the U.S. Army Combat Capabilities Development Command Ground Vehicle Systems Center, located at the Detroit Arsenal in Warren, Michigan, to conduct a re-engineering analysis of select critical parts, assemblies, or subassemblies which are no longer in production—known as Diminishing Manufacturing Sources and Material Shortages (DMSMS). DMSMS issues arise due to the long service life of many military components. This longevity may result in the original equipment manufacturer ceasing production of the component or serviceable sub-components, leaving the military without a source of additional parts or critical inventory. LIFT led a team over three months to study some of the DMSMS components to determine which are candidates for future remanufacturing, reverse, or re-engineering utilizing alternate design, 3D printing, new materials, new advanced manufacturing, or joining methods to improve operational availability. By potentially re-engineering equipment using modern materials and manufacturing processes, LIFT will improve mission capability, lifecycle costs, fuel economy, equipment availability and readiness, and program timing.

Light Weighting Military Combat Vehicles:

LIFT, together with ARRIS, a California-based advanced manufacturer, launched a project with the U.S. Army's Michigan-based Combat Capabilities Development Command Ground Vehicle Systems Center. The project focuses on reducing the weight of vehicle seats through part consolidation, topology optimization, and an aligned continuous carbon fiber composite structure. Once complete, the project will advance the use of cutting-edge technologies that enable high-strength, lighter, more fuel-efficient tactical vehicles with superior mobility and protection.

WORKFORCE DEVELOPMENT

LIFT has developed curricula and a one-of-a-kind immersive Learning Lab to educate and train the next generation of high-level advanced manufacturing technicians to help fill the existing skills gap in the U.S.

“Members of the Guard and Reserve tend to get forgotten when new initiatives are created for veterans or service members. We are delighted for this new opportunity to help them earn in-demand advanced manufacturing credentials through an innovative program like Operation Next with Valencia College.”

– Joe Marino, Executive Director, Veterans Florida

Expanding Operation Next: Operation Next prepares military personnel with the skills and competencies most needed by manufacturers and most likely to offer a new career path of advancement and growth to veterans. In FY 2021, LIFT expanded Operation Next to members of the Michigan and Florida National Guard, National Reserve, and their spouses, while also opening the program to civilians in Detroit and Pittsburgh. With funding from the DoD Manufacturing Engineering Education Program (MEEP) and in partnership with Valencia College in Orlando, military personnel can now participate in the college's Accelerated Skills Training Program. In Michigan, the training takes place in the LIFT Detroit Headquarters. Through funding provided through the CARES Act and awarded to LIFT by NIST, training is provided at no cost to the individual or their employer. LIFT also partnered with Henry Ford College to provide additional advanced manufacturing training opportunities for jobs of the future.



Operation Next Trainee. Credit: LIFT

Educating Next-generation Multi-Skilled Technicians:

High school students from University Prep Science & Math High School in Detroit continue to work through their second year of LIFT's IGNITE: Mastering Manufacturing Curriculum. Developed by LIFT and supported by DoD funding, IGNITE is a three-year foundational competency-based educational program for multi-skilled technicians needed in today's workplace. The curriculum couples learning with project-based experiences built around real industry problems and emerging technologies to prepare students for today's production environment, as well as for additional post-secondary education to become engineering technicians, technologists, or engineers. Students use LIFT's virtual simulator and electronic STEM kits, which provided hands-on learning even while students learned at home during the COVID-19 pandemic.

Supporting the Girl Scouts: LIFT continues to work with the Girl Scouts of Southeastern Michigan to enable 50 scouts to earn a LIFT patch. LIFT provided STEM kits for each girl to complete three engineering tasks and participate in three webinars with LIFT staff. Michigan Congresswomen Haley Stevens participated in the last webinar and encouraged the girls to keep "thinking like engineers" and consider a career in manufacturing. Each girl also worked throughout the summer and early fall to complete a "Take Action" project in their community that focused on women and careers in the military.

INNOVATION ECOSYSTEM

LIFT, with its 100,000 square-foot R&D lab in Detroit, rapidly contracts, designs, develops, prototypes, and tests innovative technologies for DoD to speed technology transition to the warfighter while building the future workforce of America. The institute also benefits the manufacturing ecosystem by convening members from across industries to learn from each other and find solutions to pervasive problems; building an ecosystem of companies of all sizes to learn and work together to advance manufacturing; and growing initial investments by attracting funding from additional federal and commercial sources to expand programming, research, and services.

"By working with partners such as LIFT to develop and deploy these unique approaches to adopting Industry 4.0 technologies, we are ensuring the ideas, people and companies of tomorrow can continue to find their home here in Michigan."

- Natalie Chmiko, Vice President of International Trade & Pure Michigan Business Connect, Michigan Economic Development Corporation

Expanding Presence in Michigan: LIFT opened an additional Michigan location in Macomb County, the heart of the state's defense corridor, to expand its DoD-related technology work to modernize military capabilities. The institute's main headquarters and advanced national showcase and sandbox facilities are in the Corktown neighborhood of Detroit. An additional location at The Defense Corridor Center for Collaboration and Synergy (DC3S) facility in Sterling Heights, Michigan, will house LIFT's DoD technology and program management team. The expansion also moves LIFT team members and partners closer to the U.S. Army Combat Capabilities Development Command Ground Vehicle Systems Center, located at Detroit Arsenal in Warren, Michigan.



American Institute for Manufacturing Integrated Photonics

Established: July 2015

Headquarters: Albany, NY (photonic chip fabrication facility) and Rochester, NY (photonic chip test, assembly, and packaging facility)

Mission: 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 further increase domestic competitiveness; and meet participating commercial, defense, and civilian agency needs in this burgeoning technology area.

Satellite Location: Santa Barbara, CA; Tucson, AZ

Workforce Location: Massachusetts Institute of Technology (Cambridge, MA)

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

Members: 68

Funding: \$275M Base Federal Funding
\$659.1M Base Non-Federal Cost Share

www.aimphotonics.com

OVERVIEW

AIM Photonics is advancing the use of light for applications traditionally addressed through electronics, enabling significant new opportunities in a wide range of areas including telecommunications, laser-based radar, data communications, sensing, and many others. Integrated photonics dramatically improves the performance and reliability of electronic integrated circuits while significantly reducing size, weight, and power consumption. Developing a widely accepted set of processes and protocols for the design, manufacture, and integration of photonics systems not only advances this technology, but also presents the U.S. with great economic opportunity. The Yole Silicon Photonics 2020 Market and Technology Report predicted, "Silicon photonics continues to be a very active field of innovation across many industries, with a broad range of companies and R&D labs involved worldwide. As a result, the silicon photonics market is expected to grow from \$480M in 2019 to \$3.9B in 2025." Integrated photonics is expected to advance established industries and enable new ones in the same way that semiconductors fostered the revolution in computing, telecommunications, and other fields over the past 40 years.

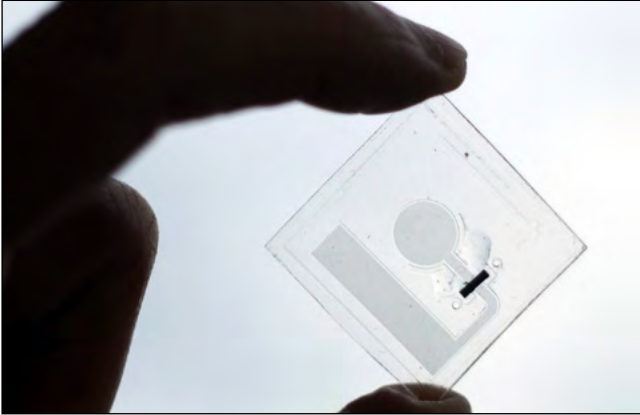
TECHNOLOGY ADVANCEMENT

AIM Photonics has created a complete Photonic Integrated Chip (PIC) manufacturing ecosystem, which provides the photonics community and DoD with access to advanced technology, capabilities, and resources throughout the entire product development cycle. This reduces time to market and advances national security.

"This country needs the capability in this area, and AIM has addressed that need over the past 5 years. We now have ready access to silicon photonics foundry capabilities. Additionally, I have international collaborators who recognized AIM's accomplishments and spoke highly of their PIC foundry services."

– Dr. Robert Norwood, CTO and Founder, Norcon Technologies

Increasing Accesses to Medical Testing: AIM Photonics developed an optical chip on a disposable card that can detect exposure to multiple viruses – including the coronavirus – within a minute from a single drop of blood. Led by University of Rochester Medical Center researcher, Benjamin Miller, Office of Secretary of Defense ManTech funded the \$1.7M project with support from the CARES Act. The project team successfully demonstrated a disposable photonics approach to COVID antibody detection and provided Ortho-Clinical Diagnostics, an industry member and project participant, with prototypes and data sets to determine whether the product is sufficiently strong to transition to marketplace. Ortho-Clinical Diagnostics intends to continue to develop this technology for market to make disposable photonics a reality for clinical diagnostics.



A passive microfluidics card able to carry a blood sample to a photonic sensor that is the size of a grain of rice. The system can detect and quantify COVID-19 antibodies within a minute. Credit: Dr. Benjamin Miller

Advancing Silicon Based Lasers: AIM Photonics made great strides with its project examining the support of high-performance cost-effective silicon-based lasers. The team focused on two primary items in the initial phase of the project: 1) integration of silicon photonics with pockets for lasers and 2) metal organic chemical vapor deposition and molecular beam epitaxy (MBE) growth optimization. MBE obtained record low defect densities that increase the quantity of quality parts. The team developed test sites and generated patterned wafers to send to industry. A full process was defined to enable device builds at AIM Photonics' 300-mm Si photonics fabrication facility in Albany, NY.

Launching New Partnership with DARPA: The Defense Advanced Research Projects Agency's (DARPA) awarded AIM Photonics \$19M to advance integrated photonics under DARPA's Lasers for Universal Microscale Optical Systems (LUMOS) program. The LUMOS program will work with AIM to enable efficient on-chip optical gain in highly capable integrated photonics platforms. This will allow complex, end-to-end photonic functionality on a single crystal silicon substrate for state-of-the-art optical microsystems.

WORKFORCE DEVELOPMENT

AIM Photonics Academy spearheads education and workforce development initiatives in integrated photonics at every level of technical expertise.

"Working with the AIM Photonics team was very special. I didn't expect to learn so much and have so much fun interacting with my colleagues. AIM Photonics is focused on each individual worker, which I genuinely appreciate."

– Erica Graham, Participant, Photonics Design Engineering Co-op at AIM Photonics

Expanding Online Photonics Education:

AIM Photonics partnered with the OSD ManTech Office and Massachusetts Institute of Technology's (MIT) Initiative for Knowledge and Innovation in Manufacturing to launch a new online Open edX platform for advanced manufacturing technologies education. The site (www.manufacturingworkforce.org) uses Open edX technology to bring accessible, digital learning to advanced manufacturing engineering students, professionals, and technicians. The site currently features seven on-demand, self-paced photonics courses developed by AIM Photonics and MIT.

Educating Technicians of Today:

AIM Photonics' technician training program at Stonehill College and Bridgewater State University has had great success. All 11 students from the course, none with previous experience in manufacturing, have obtained full-time jobs and/or internships after completing the 15-month program. Examples of students transitioning to new opportunities include a truck driver moving to precision machining, a single mom of preschool twins who struggled with homelessness going to work on semiconductor lasers, and a waitress working with lab-free sensors.



First cohort of students from Photonics Technician Certificate Program at Stonehill College and Bridgewater State University. Credit: Dr. Robert Gu

Equipping the Next Generation: AIM Photonics, in partnership with Western New England University (WNE) College of Engineering launched the Laboratory for Education and Application Prototypes (LEAP), a state-of-the-art optics/photonics training center. The Massachusetts Center for Advanced Manufacturing (CAM) established LEAP@WNE through a \$2.6M grant as part of a national effort to advance state-of-the-art manufacturing with AIM Photonics. The LEAP@WNE facility features six instrumentation and prototyping workstations with capabilities including tunable lasers and optical power meters, polarimeters and polarization controllers; optical spectrum analyzers and free space optics; electronic signal generators, oscilloscopes, spectrum analyzers, and power supplies; and PCB fabrication using subtractive and additive techniques.

INNOVATION ECOSYSTEM

Integrated photonics is approaching a high growth phase in key technologies, and AIM Photonics has established manufacturing methods supporting these key technologies to ensure the needs of the market are addressed. In addition, AIM Photonics has the most advanced 300 mm semiconductor processing research fab in the world.

"[AIM Photonics has] the cutting-edge foundry fab tools to do everything needed for photonics, with much more repetition and replicability than in a smaller foundry. And it was built to develop 300 mm wafers, which produces more chips per wafer and drives down costs."

– Dr. Thomas Brown, Interim Director, The Institute of Optics, University of Rochester

Continuing Relationship with DoD: OSD ManTech secured a new seven-year, cooperative agreement with AIM Photonics. The total awarded amount is \$321M. This includes \$165 million awarded by the Air Force Research Laboratory on behalf of U.S. Department of Defense and \$156 million in non-federal cost-share from companies, colleges and universities, and state and local governments.

Updating Membership Model: In January 2021, AIM Photonics simplified its membership model. The new membership structure has two levels: a \$25K industry/\$10K academic, all-access membership option and an observer option to simply receive quarterly newsletters and semi-annual membership meetings. Small and mid-sized manufacturers, as well as academics, are rewarded for working with AIM by receiving a credit for their membership dues equal to the dollar value of amount of work they do with AIM. Since the new model rollout, AIM signed nearly 72% of its membership under the Full Active membership option, an increase from 59% of all tiered members combined in the legacy model. As a result, AIM members are more engaged in work with and for the DoD institutes.



America's Flexible Hybrid Electronics Manufacturing Institute

Established: August 2015

Headquarters: San Jose, CA

Mission: Pioneer flexible hybrid electronics manufacturing to serve our nation's warfighters and the U.S. economy.

