REPORT TO CONGRESS
FY 2020

Including COVID-19 Emergency Response Highlights

June 2021

About This Document

This annual Report to Congress documents the progress of the Manufacturing USA program in meeting its goals and highlights accomplishments of the federal agency-sponsored manufacturing institutes that participated in the Manufacturing USA program in fiscal year 2020.

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Executive Summary

Manufacturing USA® brings together nine federal agencies to collaborate with industry and academia using a "whole-of-government" approach to ensure U.S. global competitiveness through innovation and development of advanced manufacturing technologies and skilled workers needed by industry. In this fiscal year, three federal agencies within the Manufacturing USA network managed manufacturing innovation institutes: the Department of Commerce with one institute, the Department of Defense with eight institutes (with a ninth established early in FY 2021), and the Department of Energy with five institutes (and a sixth established in late FY 2020). The Advanced Manufacturing National Program Office at DOC's National Institute of Standards and Technology oversees the coordinated activities of Manufacturing USA.

Each institute is established by its lead government agency as a public-private partnership focused on a specific technology area of critical importance to the nation's ability to establish and maintain leadership in advanced manufacturing. The institutes convene and connect their member organizations, which are comprised of companies, universities, community colleges, state and local governments, and Manufacturing Extension Partnership centers. Institute members collaborate to solve the unique manufacturing challenges within the institute's specific technology area and to educate and train the workforce needed in these new technologies. These unique ecosystems also serve as invaluable resources for the federal government to leverage to tackle agency-specific problems.

The manufacturing ecosystems associated with individual institutes prepare each to address not only the long-term well-being of the nation but also to quickly respond to national emergencies such as the COVID-19 pandemic. In March 2020, the institutes-initiated projects and activities to solve pandemic-related problems ranging from the shortage of personal protective equipment to rapid diagnostic tests. Funding from the Coronavirus Aid, Relief, and Economic Security Act (CARES Act) through DoD and DOC equipped the institutes to address manufacturing and supply chain issues specific to the current pandemic, while preparing the nation to address future emergencies.

The Manufacturing USA network continued to build on years of best practices through close collaboration across agencies and institutes. Agencies met regularly to share their institutes' progress and discuss lessons learned around the pandemic. The institutes also participated in standing meetings with their agencies and each other to explore opportunities for additional cross-institute projects and collaborations.

The need for more skilled workers trained in advanced technology continues to be a major problem for manufacturers. The institutes are well equipped to address this need in their special fields, and the pandemic prompted them to augment their on-line tools to make their innovative advanced manufacturing education and training even more widely available, including for underserved communities and communities experiencing poverty.

In FY 2020, the institutes:

- Conducted over **500** major applied research and development collaboration projects of high priority for broad industry sectors.
- Engaged **over 2,000** member organizations. 62% of members are manufacturing firms and 72% of these industry members are small manufacturers, which are key to the U.S. manufacturing supply chain.
- Educated and trained more than **70,000** workers, students, and educators through institute workforce efforts. Analysis showed that few direct industry resources are allocated for education and workforce training, indicating that the institutes must rely on federal and other non-corporate resources to support workforce training.
- Attracted **$262M** in funds from state, private investment, and federal funds not part of the base federal funding, leveraging $163M in base federal funds. This **1.6 to 1 investment match** exceeds the program design of a 1 to 1 match and represents the catalyzing effect of matching investment.

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Introduction – Ensuring American Competitiveness

The federal agencies participating in the Manufacturing USA network have established a whole-of-government innovation framework that accelerates U.S.-based technology developments to the forefront of advanced manufacturing, allowing the U.S. to remain globally competitive in the ever-expanding frontiers of manufacturing. In FY 2020, three federal agencies partnered with 14 manufacturing innovation institutes: the Department of Commerce (DOC) with one institute, the Department of Defense (DoD) with eight, and the Department of Energy (DOE) with five.[1] The institutes are established by their lead agency as public-private partnerships that connect members from U.S. industry, academia, and government to collaboratively solve manufacturing challenges in key technology areas.

While lead agencies stand up their institutes with missions specific to their agency's needs, all institutes in the Manufacturing USA network share a common vision: ensure that *the Nation's highest priority inventions and innovations are scaled up and produced in the United States*. Each institute advances a different manufacturing technology, such as biopharmaceutical manufacturing, integrated photonic manufacturing, or wide-bandgap power electronics manufacturing. Other institute topics such as smart manufacturing and cybersecurity in manufacturing serve to improve the integration and security of advanced technologies used in all fields of manufacturing. The institutes advance technologies through collaborative pre-competitive research by their membership base made up of organizations from across industry, academia, and government. The institute provides their members shared access to capital-intensive infrastructure that equips U.S. innovators of all sizes to bring their ideas to reality. The institutes also partner with organizations to educate and train workers in the manufacturing skills needed by U.S. manufacturers in these new fields.