Consortium Organizer: FlexTech Alliance

Members: 105

Funding: \$102M Base Federal Funding
\$123.2M Base Non-Federal Cost Share

www.nextflex.us

OVERVIEW

NextFlex facilitates the development and manufacturability of flexible hybrid electronics (FHE) technology that integrates low-cost printed electronics with the processing power of thin semiconductors to create a new category of stretchable, bendable, conformable, and flexible electronic devices. FHE manufacturing relies on flexible and/or conformal substrates, additively processed circuit elements, small discrete components, thinned bare-die integrated circuits, and application-dependent packaging that retains these advantages. The low cost, thin size, and lighter weight of FHE devices delivers the long-promised "Internet of Everything." The NextFlex flexible circuit board is only one-third the weight and is produced in fewer than half the process steps of traditional rigid circuit boards, making it cheaper and faster to market through digital design and manufacturing.

TECHNOLOGY ADVANCEMENT

NextFlex is facilitating design, development, prototyping, and pilot-scale manufacturing of FHE for a range of military and civilian applications at its Technology Hub facility and through member and partner organizations across the country. The combination of in-house development and projects distributed throughout the ecosystem disseminates knowledge and produces practical connections among participants. Funded project teams typically comprise several members working in collaboration, and each team reports its progress to other members so that all can learn from the effort.

"As an equipment maker focused on the thinning and dicing of chips that are integrated into FHE systems, we see the potential for a wide variety of applications that can be made with this technology in the U.S. NextFlex is a collection of nearly all the people that are focused on developing the technology and are accelerating adoption and commercialization of FHE."

– Devin Martin, Technology Development Manager, DISCO USA

Next-Generation Physiological Status Monitoring:

In FY 2021, NextFlex designed and produced an FHE-wearable chemical sensor capable of detecting ambient oxygen, volatile organic compounds (VOCs), temperature, and humidity levels. Developed using funding from the Air Force Research Lab, the project is significant for DoD as a means of monitoring Air Force worker health and safety while reducing cost, increasing productivity, and improving morale. This effort has also contributed to the FHE-knowledge base and novel processes in the areas of sensors integration, power management, communication subsystems, and encapsulation.

Advancing Hybrid Electronics for Circuit Boards:

In FY 2021, NextFlex completed multiple projects for advanced printed circuit boards. NextFlex member Universal Instruments Corporation demonstrated a commercial time-saving volume pick-and-place tool capable of placing up to 7,000 thin bare die parts per hour, from 52 individual wafers with placement accuracy greater than 15 micrometers. The tool was showcased at SEMICON West, generated interest from advanced packaging industries focused on heterogeneous integration, and ultimately delivered to the NextFlex Hybrid Electronic Technology Hub. Relatedly, NextFlex and its members are advancing high-density interconnects and thin die assembly on flexible and rigid substrates which includes metals traces and ceramic substrates to support electronics assembly for extreme environments such as DoD hypersonic missions. In FY 2021, NextFlex completed two

projects focused on protecting FHE devices from mechanical and chemical damage with members from Eastman Chemical, University of Massachusetts Lowell, Binghamton University, Acellent Technologies, Lockheed Martin, Flextronics, Auburn University, ACI Materials, and Novagard.



The NextFlex Microcontroller is thin and conformable to most shapes. Credit: NextFlex

Enabling Warfighter Performance with Exoskeleton Designs: NextFlex and members Lockheed Martin, Georgia Institute of Technology, and StretchMed completed and delivered an exoskeleton that provides structural support for patients rehabilitating from injury or to amplify strength and endurance for soldiers in the field. The project included the development of a knee exoskeleton system based on soft actuators and FHE-based electromyography sensors that measure the electrical impulses that initiate muscle movement, which allows the system to move with more synchronized timing with the wearer. The system was validated through human performance analysis and testing, showing improved metabolic cost to the wearer. These results serve as a foundation for advancing integration of FHE into future exoskeleton designs.

Fighting COVID-19 with cleanSURFACES: NextFlex and member Aionx are collaborating to eliminate pathogens in clinical settings. With Coronavirus Aid, Relief, and Economic Security (CARES) Act funding and NextFlex support, Aionx developed a product called cleanSURFACES, which is a mat that can be applied to any work surface to provide continuous elimination of many pathogens including the SARS-CoV-2 virus responsible for COVID-19. The efficacy of this product is superior

to many other intervention methods and provides continuous protection without needing episodic cleaning. Funding from Office of Secretary of Defense was used to improve product longevity in the field, double production capacity, add manufacturing automation, and conduct three successful clinical trials at Walter Reed Military Medical Center, Pittsburgh VA Long Term Care Facility, and the University of Pittsburgh Medical Center. Results of this last study were published in *Frontiers in Cellular and Infection Microbiology*.

WORKFORCE DEVELOPMENT

NextFlex facilitates and enables the creation of the talent needed by our industry partners over time.

"Working with NextFlex has created and retained jobs for several of our industry partners in New York State. As a result of recent FHE development projects, at least 16 new jobs have been created and 59 existing jobs have been retained in the areas of manufacturing, engineering, and administrative support."

– Mark Poliks, Professor of Materials Science and Engineering, Binghamton University

Engaging Underrepresented Communities in Manufacturing: The Department of Health and Human Services awarded NextFlex a \$5M grant to engage underrepresented and underserved communities with STEM-based pathways in the advanced manufacturing sector. This project focuses on increasing and diversifying the STEM talent pipeline to create the next-generation U.S. workforce with the skills, knowledge, and experience to innovate technology solutions to future defense challenges.

Advancing Military Education: NextFlex launched the virtual version of its military engagement program, FlexMil, which engages members of the broader military community with the advanced manufacturing sector. The initial program was delivered in partnership with the Alabama National Guard and served 30 participants. Participants learned about career opportunities in the advanced manufacturing sector and the FHE technology and application spaces and presented ideas for how FHE can be used to upgrade existing military equipment.

INNOVATION ECOSYSTEM

NextFlex convenes the U.S. FHE ecosystem to align technical advances with application-driven needs from industry and government, ensuring rapid transition into manufacturing and FHE industry global competitiveness. Working with state partners, NextFlex also facilitates formal and informal regional networks for the industry, including nodes in New York and Massachusetts, to convene practitioners and support supply chains and regional economic development. Both NextFlex nodes are partially funded by their respective states.

"We are excited to continue our partnership with NextFlex and its members. The Flexible Hybrid Electronic manufacturing ecosystem did not exist five years ago. Today these technologies are not only providing component solutions to our current platforms but are revolutionizing our design concepts for future transformation capabilities for 2030."

**– Dr. Richard Vaia, Chief Scientist (Acting),
Materials and Manufacturing Directorate,
Air Force Research Lab**

Exploring FHE for Automotive Applications:

In November 2020, NextFlex hosted its first virtual workshop focused on FHE for automotive applications including autonomy, in-car informatics, and communication devices. The event included an interactive Q&A with 18 panelists across four sessions. Speakers discussed other applications that have already proven benefits for FHE and can have applicability in automotive systems. More than 230 members, government, and non-member attendees participated in the livestream event.

Promoting Member Participation and

Collaboration:

In March 2021, NextFlex hosted virtual member meetings to share a vision of technology and engineering programs, workforce development programs, plans for the institutes' Technology Hub, and updates from the government program manager and chief technology officer. Select project teams presented progress reports, members shared positive stories from working with NextFlex, and DoD leadership shared their priorities with the FHE community.



*Printing electronics at the NextFlex Technology Hub.
Credit: NextFlex*

Improving Member Materials and Process

Database: In FY 2021, NextFlex initiated an extensive set of studies to understand and enhance the fundamental yield and reliability of FHE systems as a function of the process and materials. This will be a long-term effort as the team contributes important and statistically valid data into the NextFlex Member Materials and Process Database.



Advanced Functional Fabrics of America Institute

Established: April 2016

Headquarters: Cambridge, MA

Mission: Rekindle the domestic textiles industry by leading a nationwide enterprise for advanced fiber and fabric technology development and manufacturing, enabling revolutionary system capabilities for national security and commercial markets.

Consortium Organizer: Massachusetts Institute of Technology

Satellite Locations: Drexel University (Philadelphia, PA);
MIT Lincoln Laboratory (Lexington, MA);
University of Massachusetts Lowell (Lowell, MA)

Members: 133

Funding: \$75M Base Federal Funding
\$272M Base Non-Federal Cost Share

www.go.affoa.org

OVERVIEW

AFFOA's vision is a globally competitive, domestic supply chain in advanced fibers and fabrics. The institute delivers breakthrough capabilities and innovations that ultimately increase national security. AFFOA centralizes the revolutionary fiber and fabric technology capabilities of startups, manufacturers, industry, and academia and organizes them to produce and manufacture advanced textile systems for DoD and commercial markets.

TECHNOLOGY ADVANCEMENT

AFFOA and its diverse ecosystem of members are developing and transitioning advanced fiber and fabric technologies that enable a multitude of capabilities and apply to a variety of commercial and defense applications and industries.

"The AFFOA network provides valuable R&D head starts in fiber and process innovations for small to medium-size textile companies in the USA. Without this resource, these types of businesses would not have access to advanced technology until it became available on the market and commercialized. At that point, it is another country's innovation."

– Stephanie Rodgers, Director of Product Research & Development, Apex Mills

Rapidly Prototyping Extreme Cold Weather

Systems: AFFOA partnered with the U.S. Army Combat Capabilities Development Command Soldier Center (DEVCOM-SC) and Program Executive Office Soldier to rapidly prototype 300 sets of next-generation extreme cold weather clothing systems and 20 wet weather systems with integrated hydration management technology. Because of AFFOA's existing advanced fibers and textiles ecosystem, the institute was able to select performers from its network of traditional and non-traditional manufacturers and produce 300 sets of the Cold Temperature Arctic Protection System in less than eight months. In addition, DEVCOM-SC wanted to test a new, off-the-shelf hydration management technology (Hydro_Bot) as part of this year's field test. In fewer than 14 weeks, AFFOA was able to integrate the Hydro_Bot and add new sensing capabilities that allow the sponsor to track temperature, humidity, and acceleration during the course of use .

On-Shoring Manufacturing Capabilities:

Polymer optical fibers (POFs) offer better dynamic flexibility performance, resulting in longer term durability compared to glass optical fibers. AFFOA successfully completed a program for the Naval Undersea Warfare Center which leveraged the institute's advanced fiber manufacturing capability, establishing the beginning of a domestic source for POF, and achieving advancement in producing low transmission loss POF. AFFOA's polymer manufacturing process enables the creation of polymer and fiber properties tailored to customer-specific requirements (e.g., fiber bending stiffness), while the flexibility of the fiber manufacturing process

lends itself to customizable POF architectures. This provides an opportunity to shape both fiber diameter and cross-section, including smaller core or multicore fibers, as well as fibers with more complex cross-sections. In addition, for applications in which POFs are a component of a larger cable system, this work creates new possibilities for novel cable designs and domestic manufacturing capacity.



*Thermal draw process at AFFOA headquarters.
Credit: AFFOA*

WORKFORCE DEVELOPMENT

AFFOA is creating educational and workforce development programming and partnerships to inspire, prepare, and grow the domestic textile industry's workforce to meet the current and future needs of the advanced fiber and fabric industry.

"I like how AFFOA helps to facilitate the interaction and collaboration with industries and DoD. AFFOA provides a unique model for universities, industry, and DoD to work closely together to solve key manufacturing challenges and make an impact."

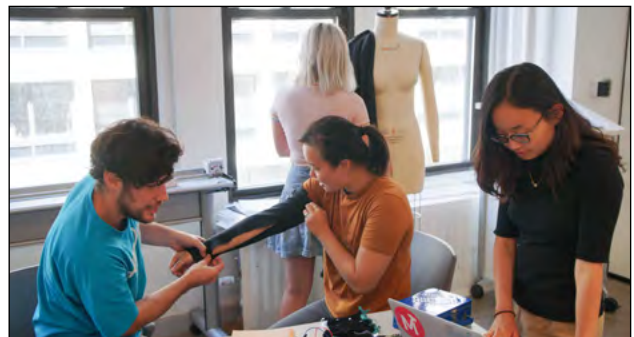
– Xiaoting Jia, Assistant Professor, Virginia Tech

Developing National Textile Industry Needs

Assessment: In FY 2021, AFFOA partnered with Educational Data Systems, Inc. to conduct a national needs assessment of the domestic textile industry's workforce. The project also assisted AFFOA in defining its education and workforce development (EWD) strategy. The goals of the assessment were to: define the current state of the textile and advanced fiber and fabric industry; define and understand current workforce challenges, opportunities facing the industry, and future workforce needs; identify workforce education and infrastructure gaps and determine for which gaps AFFOA could most beneficially impact members and stakeholders; and increase alignment of AFFOA's workforce strategy with industry.

Combining Engineering and Design:

In FY 2021, AFFOA, MIT, and the Fashion Institute of Technology, issued the *Transdisciplinary Innovation Playbook: How to Build a Virtual Workshop* that collapses walls between design and engineering and kick-starts collaboration to solve real world problems. This playbook incorporates learnings from three years of creating interdisciplinary workshops for designers and engineers and distills them into essential guidance to make a highly technical and engaging workshop for undergraduate students. The goal of the playbook is to enable other universities or institutions to build their own version of the workshop, creating more opportunities for industry to directly engage and influence the next-generation workforce.



Students participating in the Advanced Fiber and Fabrics Workshop. Credit: AFFOA, MIT, and Fashion Institute of Technology

Promoting STEM Education: AFFOA kicked off an education and workforce development program with Nautilus Defense to develop a STEM education curriculum and kit leveraging novel functional fibers and fabrics under Nautilus' SewLY brand. Designed for K-8 students, this curriculum and kit was designed to generate interest and confidence in the possibilities of technology and engineering for a diverse population of learners. Nautilus piloted the SewLY curriculum in Fall 2021 with approximately 100 students and 10 instructors in Massachusetts and Rhode Island. The goal is to make the curriculum and kits available online to K-12 institutions nationwide.

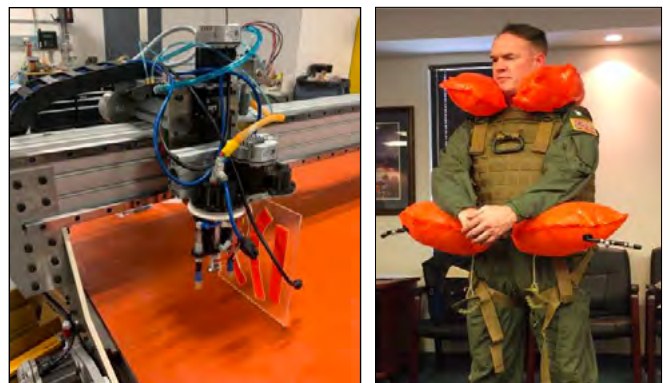
INNOVATION ECOSYSTEM

In addition to the Fabric Innovation Network, AFFOA's three Fabric Discovery Centers (FDCs) are critical elements of its innovation ecosystem. These centers include a Pennsylvania Fabric Discovery Center at Drexel University (PA FDC), University of Massachusetts Lowell Fabric Discovery Center, and Defense Fabric Discovery Center at MIT Lincoln Laboratory. Each has unique capabilities focused on the next generation of manufacturing.

"AFFOA is a great network of like-minded individuals and companies, seeking to promote and grow the domestic textile industry. It has enabled us to make connections, drive business, and continue to expand our company with non-dilutive funding. It has enabled us to keep our technology and manufacturing in the United States, versus overseas where a lot of the cheaper infrastructure and supply chain exists."

– Jordan Schindler, Founder and Chief Executive Officer, Nufabrx

Automating the Manufacturing of Next-generation Emergency Inflatables: As part of AFFOA's Advanced Fabric Technology Transfer (AFTTR) Program, member company Kennon partnered with the PA FDC to develop a pick-and-place machine to automate previously manual operations. This process innovation reduces the manual labor currently involved with hand placing internal reinforcements and building the external casing by more than an hour or more per inflatable. Automating this process is not only cost effective but also reduces human errors.



Left: The pick and place machine developed by Kennon to automate a manual labor-intensive process. Right: Soldier wearing next-generation emergency life preserver. Credit: Kennon Products

Supporting National COVID-19 Response: AFFOA is leading a CARES Act-funded program, in collaboration with a range of its academic and industry partners, to address critical gaps in the supply chain of personal protective equipment (PPE) and improve our nation's preparedness for future pandemics. Selected recent highlights of the project include: 1) completed PPE supply and demand gap analysis tool to predict gaps between normal and surge periods; 2) completed capacity assessment of more than 15 domestic companies across the PPE supply chain to identify domestic manufacturing gaps; and 3) completed design, prototype, and test of an N95 respirator duckbill-shaped mask which passed filtration efficiency, differential pressure, and liquids barrier penetration tests. Critically, the technical data packages for these designs will be government-owned, thus enabling a more rapid pivot in PPE manufacturing during future pandemics.



Advanced Regenerative Manufacturing Institute

Established: December 2016

Headquarters: Manchester, NH

Mission: Make practical the scalable, consistent, and cost-effective manufacturing of engineered tissues and tissue-related technologies to benefit existing industries and grow new ones.

Consortium Organizer: Advanced Regenerative Manufacturing Institute (ARMI)

Members: 172

Funding: \$80M Base Federal Funding
\$214M Base Non-Federal Cost Share
\$32.5M DoD-Sponsored Projects

www.biofabusa.org

OVERVIEW

Significant breakthroughs in cell biology, biofabrication, and materials science in the last decade have laid the foundation for large-scale manufacturing and commercialization of engineered tissues and tissue-related technologies. BioFabUSA has targeted the raw material, equipment, measurement, automation, logistics, and big data analytics challenges that hinder scalable, consistent, and cost-effective manufacturing. The development of tissue-engineered medical products on an industrial scale enables the DoD to accelerate creation of numerous medical products for our wounded warfighters.

TECHNOLOGY ADVANCEMENT

BioFabUSA is integrating innovative cell and tissue cultures with advances in biofabrication, automation, robotics, and analytical technologies to create research and development tools and FDA-compliant volume manufacturing processes that can accelerate medical products to improve human health and save lives.

"We've enjoyed a number of successes with the BioFabUSA Consortium, the most exciting being the first time demonstration of robotic-based, automated fabrication of complex human vascularized tissues using support from the technical project program of BioFabUSA."

– Jay Hoying, Ph.D., Partner & Chief Scientist, FAHA, Advanced Solutions

Forecasting Hospital Needs for Pandemic Response: Using CARES Act funding, BioFabUSA completed a hospital demand forecasting model to aid in the nation's response to COVID-19. The model was immediately used by a hospital system during a surge in cases in South Florida. BioFabUSA is still working on anti-viral combination drug therapies, cell therapies, novel drug/vaccine delivery methods, and virus-free red blood cells to help recover from this and future pandemics.

Accelerating Cell Therapies for Diabetes:

BioFabUSA recently achieved a major milestone by completing technology transfer and intermediate scale-up, modularization, automation, and closure of a cell manufacturing process developed at Washington University. This process leverages the Tissue Foundry platform and utilizes the institute's Deep Tissue Characterization Center. Supported by the Juvenile Diabetes Research Foundation, this project will ensure a consistent, reliable source of islets for diabetes research to enable commercial-scale production of isolated cells for the treatment of diabetes. This project is the first example of BioFabUSA manufacturing cell or tissue products for end-users. Transplantation of insulin-secreting tissues holds great promise as a curative therapy for people with diabetes.



Kim Jesseman, an ARMI | BioFabUSA associate scientist, works on manufacturing stem cell-derived pancreatic islets. Credit: David Butler II

Enabling Smart Monitoring for Bioreactor Systems:

BioFabUSA worked with Georgia Tech, Huxley Medical, and Rockwell Automation to develop a smart bioreactor platform that is portable and offers multi-spatial sensing and wireless monitoring of real-time culture conditions in large-scale cell manufacturing. The project team successfully integrated pH, glucose, temperature, and dissolved oxygen sensors into a commercially available bioreactor, which is applicable across products, and is currently enabling the measurement of product- and process-specific metabolites, lipids, and proteins.

Furthering Human Therapeutic Cell Yield Scalability:

BioFabUSA collaborated with Worcester Polytechnic Institute, Akron Biotech, Rooster Bio, and Rockwell Automation to enable unprecedented scalability of human therapeutic cell yield. This project automates the coating of cell culture surfaces with growth factor-releasing polyelectrolyte multilayers while decreasing manufacturing costs and improving cell product quality. The process has been automated as a proof of concept for large-scale automated manufacturing.

WORKFORCE DEVELOPMENT

BioFabUSA is preparing the workforce to meet the needs of this developing industry across the U.S.

Certifying Tissue Engineering Technicians:

BioFabUSA launched a pilot certificate and training program to give students the knowledge and skills required to be certified as Tissue Engineered Medical Products (TEMP) manufacturing technicians. Analysis following the first round of implementation will allow BioFabUSA to improve the program for future iterations.

"BioTrek's unique structure and cutting-edge science sparked an interest in our students that we have rarely seen. By the end of the program, students had expertly communicated with members of academia and industry to conceptualize replacement cells, tissues, and organs, while learning how to enter the field of biomanufacturing at any level. Our students were pushed to collaborate, think critically, and dive deep into research, which are all skills that this generation will need as they move into the world."

**– BioTrek Teacher, Winnacunnet High School,
Hampton, New Hampshire**

Engaging Girls in Biofabrication:

BioFabUSA and the Girl Scouts of the Green and White Mountains completed curriculum to accompany a new BioFab patch. The curriculum provides Girl Scouts in grades K-12 with diverse opportunities to engage in innovative STEM programs that introduce concepts foundational to the biofabrication field. Through biofabrication-related activities, live in-person biofabrication demonstrations and workshops, and in-person and online curriculum training, Girl Scouts can increase exposure of STEM, including biofabrication, to thousands of girls annually.

Launching BioTrek Program:

BioFabUSA launched its BioTrek program at Winnacunnet High School in Hampton, New Hampshire. This six-week program exposed participants to the field of biofabrication through a project in which groups of

students conceptualized their own hypothetical tissue engineered medical product and developed a business pitch to sell their product to a panel of judges. The hands-on learning experience was enhanced with opportunities to speak with industry professionals, see biofabrication technology in action, and participate in career readiness activities for the biomanufacturing industry. BioFabUSA is poised to expand this program to five high schools in New England that represent a diverse group of students. BioTrek was adapted from the NextFlex FlexFactor program through NextFlex's Office of Naval Research Manufacturing Engineering Education Program grant.

INNOVATION ECOSYSTEM

Prior to the establishment of BioFabUSA, the tissue engineering field was fragmented and lacked a mechanism with which to turn laboratory breakthroughs into manufactured products. BioFabUSA filled a critical need by creating and convening this community.

“As a member, I feel that we are making a direct impact to improve the regenerative medicine industry. It is amazing to work with like-minded, goal-oriented people to solve challenges that haven't been addressed elsewhere. We know we are working toward a greater goal in bringing life-changing technologies to market where they can have the most impact on people's lives.”

– Sarindr “Ik” Bhumiratana, Ph.D., Chief Scientific Officer and Co-Founder, Epibone

Ensuring Regenerative Medicine Quality and Safety: BioFabUSA published the *Standard Guide for Characterizing Fiber-Based Constructs for Tissue-Engineered Medical Products*. The institute leveraged meetings between BioFabUSA and NIST to develop standards for measuring the structural, mechanical, and biological properties of fiber-based scaffolds. Fiber-based scaffolds have the potential to mimic the properties of functional tissue better than a scaffold with a regular repeating pattern. As a result, they are used and considered for a wide variety of tissue engineering applications. The new guide helps ensure quality and safety within the regenerative medicine community.

Furthering Federal Partnerships: BioFabUSA established a public-private partnership with the Food and Drug Administration's (FDA) Center for Biologics Evaluation and Research to ensure alignment between industry and regulators as the tissue engineering industry grows. This partnership has two foci: (1) the development of scalable, modular, automated, and closed process development and Good Manufacturing Practice-compliant manufacturing; and (2) the development of measurement assurance for in-line and near-line sensor systems to facilitate application of process analytical technology and quality-by-design principles to scalable, modular, automated, and closed manufacturing of engineered tissues.

Educating on Federal Regulation Processes: BioFabUSA hosted a Regulatory Bootcamp for institute members to introduce them to regulatory issues relevant to the manufacturing of cells, tissues, and organs. This sold-out event led by Dr. Richard McFarland, former associate director of policy for the Office of Tissues and Advanced Therapies at the FDA's Center for Biologics Evaluation and Research, included lecture and small group interactive activities.



Advanced Robotics for Manufacturing Institute

Established: January 2017

Headquarters: Pittsburgh, PA

Mission: Accelerate the development and adoption of robotics technologies that are the foundation of every advanced manufacturing activity today and in the future. The institute leverages a unique, robust, and diverse ecosystem of partners across industry, academia, and government to make robotics, autonomy, and artificial intelligence more accessible to U.S. manufacturers large and small, train and empower the manufacturing workforce, strengthen the U.S. economy and global competitiveness, and elevate the nation's security and resilience.

Consortium Organizer: Carnegie Mellon University

Members: 323

Funding: \$80M Base Federal Funding
\$173M Base Non-Federal Cost Share

www.arminstitute.org

OVERVIEW

The ARM Institute is leading the way to a future where people and robots work together to respond to our nation's greatest challenges and develop and produce the world's most desired products. A national consortium, ARM's membership spans industry, advanced technology, academia, and government organizations. ARM integrates diverse industry best practices and institutional knowledge about robotics technologies across many disciplines to realize the promise of a robust manufacturing innovation ecosystem. Key focus areas include human-robot interaction; interoperability; artificial intelligence; reconfigurable, agile, and flexible robotics systems; and easier adoption and risk reduction. ARM also works to prepare the U.S. workforce for Industry 4.0 careers working with robotics. In defining robotics career pathways, ARM is working to expand the size, diversity, and skill set of the U.S. robotics workforce.

TECHNOLOGY ADVANCEMENT

By leading projects related to human-robot interaction, ARM is helping DoD meet its autonomy modernization goals. ARM's projects address issues related to persistence, speed, maneuverability, and reduced risk to human life.

"Working alongside ARM was pivotal, and we are thrilled to now be taking our innovations to market both here in Texas and across the country during this important juncture."

– Will Wilder, Chief Executive Officer,
Wilder Systems

Advancing Sanding Efficiency and Effectiveness: ARM's Collaborative Sanding Technology Project led by Spirit AeroSystems with Wichita State University and Southwest Research Institute conducted its final demonstration. The project aims to increase sanding efficiency and effectiveness by using robots to perform 80% of the repetitive tasks while human workers oversee the process and identify areas requiring additional processing. The team created a low-cost robot cell that collaboratively sands aircraft panels in preparation for paint. Work continues to further enable the advancement of the process.

Enabling Virus Sample Testing: ARM and Wilder Systems created a robotic cell for testing potential COVID-19 samples which is now in production in Austin, TX. Using CARES Act funding, the project addresses insufficient availability of personnel to analyze samples and provide test results for COVID-19 or other future pandemics. The project team built an all-in-one robotic test cell that contains a seven-axis robotic arm, robotic liquid handlers for collection tube plating, polymerase chain reaction (PCR) testing prep, the RT-qPCR analyzer itself, a hazardous waste bin, and control software. A technician starts the testing process by supplying the sample in a test tube, the robotic system then processes it, and the results are quickly delivered. The entire system can be deployed at any lab and has demonstrated its ability to continuously run test samples with minimal human involvement. The system can run continuously for 24 hours with minimal technician supervision and test up to 2,000 samples per day, a seven-time increase over an all-manual process with the same number of staff. Results to patients are delivered within 24 hours, and dramatically augment the country's processing of rapid test results.

Advancing Mixed Reality for Manufacturing:

The ARM Institute's Autonomous Swarm Inspection and Interactive 3D Modeling with Orchestrated Visualization project concluded in September 2021. The project, led by Siemens Global Technologies with the support of Altem Business Ventures, successfully developed multi-drone navigation software, asset survey capability without prior knowledge, high-resolution image acquisition, high resolution 3D model creation, and the use of a mixed reality interface to operate and interact with a swarm of drones. These new methods eliminate resource intensive processes and facilitate accelerated high-quality autonomous inspection in complex and remote environments. The Siemens team successfully demonstrated the following multi-drone inspection technology capabilities: reduced inspection time for large assets and assets in complex environments with little infrastructure support (e.g., ships, wind-turbines, off-shore oilrigs); improved safety by eliminating manual processes in complex or difficult environments; and accelerated high-quality inspections of critical assets and infrastructure. The ARM Institute convened the project review at the Battleship USS New Jersey in Camden, NJ for representatives from the Office of Deputy Assistant Secretary of Defense for Materiel Readiness, Office of Secretary of Defense (OSD) ManTech and DoD Manufacturing USA Institutes, U.S. Army, U.S. Navy, and Siemens Energy and Siemens Government Affairs. This pervasive technology developed through the partnership between the ARM Institute, Siemens Global Technology, and the U.S. Navy, is making automated inspection capabilities of large assets a reality.



Institute's Autonomous Swarm Inspection and Interactive 3D Modeling with Orchestrated Visualization Drone Inspection project team representatives.
Credit: ARM Institute

WORKFORCE DEVELOPMENT

By expanding the size, diversity, and skill set of the U.S. manufacturing workforce, the ARM Institute catalyzes the U.S. manufacturing industry and its competitive position.

“RoboticsCareer.org is an exceptional resource to address training and re-training. The platform is particularly beneficial for small and medium-sized businesses who may not have the resources to take on training in-house.”

**– Catherine Ross, Director of Education,
Association for Manufacturing Technology**

Training Veterans for Robotics Careers:

ARM's robotics technician training for transitioning military and veterans recently completed training for 18 participants. The program provides career counseling, training, and placement in manufacturing jobs for transitioning military personnel and veterans, and leverages participants' existing skills while addressing manufacturers' need for skilled workers.

Launching National Robotics Career Resources:

ARM created and launched roboticscareers.org to connect workers and employers with vetted training opportunities. The new website increases awareness of career pathways for robotics in manufacturing along with the most relevant and effective training programs in the field. ARM created this resource in collaboration with government, industry, and academia to connect civilians and military personnel with the industry-vetted training needed for high-value robotics careers in manufacturing. Since launch, ARM expanded the number of educational programs and institutions on the site from 2,000+ organizations to 13,341 programs. Additional capabilities such as job matching are under development to further address the labor gap in manufacturing.



Home page of roboticscareer.org. Credit: ARM Institute

Endorsing Educational Efforts: The institute launched the ARM Endorsement Program to identify organizations that are most effective at preparing students for robotics careers in manufacturing. The Endorsement program was created with input from the ARM Institute's 300+-member national consortium, giving equal voice to the need of manufacturers, education providers, and government stakeholders. The program leverages the ARM Institute's competency and skills framework that outlines the career options and skills needed for a manufacturing career working with robotics.

INNOVATION ECOSYSTEM

By lowering barriers to the adoption and expansion of robotics for manufacturing, ARM is elevating the U.S. manufacturing industry and its competitive position.

"The collaborations and connections we have made through the ARM Institute have given us the opportunity to be part of some of the advanced technology development that I believe will move this country forward."

– Aaron Prather, Senior Advisor for Technology Research and Planning, FedEx

Furthering Artificial Intelligence for Robotics:

In support of DoD's modernization priorities, ARMhosted discovery workshops to generate a roadmap for artificial intelligence (AI) applications in robotics for manufacturing. Leveraging its public-private partnership of close to 300 organizations and four Defense Manufacturing Communities (DMCs), ARM is a key part of the strategy to get the nation AI-ready by 2025. To continue building on the institute's existing momentum in AI, ARM invited a group of thought leaders representing industry, government, and academia to participate in an AI Discovery Workshop. The workshop generated more than 300 ideas that will be mapped to the core AI technology capabilities critical to advancement of robotic manufacturing. Ultimately, this will inform the institute's overall technology strategy.

Promoting Women in Manufacturing:

The Society of Manufacturing Engineers (SME) selected ARM's Chief Workforce Officer Lisa Masciantonio as one of 20 Exceptional Women in Robotics and Automation. The list was developed by SME's *Smart Manufacturing* magazine, in consultation with leaders from across the robotics and automation industries.



Lisa Masciantonio, Chief Workforce Officer of ARM Institute, selected one of SME's 20 Exceptional Women in Robotics and Automation. Credit: ARM Institute

Continuing Local Prominence: For the fourth consecutive year, the Pittsburgh Technology Council has recognized the ARM Institute as a Tech50 Finalist in the Innovator of the Year, Non-Profit/Education/Community category. Each year, the Pittsburgh Technology Council celebrates the most successful and innovative companies in Southwestern Pennsylvania.



BioMADE — Bioindustrial Manufacturing and Design Ecosystem

Established: October 2020

Headquarters: St. Paul, MN

Mission: BioMADE's mission is to enable domestic bioindustrial manufacturing at all scales, develop technologies to enhance U.S. bioindustrial competitiveness, de-risk investment in relevant infrastructure, and expand the biomanufacturing workforce to realize the economic promise of industrial biotechnology.

Consortium Organizer: Engineering Biology Research Consortium

Satellite Locations: Berkeley, CA, Cambridge, MA

Members: 80

Funding: \$87.5M Base Federal Funding
\$187.5M Base Non-Federal Cost Share

www.biomade.org

OVERVIEW

BioMADE, the Bioindustrial Manufacturing and Design Ecosystem, is the ninth and newest DoD Manufacturing Institute. Together with its members, BioMADE collaborates to advance sustainable and reliable bioindustrial manufacturing technologies for economic and national security impact. Its technology area is broad and diverse with the potential to affect nearly every sector of the economy, especially those needing industrial chemicals and materials.

TECHNOLOGY ADVANCEMENT

“ Our team is dedicated to the synergy of BioMADE, because bringing together the components of this initiative will help us to achieve more than one organization can do on its own to support digital fortitude and workforce development. We see these as key things that will really move us forward to allow biotech to deliver technologies.”

– Nancy Kelley-Loughnane, Biosciences
Technical Advisor, Air Force Research Lab

Launching Technology Development Activities: BioMADE completed its technical roadmap to detail longer-term efforts to establish project calls. Crafted by the Transition Technical Working Group, the roadmap incorporates insights from 19 industry and academic partners, and eight subject matter experts from the U.S. Government.

Initiating DoD Project Work: BioMADE initiated its first government-directed research project to scale a precursor molecule with optical properties of interest to the DoD. The project also includes an understanding of the techno-economic landscape of the molecule. The project team developed the framework for the first Global Technology Landscape report on biomolecule production routes to enable a robust technoeconomic analysis of production options.



*BioMADE Deputy Chief Technology Officer Mike Smanski in a lab facility at the University of Minnesota.
Credit: University of Minnesota*

WORKFORCE DEVELOPMENT

"I'm excited about working in the education and workforce development area. I want to introduce students and trainees to the unique research projects that are going on and how they can meet future U.S. Navy and Marine Corps needs and operations."

– Dascha Leary, Research Biologist,
U.S. Naval Research Lab

Launching Education and Workforce Development Activities: In March 2021, BioMADE conducted a workshop for education and workforce development stakeholders. Panels discussed training gaps identified by industry and success stories from other workforce programs. Feedback and discussions from this meeting were used to craft BioMADE's first education and workforce development community-informed project call.

Building the BioMADE Education and Workforce Development Ecosystem: In Spring and Summer 2021, BioMADE partnered with the National Science Foundation InnovATEBIO National Biotechnology Education Center to host a series of community-building web conferences. These events targeted regional engagement of community colleges and K-12 educators who serve as leads for biotechnology program instruction and development. As part of BioMADE's launch, this activity successfully exposed 500+ key stakeholders in the education and workforce development community to the scope of impact and capabilities of BioMADE. A follow-up with session attendees and new community participants was held during a BioMADE-sponsored session at the July 2021 NSF High Impact Technology Exchange Meeting.

Launching BioMADE–InnovATEBIO Biotechnology Leadership Academy:

In June 2021, BioMADE partnered with the NSF Advance Technology Education Program to develop and implement a Biotechnology Leadership Academy. This Leadership Academy engaged 22 nationally distributed community college biotechnology program department chairs to develop program leadership continuity and integrate bioindustrial manufacturing into course and program curricula. The event included an industry-driven five-day virtual workshop and was followed by phase two of the project, which involves critical analysis of case studies, experience-based application, and leadership reflection during the academic term.



Student in a BioMADE-InnovATEBIO biomanufacturing classroom at Solano Community College.
Credit: Jim DeKloe

INNOVATION ECOSYSTEM

“By bringing together government, academia, industry, and nonprofit organizations, BioMADE will harness the most creative science and most innovative technologies to develop solutions for the challenges associated with bioindustrial manufacturing. BioMADE will be a major growth engine of the U.S. economy.”

– Carol Christ, Chancellor,
University of California Berkeley

Launching BioMADE Website: BioMADE launched its website in April 2021. After further development, this website will be a one-stop shop for members, potential members, researchers, and the public about bioindustrial manufacturing.

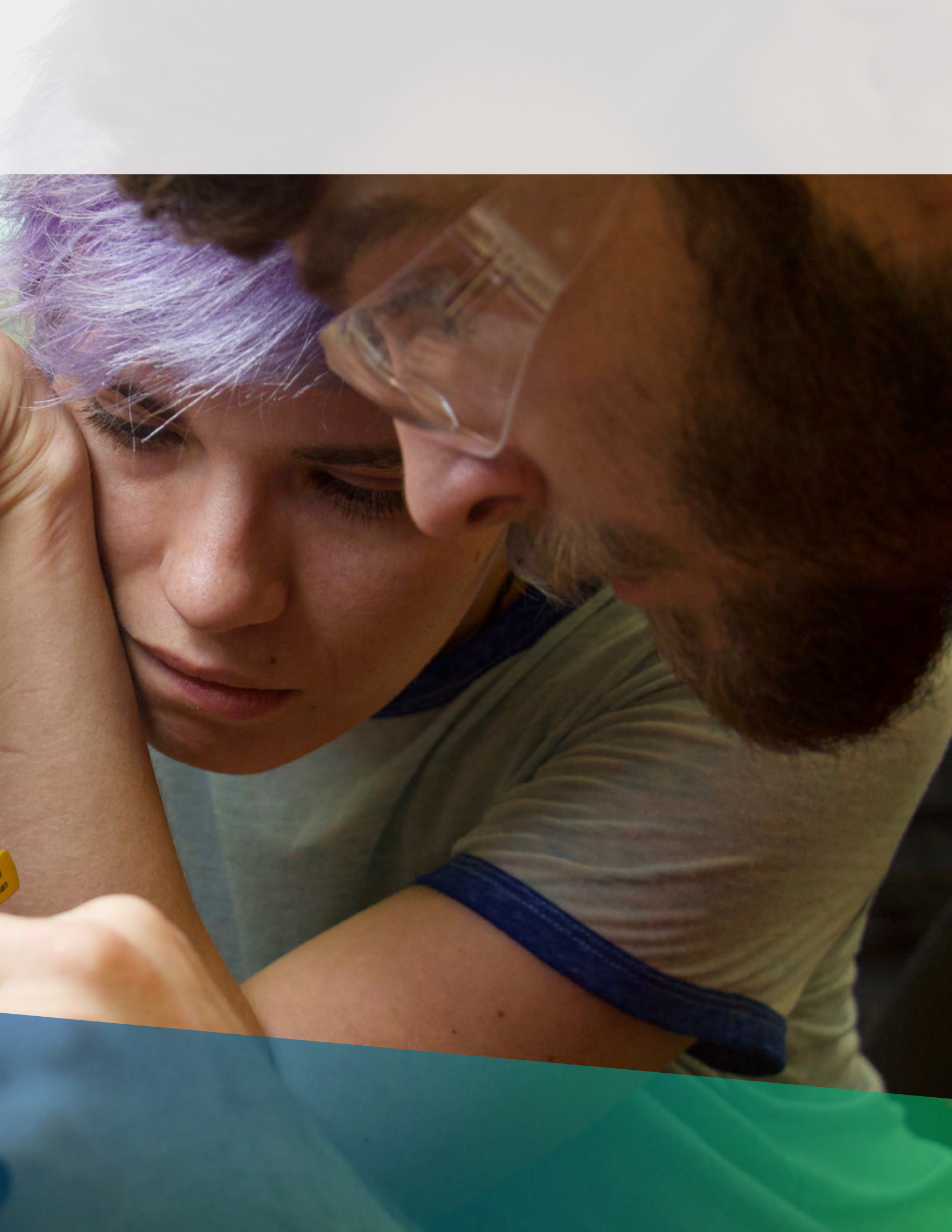
Advancing Federal Partnerships: In FY 2021, BioMADE established its Government Advisory Council of senior executive and military service personnel. The council meets quarterly to discuss BioMADE endeavors and opportunities, and the needs of DoD and other government partners.

Increasing Awareness and Broader Impacts for Bioindustrial Manufacturing: In April 2021, BioMADE leadership partnered with the NSF Advancing Research Impact in Society National Center to host a Summit for the Future of Technical Workforce in STEM. This event attracted 250 participants from workforce development and 4S (social responsibility, safety, security, and sustainability).



DEPARTMENT OF OF ENERGY INSTITUTE HIGHLIGHTS







Institute for Advanced Composites Manufacturing Innovation

Established: June 2015

Headquarters: Knoxville, TN

Mission: Create an ecosystem supporting innovation and workforce development to drive commercial outcomes and increase national competitiveness in the advanced-composites field.

Satellite Locations: IACMI Scale-Up Research Facility (SURF) (Detroit, MI); Michigan State University Composites Lab (Lansing, MI); University of Dayton Research Institute's Composites Laboratory (Dayton, OH); The Composites Manufacturing Education and Technology Facility (CoMET) at the National Renewable Energy Laboratory's Flatirons Campus (Boulder, CO); The Indiana Manufacturing Institute at Purdue University (West Lafayette, IN); The University of Tennessee's Fibers and Composites Manufacturing Facility (FCMF) (Knoxville, TN); Oak Ridge National Laboratory (Oak Ridge, TN); Vanderbilt University's Laboratory for Systems Integrity and Reliability (LASIR) (Nashville, TN); The University of Kentucky Center for Advanced Energy Research (Lexington, KY)

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

Members: 119

Funding: \$18.9 M Federal
\$22.6 M Non-Federal*

www.IACMI.org

* Federal dollars and cost share expended by the Institute during FY 2021 are reported here. It does not reflect federal funds appropriated in FY 2021 (if any) for given DOE Institute.

OVERVIEW

IACMI – The Composites Institute is a 100+ member community of industry, academia, and government agencies leading innovation and workforce development initiatives to drive the adoption of advanced composites, grow U.S. manufacturing, and support national security. Advanced composites provide strength and stiffness while being very lightweight, enabling advantages in transportation, energy, and infrastructure applications. Greater deployment of advanced composites can offer far-reaching benefits, such as safer, more energy-efficient vehicles.

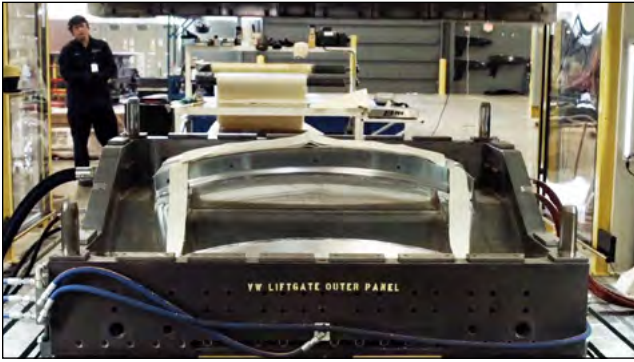
TECHNOLOGY ADVANCEMENT

“IACMI has proven to be truly effective at bringing academic-led research, government labs and industry into a collaborative environment to solve important manufacturing challenges. The recent successful demonstration of a practical method of joining thermoplastic composite assemblies may ultimately result in cost-effective technologies to fabricate wind turbine blades with entirely recoverable materials at end-of-life.”

–Steve Nolet, TPI Composites, Inc.

During FY 2021, the institute completed 11 projects. These projects address key challenges and opportunities facing the industry.

Automated Blade Finishing Trials Demonstrate Throughput Boost of 30%: An IACMI-supported automated blade finishing project successfully completed full-scale trials in a wind turbine factory that lower costs, improves worker safety, and has the capability to transform wind technology manufacturing. Launched in 2020, the partnership facilitated by IACMI among GE Renewable Energy, LM Wind Power and GE Research, and DOE’s National Renewable Energy Laboratory (NREL) enabled innovative solutions with meaningful impact on domestic wind blade manufacturing. Blade finishing includes trimming excess material after molding and grinding blade surface to meet quality requirements. The IACMI project leveraged knowledge of advanced composite processing along with sensing, robotics, and automation to develop low-cost solutions with potential to increase throughput by 30 % and improve health and safety in factories. Industrializing these R&D concepts aligns well with increasing deployment and reducing costs of wind power once implemented in a production environment. The program is supported by funding from DOE’s Advanced Manufacturing Office and Colorado’s Office of Economic Development and International Trade.



Volkswagen liftgate outer panel on Schuler compression press at IACMI's Scale-up Research Facility in Detroit.
Credit: IACMI

Lightweight Body Panels Reduce Weight and Cost in Vehicles: Lighter cars use less energy to travel the same distance, reducing operating costs and environmental impacts. For that reason, composites are increasingly replacing metal components on vehicles. Sheet molding compound, a common exterior composite body panel, offers significant mass reduction with high strength. An IACMI-led group—including automaker Volkswagen Group of America (VW), Continental Structural Plastics, Ashland Composites (now INEOS Composites), IDI Composites, Owens Corning, Oak Ridge National Laboratory, and academic partners University of Tennessee-Knoxville, Purdue University, and Michigan State University—spent 36 months developing the new composite to reduce processing costs, cycle times, and waste. The liftgate of VW's Atlas SUV was used to demonstrate the material. Sheet molding compound liftgates were molded, assembled to the body, and tested. Results showed a more than 35% reduction in weight from comparable steel bench and cost-competitive with comparable aluminum parts. The composite solution provides aesthetic, strength, and performance characteristics demanded by industry standards.

Vertical Axis Wind Turbine Research for Remote Power Generation: Recyclable plastic composites may soon enable decentralized wind-based power generation. Vertical-axis wind turbines could be well-suited to meet decentralized or remote energy needs, like powering marine vessels,

isolated cell phone towers, or disaster relief work. The work of an IACMI-supported innovation team led by Steelhead Composites is starting design, material and manufacturing technological development by investigating and developing thermoplastic composites technology for vertical-axis wind turbine application.

WORKFORCE DEVELOPMENT

IACMI's workforce development initiatives train the advanced manufacturing workforce on technologies immediately relevant to industry. IACMI's workforce development initiatives span K-12 STEM outreach, an internship program, and technician training opportunities. IACMI recognizes onshore manufacturing supports national security, and IACMI is training workers to meet those industry needs.

"IACMI and Vartega opened many doors for me, allowing me to become a project leader, attend industry events, offer client-facing solutions, and present my work. My IACMI internship has given me knowledge of the full life cycle of composites while strengthening my report writing, networking, and presentation skills. In 2020, I joined Vartega fulltime and now focus on scaling up our production and producing a consistent, high-quality material."

– Kylie Van Aken, IACMI intern in 2018 now at Vartega

IACI Advanced Composites Internship Program:

The IACMI intern program is based on structured experiential learning, mentorship, industry collaboration, and professional development. This program has provided 121 appointments of interns with 40 partners at 25 unique host sites including member companies, national labs, and universities. Collectively, students have received 50,000 participation hours working with mentors, peers, and partners to advance industry-led projects involving composites research and innovation.

Advanced Composites Career Pathways:

In late 2020 and 2021, IACMI expanded advanced composites training by partnering with the DoD to create a national Advanced Composites Career Pathways learning network for development of a skilled advanced composites manufacturing workforce to serve the supply chain. The workforce initiative is part of DoD's Office of Naval Research's Manufacturing Engineering Education Program to prepare current and next-generation manufacturing workers to produce military systems and components that assure defense technological leadership. Based on a best-in-class composites training program at Davis Technology College in Utah, composite technician learning centers are underway in three states: Enterprise State Community College in Enterprise, Alabama, East Florida State College in Cocoa, Florida, and at the Composites Prototyping Center in Long Island, New York.

America's Cutting Edge Launch:

IACMI launched a national training program, America's Cutting Edge, with DoD to address the nation's critical manufacturing skills gap and improve productivity competitiveness. The program empowers manufacturers to adopt cutting edge machine tool programming and technology for metals and composites. Using novel workforce training and education initiative helps manufacturers, particularly small and medium manufacturers, successfully deploy and implement modern tooling technology and sensors, enabling them to compete in today's evolving economy. Supported by DoD's Industrial Base Analysis and Sustainment (IBAS) Program

from the Office of Industrial Policy, the program brings together the scientific expertise of Oak Ridge National Laboratory and includes the University of Tennessee and Pellissippi State Community College in Knoxville as education partners. The program combines virtual training and machining simulation with hands-on training. To date, more than 1,600 student and industry participants in 47 states have enrolled in the online training component. Nearly 70 participants completed weeklong in-person training sessions during the summer at an East Tennessee testbed initiative.

Celebrating National Manufacturing Day:

IACMI and Michigan State University engaged with hundreds of students in Detroit to showcase employment opportunities in composites manufacturing as part of a Manufacturing Day event organized by the National Association of Manufacturers. IACMI and MSU engineers shared insights during virtual "Ask an Engineer" sessions, providing attendees information about composites-related organizations in their community and training opportunities for the future workforce.

INNOVATION ECOSYSTEM

IACMI continues to serve its membership and stakeholders through annual meetings, dedicated sessions at technical meetings, active engagement with industry trade and supporting organizations, demonstrations and exhibits in key conferences, targeted outreach to share information, and opportunities for collaboration.

Award Winning Organization:

In 2021, The Society for the Advancement of Materials and Process Engineering (SAMPE) North America recognized IACMI with its SAMPE 2021 Organizational Excellence Award. The award recognizes organizations from industry, academia, and government that exemplify the best of SAMPE from within the advanced materials and process community.



Reducing EMbodied-Energy and Decreasing Emissions

Established: May 2017

Headquarters: Rochester, NY

Mission: REMADE Institute focuses on mitigating technical and economic barriers to enable greater material recycling, recovery, remanufacturing, and reuse, and motivating industry investments to advance technology development in support of U.S. manufacturing.

Consortium Organizer: Sustainable Manufacturing Innovation Alliance

Members: 130

Funding: \$70 M Federal
\$70 M Non-Federal

www.remadeinstitute.org

OVERVIEW

The REMADE Institute collaborates with more than 130 industry, academic, national lab, and trade association partners to conduct applied research and development of key industrial technologies that could dramatically reduce the embodied energy and carbon emissions associated with materials production and processing.

To accomplish this, REMADE focuses on accelerating U.S. transition to a circular economy through technology innovations that will enable greater reuse, remanufacturing, recovery, and recycling of metals, fibers, plastics/polymers, and electronic waste. Since the institute's founding in 2017, REMADE has facilitated 61 projects, representing a total public-private investment value of \$52.4M. Cumulatively, the technologies developed through these projects can deliver the following annual benefits to U.S. manufacturers:

- Saving 1 quad of energy, the equivalent of conserving 180 million barrels of oil
- Reducing U.S. CO₂ emissions by 50 million metric tons, which is equivalent to taking 11.5 million cars off the road
- Creating up to 700,000 direct and indirect jobs to increase the nation's competitiveness
- Generating up to \$50 billion in new revenue to support U.S. economic growth

These CO₂ emissions savings, alone, represent more than 10% of annual manufacturing emissions in the U.S., making them critically important in the nation's fight against climate change and meeting multiple national energy, environmental, industrial decarbonization, and economic goals including net zero emissions economy-wide by 2050 and the creation of good-paying clean-energy jobs.

TECHNOLOGY ADVANCEMENT

"Networking with different members is probably one of the greatest assets of the institute, identifying topics of common interest, enacting projects, and seeing them come to fruition."

– Robert Radulescu, Michelin North America

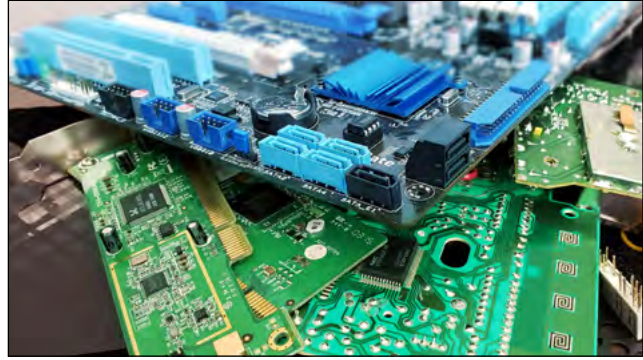
The REMADE technology portfolio is organized around five focus areas, designed to address cross-cutting challenges through applied research to enable the transition to a circular economy. REMADE is helping U.S. manufacturers tackle barriers that limit recovery, reuse, remanufacturing, and recycling of metals, fibers, polymers (plastics), and e-waste across the product lifecycle in industries as diverse as automotive, consumer products, electronics, and heavy-duty equipment.

Recycling Plastic for Sustainable Food Packaging:

Food packaging containers account for 30% of waste generation in the U.S., less than half of which is currently recycled. Multilayered packaging retains the product in a commercially sterile state for months or even years but is difficult to recycle. The project team--MuCell Extrusion LLC, Plastilene SAS, Wingate Packaging, Sugar Creek Packing Co, CIFT - Center for Innovative Food Technology, and The Ohio State University --is developing a process that would replace these multilayer materials with a single mono-material packaging solution produced from recycled PET (the same plastic that water bottles are made from). This packaging could also be recycled back into the same or comparable product with minimal reprocessing, handling, and transportation. The team is validating the performance of materials and manufacturing process at industrial scale and conducting a recycling pilot with the support of a material recycling facility to quantify recycling rates and recycled material quality. Following the successful completion of the project, implementation is anticipated through the Ohio Safe Food & Packaging Initiative.

Condition Assessment of Used Electronics for Remanufacturing:

One factor that limits electronics remanufacturing is the inability to detect solder joint and interconnect failures in printed circuit boards (PCBs). Although these defects, which account for 13% of all electronics failures, can be easily and effectively repaired once they have been identified, detecting these types of failures on used electronics is costly because inspections are performed manually. To reduce this barrier and increase the number of PCBs that can be remanufactured, the project team, comprised of Rochester Institute of Technology, Caterpillar, Inc., and CoreCentric Solutions evaluated several inspection methods to determine which successfully identified defects and could be cost-effectively implemented. The team is currently building an inspection system and decision support tool that will be validated at one of the team member's remanufacturing facilities. Once implemented, this technology is expected to increase PCB remanufacturing by 25-35% and reduce embodied energy by 30% compared to the current baseline.



Used Circuit Boards. Credit: REMADE Institute

Vehicle Design for High-Value Recycling of Aluminum:

The shift to electric vehicles (EVs) has many recycling and manufacturing repercussions: increasing the demand for high-quality aluminum auto body sheet and advanced high strength steels for light weighting; doubling the amount of copper wire (and thereby increasing end-of-life, or EOL, contamination); and potentially reducing demand for vehicle castings that could utilize the lower quality scrap. To address these end-of-life issues upfront, the project team (Ford Motor Company, Novelis, Argonne National Laboratory, The Aluminum Association, Institute of Scrap Recycling Industries and Light Metal Consultants) is developing a new recycling tool that considers how vehicle design, recycling system infrastructure, and sheet manufacturing process decisions impact factors such as EOL recycled content, closed and openloop recycling rates, greenhouse gas emissions, and primary feedstock consumption and energy demand under different scenarios up to the year 2050, when rapid deployment of EVs is anticipated. The tool will be integrated into the Argonne National Laboratory Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model. Once developed and implemented, this tool has the potential to reduce the consumption of primary steel and aluminum by 2.35 and 0.19 million metric tons, respectively.

Transitioning to a Circular Economy for PET and Olefin Polymers: Today, the U.S. recycles less than eight-and-a-half % of all plastic waste that is collected. With a focus on polyethylene terephthalate (PET) and olefin plastics, which together comprise nearly two-thirds of U.S. plastic production, the project team successfully built a model that evaluated how the manufacturing and recycling processes in a plastics circular economy can be configured to minimize energy consumption and reduce greenhouse gas emissions by 24% compared to current recycling approaches. In the next phase of the project, the team is expanding the model to include material flow analyses, material transportation and logistics analyses, recycling process modeling, energy and environmental life cycle assessments, techno-economic analyses, and regional and national economic studies. The model will be validated with a case study in Michigan in collaboration with the Michigan Department of Environment, Great Lakes, and Energy. This process will save material, energy, and emissions associated with plastic recycling and close the annual gap of more than one billion pounds between the current U.S. supply and projected 2025 demand for recycled PET for use in bottles. Project team members are Michigan Technological University, Idaho National Laboratory, Resource Recycling Systems, Yale University, Chemstations, and Honeywell UOP.

WORKFORCE DEVELOPMENT

"We feel it is important to collaborate on common challenges we deal with as remanufacturers. Workforce development is really key, and REMADE plays a big part in it. I appreciate what they've done to develop the REMADE Academy."

– Jena Holtberge-Benge, John Deere Reman

Launching REMADE Academy Learning Management System



In 2021, REMADE Institute was proud to launch the REMADE Academy learning management system offering more than 50 hours of unique training content including tiered certificate pathways, short courses, and recorded webinars. REMADE's position at the crossroads of academia, industry, and government enables the institute to draw from the nation's top subject matter experts to create training opportunities tailored to the needs of industry for emerging and incumbent engineers and technicians.

With the dramatic shift to online training due to the COVID-19 pandemic, REMADE worked with members to expand its catalog of asynchronous training, including the launch of the Emerging Trends in Plastics Recycling certificate program and the development of two new certificates that will launch in 2022: Advanced Fibers Recycling and Systems Analysis Tools & Insights from REMADE Projects. Over 2,500 people have participated in REMADE training events and online training since 2018 and more than 100 engineering and science students, including undergraduates, graduate students, and co-op students, have worked on REMADE projects.

With courses as diverse as Additive Repair Technologies for Remanufacturing, Chemical Recycling for Plastics, Product Design Considerations, and End of Life Recovery for a Circular Economy, REMADE is developing unique and valuable content for industries across the U.S. to improve sustainable manufacturing and accelerate the transition to a more circular economy.

INNOVATION ECOSYSTEMS

“By joining REMADE we have access to some of the best and brightest minds who offer smart and economical technology solutions to big problems.”

– Adam Shine, Vice President, Sunnking Inc.

Diversity of industry sectors, proliferation of small and medium sized businesses, and engagement of industry trade organizations are key drivers in the success of REMADE's innovation ecosystem. Membership highlights include:



REMADE Member Logos. Credit: REMADE

- 40% membership growth in 2021 and 94% retention rate
- 50% of industry members are classified as small and medium-sized businesses, who gain access to research and development through their collaboration with institute industry powerhouses with the scale to develop and commercialize new technology. These include such companies as Unilever, Ford Motor, Caterpillar, John Deere, Michelin, Nike, BASF, Alcoa, and Dow Chemical.
- Trade organizations, nonprofits, and affiliates that expand REMADE's sphere of influence to more than 4,000 entities across the United States, including Institute of Scrap Recycling Industries, American Chemistry Council, American Forest & Paper Association, The Aluminum Association, and more.
- Academic partners with a track record of innovation including Rochester Institute of Technology, University of Illinois-Urbana Champaign, Yale University, Massachusetts Institute of Technology, Georgia Tech, Michigan State, Penn State, Ohio State, University of Michigan, and more.

SUCCESS STORY

A Dynamic Techno-Economic Systems Modeling Framework for U.S. Fiber Recycling



Paper Strips Bales. Credit: Shutterstock

At the beginning of 2018, the global scrap market began experiencing unprecedented disruptions as the balance of trade between nations dramatically shifted. The impact in the U.S. was a 10% decrease in scrap exports to our primary customer (China) from 2016 to 2017, which required the U.S. to find alternate markets for 13.2M metric tons of this material.

In response, the project team – University of California-Santa Barbara, Northwestern University, Yale University, and Institute of Scrap Recycling Industries – developed a technology systems model to identify new process pathways for the U.S. fiber recycling industry to expand domestic capacity, improve profitability, and increase environmental benefits. This Paper Recycling Integrated System Model (PRISM) allows fiber recyclers and Institute of Scrap Recycling Industries members to modify process parameters, technologies, and operating practices at material recovery facilities and reprocessing mills to achieve REMADE's technical performance goals related to reducing embodied energy and emissions, increasing recycling rates and secondary feedstock use, and reaching cost parity. To broaden the potential benefits of this project, PRISM uses a web-based interface by Analytica software. Beta tests of this software identified pathways to reduce process energy use and greenhouse gas emissions at mills from 37%-83% and 15%-60%, respectively.



Clean Energy Smart Manufacturing Innovation Institute

Established: January 2017

Headquarters: Los Angeles, CA

Mission: To accelerate smart manufacturing adoption through the integration of advanced sensors, platforms, and controls to radically impact manufacturing performance through measurable improvements in areas such as quality, throughput, costs/profitability, safety, asset reliability, and energy productivity.

Consortium Organizer: University of California at Los Angeles (UCLA)

Members (as of 9/20/21): 134

Funding: \$11.8 M Federal
\$15.3 M Non-Federal*

www.cesmii.org

* Federal dollars and cost share expended by the Institute during FY 2021 are reported here. It does not reflect federal funds appropriated in FY 2021 (if any) for a given DOE Institute.

OVERVIEW

The Clean Energy Smart Manufacturing Innovation Institute (CESMII) is committed to transforming the U.S. manufacturing market through increased energy productivity and increasing global competitiveness via the application of smart manufacturing (SM) technologies. CESMII aims to achieve the following objectives through an integrated portfolio of projects, services, and training enabled by the Smart Manufacturing Innovation Platform (SMIP) and infrastructure:

- Research and develop SM technology to enable cost-effective information and communication technologies for real-time management and control of energy in manufacturing across the unit-process, facility, enterprise, and supply chain.
- Through collaborative R&D, advance key enabling technologies for SM, including advanced sensors, data analytics tools, process controls and data models, and build a unified innovation platform, marketplace, and ecosystem to scale SM to all U.S. manufacturers.
- Establish a technical education and workforce development program that leverages the national network of Smart Manufacturing Innovation Centers (SMICs).

TECHNOLOGY ADVANCEMENT

"Leveraging our CESMII membership, J&J implemented an SM strategy that resulted in improvements in predictive maintenance, chemical cleaning efficiency, and reduced waste of scrapped product. This all has indirect and direct impact on energy productivity."

– Ken Creasy, VP Smart Platforms Technology and Innovation, Johnson & Johnson

The institute's portfolio of projects grew in FY 2021 to 43. This included successful continuation of the 10 enabling R&D projects launched in FY 2019 and bringing three to completion. The institute's 34 new projects cover initiatives in new enabling key industry verticals, manufacturing use cases, R&D, education and workforce development, SMIP capabilities, innovation, and applications.

Smart Manufacturing for Thermally Intensive Processes:

This project developed by Virginia Tech and its partners automates process monitoring and control solutions to reduce energy consumption at Honeywell's composite brake manufacturing facilities. The solution includes a machine learning model for prediction of key performance indices, data-driven anomaly detection, as well as a hybrid (physics-based + data driven) model for predicting performance of carbon vapor deposition furnaces. The solution has been validated in a lab-based facility. Implementation of the solution at Honeywell is expected to result in a 15% decrease in energy consumption for the aerospace brake manufacturing process.

Predictive Control for Anti-Foaming Agent:

This project created by Auburn University and Rayonier Advanced Materials employs a soft sensor to monitor usage, wash water flow, and pulp quality in paper manufacturing with statistics pattern analysis and machine learning.

Finding Defects in Alloys with Ultrasound:

United Technologies Research Center, Purdue University, and the Connecticut Center for Advanced Technology Inc. are simulating and testing to determine the feasibility of identifying defects in engine parts, often used in the aerospace industry, and the impacts due to the remelting process.

Smart Manufacturing Innovation Platform (SMIP):

This platform is being developed by ThinkIQ for infrastructure, user-focused interfaces, and platform services to increase adoption by member organizations for CESMII's marketplace. The platform provides secure connectivity to equipment and processes, and adds valuable context, so that applications can access a firm's information intelligently and in an assisted or automated way. The key technology in the platform is Profiles, the standards CESMII is creating to contextually describe sensors, equipment, and processes, as well as the ability to create semantics for data, showing how variables relate to each other.

Reusable CNC Models for Energy and Operational Efficiency:

Models are in development for machines at South Bay Solutions in partnership with North Carolina State University for structured information and leveraging of SMIP capabilities.

An Edge-Computing Solution for Machine and Process Monitoring:

A solution is being created by TechSolve, the Ohio Manufacturing Extension Partnership, for AI-based prognostics, healthcare management, and integration with the CESMII SMIP for estimation of the remaining useful life of bearings or cutting tools.

WORKFORCE DEVELOPMENT

CESMII and the Society for Manufacturing Engineers announced a partnership to drive smart manufacturing further and faster by aligning resources and educating the industry to help companies boost productivity, build a strong talent pipeline, and reduce manufacturers' carbon footprint.

"Our vision, as two nonprofit organizations [CESMII and SME] focused on creating a more productive and competitive manufacturing environment, is completely aligned around accelerating the transformation of the U.S. manufacturing workforce."

– Jeannine Kunz, Vice President, Tooling U–SME

Education and workforce development is one of CESMII's four strategic pillars. The institute continues to democratize the knowledge for smart manufacturing accessibility for the U.S. manufacturing industry through formal education and informal knowledge sharing. Education and Workforce Development Roadmap Project teams are developing smart manufacturing curricula and hands-on tools to be shared in the education ecosystem. Two projects have been completed, four are in execution at university level, and four projects focused on workforce upskilling, credentials, and community college level education resources have been selected and will launch in FY 2022.

Successful Smart Manufacturing Workforce

Model: The project team of El Camino Community College (ECCC), California State University Northridge (CSUN), UC Los Angeles (UCLA), and UC Berkeley (UCB) leveraged existing education and workforce training systems to deliver the workforce needed for the adoption of SM. Their work resulted in: launching a SM certificate program at CSUN in Advanced Professional Development – Smart Manufacturing that is comprised of four 36-hour courses and an 18-hour project; incorporation of SM modeling and process control into existing UCLA chemical engineering classes that resulted in six journal publications; commitment from five California high school districts and colleges to adopt a new SM Career Pathway Program; and ECCC training of its incumbent workforce that resulted in engaging 53 manufacturers, training 2,017 employees and training-the-trainers with 17 colleges.

CESMII's In-Depth Training Content: Members are providing input on smart manufacturing technology, business practices, and workforce development through SME's training organization, Tooling U-SME, which leverages its extensive reach into industry and academia for training portfolios and new content collaborations. The partnership is expected to expedite smart manufacturing adoption and drive progress through transformational workforce development by identifying Will training gaps and content needed be identified for future programming.

The CESMII Knowledge Portal: CESMII's Knowledge Portal offers a wide array of resources for members, including articles, white papers, guides, and videos on smart manufacturing. The library offers resources from professionals and experts of all industries on topics including the fundamentals of smart manufacturing, demonstrations of the smart manufacturing platform, information modeling, machine learning, integration practices, and the impact of smart manufacturing on workforce, sustainability, energy productivity and supply chain resiliency. More than 300 users have accessed the library to date.

INNOVATION ECOSYSTEM

“CESMII is a very special organization, delivering game-changing guidance and technology for manufacturers, to support them in the transfer and adoption of new Smart Manufacturing technologies. CESMII provides CMTC the necessary resources to successfully engage California manufacturers in the deployment of smart solutions.”

– James Watson, President and CEO, California Manufacturing Technology Consulting

CESMII is “the home of smart manufacturing” and brings together a diverse ecosystem of manufacturers, systems integrators, technology vendors, and academic institutions to tackle challenges no single entity can address on its own. CESMII's Small-to-Medium Manufacturers Affinity Group – a collaborative working group of CESMII members – gives organizations a voice to shape the future of the institute's roadmap and initiatives, just as industry-focused affinity groups do for vertical markets.

CESMII is a network of networks, dedicated to driving Smart Manufacturing awareness, understanding, and adoption through the use of Smart Manufacturing Innovation Centers (SMICs). SMICs are stand-alone, innovative, value-driven centers that further CESMII's mission in a hands-on and learning-centric way. The SMICs increase the U.S. manufacturing ecosystem's exposure to SM technologies, knowledge, and collaboration. CESMII has increased its SMIC footprint from three to seven, along with an increased focus on small and mid-sized manufacturer) which represent over a large % of the U.S. manufacturing ecosystem. CESMII's SMICs are located at University of California Los Angeles, Rensselaer Polytechnic Institute, North Carolina State University, Purdue University, Penn State University, Case Western Reserve University, and Feyen Zylstra, Inc.

These SMICS are making significant strides in providing value to regional manufacturers, solution providers, and the entire manufacturing ecosystem. North Carolina State University and Rensselaer Polytechnic Institute (RPI) SMICs are successfully integrating manufacturing assets to the Smart Manufacturing Innovation Platform alongside UCLA and its El Camino Community College satellite. RPI is utilizing its connected assets as educational content for its undergraduate Design Lab and graduate-level Advanced Manufacturing Processes and Systems class to train on smart manufacturing in tool wear analyses, overall equipment effectiveness calculations, and energy monitoring analyses.

Efforts like these create powerful educational platforms to promote active and immersive learning for current and future manufacturing workforce development. Each of these SMIP integrations creates a smart manufacturing profile which will be made available to CESMII membership and drive reusability and simplify smart manufacturing adoption.



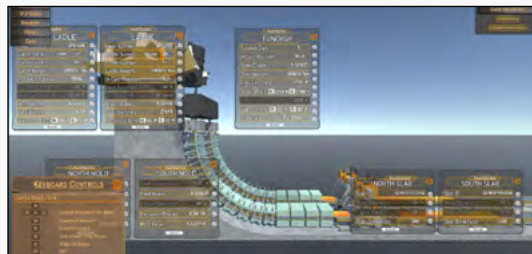
Making smart manufacturing more accessible to small-to-medium manufacturers. Credit: North Carolina State University

CESMII worked with small and medium-sized members to develop a variety of low cost, easy to use, and “smart” manufacturing solutions. CESMII worked with its Oregon State University (OSU) satellite to formalize an engagement model to integrate smart manufacturing into its energy assessments. OSU is currently the only DOE Industrial Assessment Center that incorporates Smart Manufacturing in energy productivity assessments conducted with SMMs. CESMII also has 12 Manufacturing Extension Partnership center as members and aligns the MEPs with their closest SMICs to engage SMMs in smart manufacturing technologies and knowledge.

SUCCESS STORIES

Smart Manufacturing Technologies Improving Quality and Productivity in Continuous Steel Casting

Smart Manufacturing Technologies Improving Quality and Productivity in Continuous Steel Casting: Project partners Arcelor Mittal, Missouri University of Science & Technology, Purdue University Northwest, and Rensselaer Polytechnic Institute are working to reduce effects and energy usage through advanced strain measurement, 3D displacement sensors and digital twin simulations for machine learning models. A small (<1%) savings in yield (from reduction of defects) is equivalent to an annual savings of \$90M for the whole U.S. steel industry,



Continuous caster digital twin.
Credit: Purdue University Northwest

along with more than 2.68 petajoules of energy savings per year or the equivalent of the annual combined energy use of 50,000 homes. In addition, predictive maintenance tools could save an additional \$2M per caster strand per year. The project goals include a developed and validated Smart Manufacturing technology to improve energy productivity through improved efficiency by 25% in five years, up to 50% in 10 years, and validation of smart manufacturing in first-of-kind applications for energy intensive manufacturing processes and facilities as replicable models for wide-spread deployment.

Smart Manufacturing Education Programs with CESMII Curriculum Recommendations

Smart Manufacturing Education Programs with CESMII Curriculum Recommendations: Manufacturers need trusted sources of up-to-date education to provide their workforce the skills needed to implement and sustain SM practices. In 2021, the institute established a new CESMII-endorsed label to promote Smart Manufacturing education programs that have been developed by partners and have adopted CESMII's curriculum recommendations. The SM Education Catalog includes five programs teaching a variety of SM skills with plans to increase the number of available programs in 2022. For more information on the SM Education Catalog visit: <https://www.cesmii.org/cesmii-education-program-catalog/>

CESMII-Endorsed Smart Manufacturing Education and Workforce Development Programs			
Course Title	CESMII-Endorsed Training Organization	Modality	Time Commitment
Smart Manufacturing: Moving from Static to Dynamic Operations	Massachusetts Institute of Technology	Instructor Led	50 hrs. over 10 wks.
Smart Manufacturing Certificate	North Carolina State University	Instructor Led	35 hrs.
Digital Manufacturing Professional	Penn-State University	Instructor Led	42 hrs. over 4 wks.
Advanced Professional Development – Smart Manufacturing	California State University Northridge (CSUN)	Instructor Led	36 hrs + 18 hr project
Smart Manufacturing: Moving Machine Data to the Cloud via MQTT	North Carolina State University	On Demand	12 hrs.



Rapid Advancement in Process Intensification Deployment Institute

Established: March 2017

Headquarters: New York, NY

Mission: Advance modular chemical process intensification technologies to reduce energy consumption, improve process efficiencies, and reduce investment and operating requirements.

Consortium Organizer: American Institute of Chemical Engineers (AIChE)

Members: 90

Funding: \$70 M Federal
\$95 M Non-Federal*

www.aiche.org/rapid

* Federal dollars and cost share expended by the Institute during FY 2021 are reported here. It does not reflect federal funds appropriated in FY 2021 (if any) for a given DOE Institute.

OVERVIEW

For more than 100 years, chemical engineers have developed processes based on standard unit operations and scaled those processes to build large, centralized manufacturing facilities. The industry is moving toward modular processes built on standardized, smaller-scale operations that can be scaled in number. Process intensification (PI) enables new combined-unit operations that are more energy- and raw-material efficient and safer to operate.

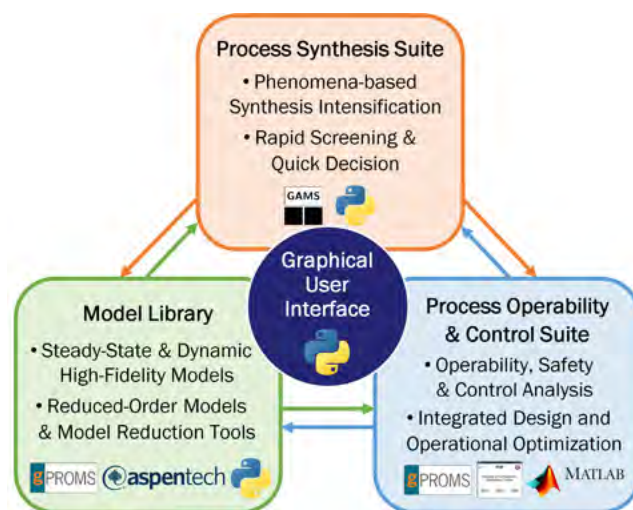
While modular processing and PI stand on their own, when combined into modular chemical process intensification (MCPI) they allow manufacturers to reduce risk by building and operating smaller footprint systems designed to produce just the amount of product needed to satisfy demand at any time, and then scale up to meet market needs. MCPI offers manufacturers the opportunity to build a more efficient, distributed supply chain that is both sustainable and resilient. RAPID was created to lead the nation's efforts to research and develop high-impact MCPI solutions for the benefit of members from industry, academia, national laboratories, and other nonprofits.

TECHNOLOGY ADVANCEMENT

RAPID worked with members to refine its technology roadmap, expanding areas of interest to include MCPI solutions for carbon capture and utilization, biomass and plastic waste reuse and valorization, and process electrification. Some technical projects of note include:

Intensified Continuous Manufacturing of Dispersants: University of Pittsburgh developed a continuous modular process to make an existing specialty chemical at much lower operating and capital cost. The new process has a smaller footprint in the manufacturing plant than the existing batch process and produces higher quality product with virtually no waste generation and 90% less energy. The project focused on production of specialty dispersants used in engine oil. During FY 2021, Pitt and partners at The Lubrizol Corporation designed

and built a second-generation modular process which entered commercial service. The modular, continuous manufacturing platform is being adopted as new standard practice at Lubrizol, lowering capital and operating cost, dramatically reducing energy, and shortening time to market.



*Schematic of SYNOPSIS structure and capabilities.
Credit: RAPID*

Synthesis of Operable Process Intensification:

The goal of the SYNOPSIS (SYNthesis of Operable ProcesS Intensification Systems) project is to develop a framework for the discovery of highly-intensive, verifiable, operable, and safe chemical process systems. SYNOPSIS will deliver generic software platforms, operability assessment tools, and model libraries for intensified operable modular chemical processes. The capabilities of the framework are being demonstrated on a methane conversion process for hydrogen and carbon products, including in silico and experimental validation. The SYNOPSIS team (Texas A&M University, Georgia Tech, Auburn University, Dow, Shell, and Siemens PSE) is developing a user-friendly demonstration software prototype tool with a Python-developed Graphical User Interface controlling the three distinct toolkits (process synthesis, model library and operability suite) as well as integrated functionality – starting with synthesis with operability, and design and control optimization.

Microwave Chemistry for Enhancing Natural

Gas: West Virginia University is developing direct routes for conversion of natural gas to value-added products using selective microwave reactor heating and catalysts. The new approach is more energy and capital efficient and could enable the conversion of U.S. natural gas resources to easily transportable liquid products. Initial techno-economic assessments indicate the potential for over 60% improvement in energy efficiency and 50% reduction in capital cost compared to a baseline indirect syngas route. Other project partners include the University of Pittsburgh, Shell, and the National Energy Technology Laboratory.

WORKFORCE DEVELOPMENT

RAPID is working with members to create and deploy educational content that ensures a robust pipeline of skilled engineers, operators, and technicians who can design, develop, and deploy modular chemical process intensification technologies. Highlights of RAPID's Education and Workforce Development activities include:

RAPID Internship Program: In this structured, 10-week virtual program, engineering undergraduate and graduate student interns at RAPID member organizations join a virtual community and receive online safety, technical, and leadership training, as well as professional development and mentorship. The program helps smaller organizations gain access to interns nationwide and allows their student interns to become part of a broad virtual network across the U.S. This creates a shared learning community and offers interns the chance to network with students at peer organizations. The combination of technical know-how and professional development gives interns the diversity of skills necessary to be successful in the workforce. Through Fall 2021, 103 interns have participated in the program at more than 20 universities and companies. RAPID continues to offer spring, summer, and fall rotations, engaging at least 70 new students each year.

Process Intensification (PI) Credential: Building on a strong portfolio of eLearning courses, RAPID developed a new credential program for learners interested in becoming expert in modular chemical process intensification concepts. Registrants take four core courses, including Fundamentals of PI, Process Design for PI, Modeling & Simulation for PI, and Introduction to MCPI, and one elective. Learners complete the online courses and a comprehensive test to receive a PI credential.

ChemE Cube: In 2021, RAPID launched a new chemical engineering undergraduate student competition. Student teams from five RAPID member universities (Carnegie Mellon University, Missouri University of Science and Technology, North Carolina State University, University of Delaware, and University of Pittsburgh) participated in the pilot competition to design, build, and demonstrate a one-cubic foot manufacturing plant. Designed around the theme of modular on-demand water purification, teams effectively demonstrated teamwork, creativity and innovation, sustainable development, and diversity and inclusion. Teams competed on cube performance via a head-to-head duel and promoted their technology in a three-minute ad, poster, and 20-minute "shark tank" style pitch to a panel of mock investors.

Woody-Plant Matter Wastes to Sugars and Other Biobased Products: Biomass has long promised to be a source for low cost, sustainable feedstocks—particularly C5 and C6 sugars—for production of specialty chemicals and performance materials. However, the breakdown of woody-plant matter (lignocellulose) into fermentable sugars is among the major challenges in producing sustainable products such as cellulosic biofuels and other biobased products. Typical pretreatment methods (e.g., enzymatic hydrolysis) used to convert biomass to sugars are energy intensive and expensive, accounting for as much as 30% of the cost of producing cellulosic biofuels. Further, most pretreatments do not completely fractionate lignin and cellulose.



Demonstration autothermal pyrolysis unit at Iowa State University based on RAPID-funded pilot work. Credit: RAPID

In this project, a team led by Professor Robert Brown at Iowa State University, in partnership with Stine Seeds, developed a pyrolysis-based Modular Energy Production System (MEPS) for the thermal deconstruction of lignocellulosic biomass into C5 and C6 sugars and other value-added products, including phenolic oil. The MEPS concept promises to intensify and modularize biorefineries, simplify design, reduce energy consumption, and increase feedstock throughput. In the MEPS concept, mass-produced modules are sized to fit in standard shipping containers and ready for field integration to form fully operational biorefineries at a smaller footprint and on-demand scale. MEPS will allow for distributed biomass processing at point of generation to significantly reduce logistical time and cost hurdles for feedstock and products.

The team recently built and installed MEPS modules to create a pilot biorefinery at a test location on Iowa State's campus. Lab and pilot scale results were consistent and successful across a range of biomass feedstocks. The team also extended the process to demonstrate conversion of waste plastics feedstock to oxygenated bio-oils (e.g., fatty acids, carbohydrates, and other related compounds). In collaboration with RAPID, Clemson University, and Sandia National Laboratory, Iowa State won funding for a project from the DARPA ReSource program to convert warfighter-generated plastic to fermentable products for eventual conversion to protein-rich foodstuffs for human consumption.



POWERAMERICA

The Next-generation Power Electronics Manufacturing Innovation Institute

Established: January 2015

Headquarters: Raleigh, NC

Mission: The PowerAmerica institute led by 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.

Consortium Organizer: North Carolina State University

Members: 68

Funding: \$9.3M Federal
\$8.5 M Non-Federal
(Note: DOE funding ended 4/20/21)

poweramericainstitute.org

OVERVIEW

PowerAmerica was created to help ensure U.S. global leadership in the development and adoption of advanced power electronics 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 and are smaller and more energy efficient than the high-power electronics widely available today.

The institute's objective is to reduce the cost and perceived risk inherent with this new technology. PowerAmerica brings together top researchers, industry, and government to foster an exchange of knowledge and processes and help develop a skilled workforce. This enables U.S. industry to develop more innovative power electronics products and systems.

Wide bandgap semiconductors can greatly improve energy savings in industrial processes, data centers, and consumer devices; increase electric vehicle driving range; and help integrate renewable energy onto the electric grid – all while reducing the impact on the environment.

TECHNOLOGY ADVANCEMENT

High-Volume, Low-Cost 150-mm Silicon-Carbon (SiC) Microchip Fabrication: This project supported the establishment of high-volume low-cost SiC device manufacturing in Microchip's Fab5, located in Colorado Springs, Co. Processing SiC in mature, fully depreciated Si units requires a modest capital investment and provides the surplus wafer capacity to maximize the factory's utilization. In addition, it exploits silicon economies of scale in producing SiC devices. The project successfully installed SiC device fabrication capability, developed process flows, and fabricated and tested for reliability. Through this project, domestic microelectronics fabrication was strengthened, and high-tech jobs were created. Below is a table showing SiC device applications:

Microchip Production and Updated Transistors for Semiconductors: Using the Microchip USA factories, this project designed and fabricated electronic transistors to compete with and displace older models. The large volume markets for these SiC devices include high power traction, transmission, distribution, medical, and defense. Reliability and ruggedness testing strengthened microelectronics domestic fabrication.

Enabling High Voltage Power Module Commercialization and Manufacturing: The mass volume electric vehicle market is leading to major development and commercialization of high voltage SiC devices, modules, circuits, systems. This project enabled US-based production manufacturing capability for all-SiC medium and high voltage power modules with superior attributes in high voltage wide bandgap devices. The project developed module evaluation kits with fast short circuit and voltage protection. This Wolfspeed project at Fayetteville promoted newly developed high-voltage module applications within critical electromagnetic interference and compatibility systems to reduce signal disruption.

Asynchronous Microgrid Power Conditioning System: High voltage SiC electronic parts connected in series are crucial in renewable energy grids, large motor drives, and fast electrical vehicle charging for potential microgrids, and has fallen behind as companies allocate resources to develop lucrative electric vehicle designs. This project in collaboration with North Carolina State University completed a new gate design and testing for in-series components. A signal converter was built and tested at high power with voltage reaching 97.2% energy efficiency. These series connections of high voltage devices allow larger applications of this work toward important demonstration and commercialization projects for future connected grid amenities.



Cybersecurity Manufacturing Innovation Institute

Established: September 2020

Headquarters: San Antonio, TX

Mission: The Cybersecurity Manufacturing Innovation Institute (CyManII) introduces a cybersecure energy-return on investment (ROI) for energy-efficient manufacturing and supply chains to secure and sustain American leadership in global manufacturing competitiveness.

Consortium Organizer: The University of Texas at San Antonio

Members: 42

Funding: \$3.4 M Federal

\$4.9 M Non-Federal

*Funded by the U.S. Department of Energy and led by The University of Texas at San Antonio, CyManII was launched in FY 2020 and comprises 59 proposed members: three Department of Energy National Laboratories (Idaho National Laboratory, Oak Ridge National Laboratory, and Sandia National Laboratories), four manufacturing innovation institutes, 24 universities, 18 industry leaders, and 10 nonprofits. This national network of members will drive impact across the nation and solve the biggest cybersecurity challenges facing the U.S manufacturing industry.

www.cymanii.org

APPENDIX A: FEDERAL AGENCIES PARTICIPATING IN MANUFACTURING USA

Department of Commerce

The U.S. Department of Commerce (DOC) mission is to create the conditions for economic growth and opportunity for the nation. The Department hosts the Advanced Manufacturing National Program Office (AMNPO), an interagency team with participation from federal agencies involved in advanced manufacturing. The AMNPO oversees planning, management, and coordination of Manufacturing USA.

The DOC conducts open-topic competitions for institutes, in which industry is invited to propose institutes dedicated to any advanced manufacturing area where new manufacturing technology development is not adequately addressed. The National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) is the first institute with a focus area proposed by industry and the first funded by DOC.

The Department more broadly increases regional and national capacity for innovative manufacturing through partnerships with state and local governments, academic institutions, and the private sector. Through its convening power, regional economic-development programs, and statistical and economic analysis, it empowers industry-driven solutions to the shortage of in-demand skills. Finally, DOC supports research and development leading to transformative changes in technology and promotes intellectual-property policy that supports and protects innovation. By all these means, the DOC helps 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 DOC's National Institute of Standards and Technology (NIST) is the only research laboratory in the U.S. Government specifically focused on enhancing industrial competitiveness; its robust research portfolio is concentrated on the technical challenges associated with advanced manufacturing. In addition, the Manufacturing Extension Partnership National Network is a critical resource for engaging small and medium-sized manufacturers to develop new products, expand into global markets, and adopt new technologies, such as those being developed at the Manufacturing USA institutes. NIST also serves as headquarters for the AMNPO.

Department of Defense

DoD provides a staffed, trained, and equipped military force needed to deter aggression and protect the security of our nation. To transition DoD science and technology advances into production, the Department must have access to a robust and responsive U.S. industrial base equipped with advanced manufacturing technologies that deliver critical products and systems affordably and rapidly. To help develop the technology and manufacturing ecosystems needed to support the Department's mission, the DoD established nine Manufacturing Innovation Institutes (DoD MIIs) through the Office of the Secretary of Defense Manufacturing Technology program. Unlike the other manufacturing institutes, the DoD-sponsored institutes have the additional mission to develop innovative technologies that will ultimately aid the warfighter.

The DoD MIIs address commercial and defense manufacturing needs via public-private partnerships with active participation and support from the military departments and defense agencies. The institutes' flexible business models and focus on highly collaborative R&D catalyze important new organizational relationships across government, industry, and academia. Under the leadership of the Under Secretary of Defense for Research and Engineering, DoD continues to foster long-term engagement with its institutes to support the DoD critical technology areas. Already, the institutes have shown progress in support of cybersecurity for manufacturing, microelectronics, biotechnology, hypersonics, and autonomy, among other technology priorities.

The DoD intends to continue strategic partnerships with their institutes to further enable the development of defense-critical technologies into affordable, domestic defense products. Continued engagement helps to maintain and enhance manufacturing innovation ecosystems. By fostering Department engagement, these public-private partnerships help ensure domestic and defense manufacturing needs can be met while protecting intellectual property and providing overmatching technology to the warfighter. The DoD institutes further the Department's vision for a national technology innovation base and help ensure that key advanced technologies that are invented in the U.S. are manufactured in the U.S.

At the end of 2020, the DoD awarded a ninth institute, BIOMADE, focused on bioindustrial manufacturing of non-medical materials.

Department of Education

The mission of the U.S. Department of Education is to promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access. The Department administers the \$1.4 billion Carl D. Perkins Career and Technical Education Act, the purpose of which is to develop more fully the academic and career and technical and employability skills of secondary education students and postsecondary education students who elect to enroll in career and technical education programs.

The Department has been active in helping develop Manufacturing USA from its formation. In the past year, the Department has been working with the Department of Defense to plan upcoming technical assistance efforts. The overall objectives of such assistance are to support participating institutes to position themselves as key intermediaries between secondary and postsecondary institutions, companies of all sizes, relevant local and state governments, and other key players in the workforce education system. Such efforts are to foster next-generation career and technical education pathways for students, helping them to attain careers in advanced manufacturing. A keynote of upcoming assistance will be to assure that workforce education efforts support diversity, equity, inclusion, and accessibility.

Department of Energy

The DOE Advanced Manufacturing Office (AMO) — within the Office of Energy Efficiency & Renewable Energy (EERE) — is the only technology development office within the U.S. Government dedicated to improving the energy and resource efficiency of manufacturers across the industrial sector. Effective and efficient use of energy, water, and material resources in manufacturing is essential for the nation's energy security, economic competitiveness, and environmental stewardship.

AMO partners with manufacturers, not-for-profits, universities, national laboratories, and state and local governments to develop technologies that will improve energy productivity and make the U.S. manufacturing sector more competitive and efficient. By addressing energy related manufacturing challenges and reducing risk through merit-based research and development, adoption of AMO-developed technologies can save energy and lower expenses for industry, reduce emissions, industrial waste, materials, and water usage, and improve the life cycle energy of manufactured goods.

At the end of 2020, DOE awarded a sixth institute, Cybersecurity in Manufacturing Innovation Institute (CyManII), focused on cybersecurity in manufacturing.

Department of Health and Human Services

The mission of the U.S. Department of Health and Human Services (HHS) is to enhance and protect the health and well-being of all Americans. The Department achieves this mission by providing for effective health and human services and fostering advances in medicine, public health, and social services. The HHS considers robust manufacturing to be critical to public health security and resilience in the U.S.

The Food and Drug Administration (FDA), an operating division within the HHS, is responsible for protecting public health by ensuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation. The FDA continues to support development of new tools, standards, and approaches to evaluate the advanced manufacturing of FDA-regulated products. During the 2020 COVID-19 pandemic response, FDA collaborated with Manufacturing USA institutes, especially America Makes, to facilitate use of advanced manufacturing, where possible, for pandemic response and improvements to future responses. The FDA also has several Working Groups that monitor the technology landscape and work closely with Manufacturing USA Institutes. Promising technologies 5 to 10 years in the future are explored by the FDA Emerging Sciences and Technology Working Group. Technologies that are ready for implementation and adoption are considered by the FDA Advanced Manufacturing

Technologies Working Group. Furthermore, the FDA awards projects through the FDA's Broad Agency Announcement to support emerging and enabling technologies for advanced manufacturing. Several of the FDA product Centers also have programs to facilitate and foster use of advanced technologies in medical products.

The HHS Biomedical Advanced Research and Development Authority (BARDA) engages regularly with manufacturing organizations through its DRIVE Broad Agency Announcement for funding proposals as well as through outreach efforts. BARDA has allocated \$6.5 billion in CARES Act funding to various critical manufacturing and development projects for pandemic response, including advanced manufacturing activities that will improve supply chain resilience and manufacturing efficiency.

Department of Labor

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

ETA oversees a diverse portfolio of programs and services provided by the public workforce system, a network of federal, state, and local government-funded agencies and programs. The public workforce system delivers quality job opportunities and assistance in acquiring skills and credentials to workers and connects businesses with skilled workers to meet their workforce needs. Partnerships at the federal, state, and regional levels connect employers, educational institutions, the public workforce system, and economic development partners to address the workforce needs of industry sectors, such as advanced manufacturing. These partnerships ensure that job creators have the talent they need to grow and thrive and provide job seekers the opportunity to develop in-demand skills through work-based learning and Registered Apprenticeships and to earn industry-recognized credentials.

ETA supports and is part of the Manufacturing USA Interagency Working Team and the Manufacturing USA Education and Workforce Subcommittee. The agency continues to engage in partnerships, share tools and resources, and identify strategies that can be leveraged to support the Manufacturing USA institutes.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration is the United States government agency responsible for aeronautics, space exploration, space technology, space and Earth science. NASA contributes to our Nation's economic competitiveness, fueling growth in American industry and supporting quality, high-paying jobs across the country. NASA emphasizes leadership in climate change, as a leading provider of Earth systems science and data. NASA also inspires young explorers, scientists, and technologists who will lead our Nation's skilled STEM workforce.

The Space Technology Mission Directorate (STMD) is the NASA organization most closely related to Manufacturing USA. STMD invests in transformational technologies that help offset future mission risk, reduce cost, advance capabilities that enable NASA's missions, and support space industry growth and high-quality job creation. STMD identifies and promotes research and technology development, demonstrates applicability, and supports the infusion of these technologies into NASA's exploration and science missions as well as commercial space activities.

Advanced manufacturing research and development within STMD is focused on several areas, including in-space manufacturing, additive manufacturing, advanced materials, polymer matrix composites, metals processing and joining, digital transformation, and other technology development areas critical to achieving NASA's missions. Research and development are conducted through a combination of in-house activities at NASA centers, competitively funded research with universities and industry, and collaborations with other agencies. The rapid infusion of advanced manufacturing technologies into mission applications is a major emphasis of NASA's technology investment strategy.

National Science Foundation

The National Science Foundation (NSF) works to promote the progress of science and maintain our Nation's scientific leadership and global competitiveness. It supports basic research and education in all fields of fundamental science and engineering, other than medical sciences, to create knowledge that transforms the future.

NSF supports fundamental advanced manufacturing research, education, and workforce training through awards from almost all of its Directorates and Offices. The most targeted support is provided through the Advanced Manufacturing Program, and through the Future Manufacturing solicitation, first published in 2020. NSF 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.

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. NSF strives to encourage the full participation of all Americans in STEM and to remove barriers to their doing so.

All NSF programs welcome the submission of proposals to collaborate with Manufacturing USA institutes on cutting-edge research and educational projects, and it is expected that the incorporation of the resources, expertise, and experience of the institutes and their member companies will increase the competitiveness of such proposals in merit review.

U.S. Department of Agriculture

The U.S. Department of Agriculture (USDA) provides leadership on food, agriculture, natural resources, rural development, nutrition, and related issues based on public policy, the best available science, and effective management.

USDA focuses on collaborative science which aligns work in fundamental and applied research funded through extramural and intramural research programs and recognizes that manufacturing is part of value-added innovations that have an important role in maximizing the benefits of a sustainable rural economy. Of specific interest is the expansion of the bio-economy, which has the potential for the sustainable harvest and use of substantial renewable biomass in the U.S. to support existing food, feed, and fiber markets while creating new jobs. The bio-economy is supported by innovation in biomanufacturing, biotechnology, and bioproduct development. Innovation in scaling up biomanufacturing can improve technology to more efficiently and sustainably process biological materials to produce high-value bioproducts. Biotechnology can create new or improved biomaterials, and engineer forestry and agriculture crops to adapt to vulnerabilities from climate change to sustain the production of food and non-food products.

USDA supports research, development, and deployment of forest and agricultural feedstocks to produce biobased products such as biofuels, industrial chemical intermediates, performance polymers, and finished higher-value products, as well as biotechnologies to support new markets, such as cellular agriculture, alternative proteins, and precision nutrition.

APPENDIX B: ADVANCED MANUFACTURING NATIONAL PROGRAM OFFICE INTERAGENCY WORKING TEAM PARTICIPANTS

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Advanced Manufacturing National Program Office

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