The United States continues to face significant manufacturing challenges. The threat to U.S. leadership in advanced manufacturing technology remains high, including serious supply chain difficulties and fierce international competition. Despite a long history of global leadership in advanced technology products, our trade deficit in these products continues to grow.[2] Additionally, there are not enough U.S. workers trained in the skills needed by today's manufacturers. Within each technology focus, the institutes provide the infrastructure and collaborative environment needed to help alleviate these shortfalls.

This Report to Congress[3] describes how the Manufacturing USA network addressed these challenges in FY 2020.

Organization and Management

Manufacturing USA includes nine member agencies: The Departments of Commerce, Defense, and Energy, which each partner and oversee their own institutes; the Departments of Agriculture, Education, Health and Human Services, and Labor; the National Aeronautics and Space Administration; and the National Science Foundation. The Advanced Manufacturing National Program Office (AMNPO), at DOC's National Institute of Standards and Technology (NIST), oversees the coordinated activities of Manufacturing USA and convenes the Manufacturing USA interagency team.

DOC, DoD, and DOE coordinate with the other federal agencies through the AMNPO, enabling cooperation over a wide range of support activities. Manufacturing USA's national goals, while well aligned with each individual agency's mission, are best realized by a whole-of-government effort that focuses broadly on increasing U.S. advanced manufacturing competitiveness.

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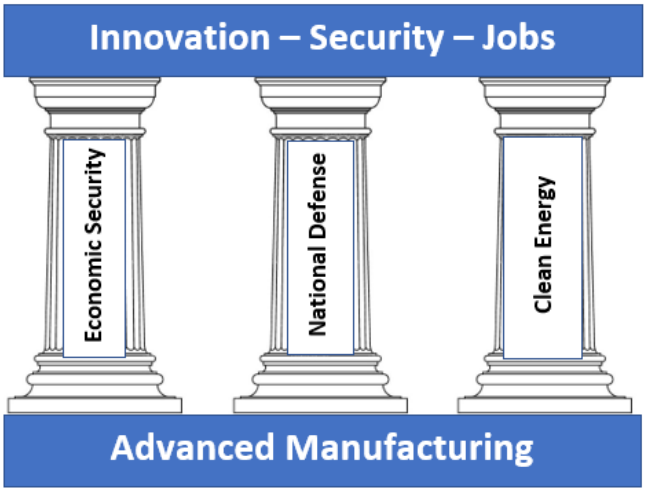
[1] DOE and DoD held competitions for two new institutes in FY 2020, and awards were made in late FY 2020 and early FY 2021.
[2] The trade deficit in advanced technology products grew approximately 40% in 2020. https://www.census.gov/foreign-trade/balance/c0007.html#2020.
[3] 15 U.S.C. § 278s(i)(2), as amended. http://uscode.house.gov/view.xhtml?req=(title:15 section:278s edition:prelim).

Vision, Mission, and Goals



As articulated in the program's strategic plan, the vision of the Manufacturing USA network is "*U.S. global leadership in advanced manufacturing.*"[4]

To achieve this vision, the network's mission is:

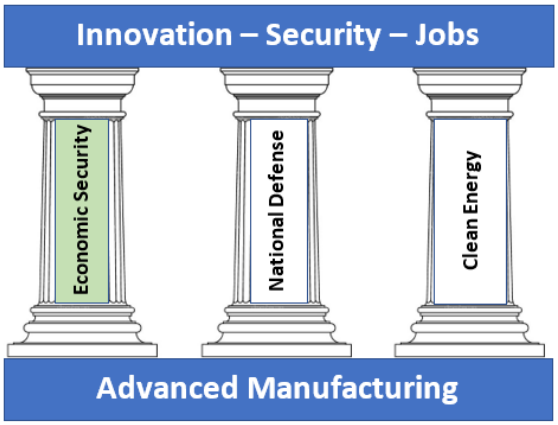
> *"Connecting people, ideas, and technology to solve industry-relevant advanced manufacturing challenges, thereby enhancing industrial competitiveness and economic growth, and strengthening our national security*."[5]

Manufacturing USA's four goals are to:

- Increase the competitiveness of U.S. manufacturing;
- Facilitate the transition of innovative technologies into scalable, cost-effective, and high-performing domestic manufacturing capabilities;
- Accelerate the development of an advanced manufacturing workforce; and
- Support business models that help the institutes become stable and sustainable.

The institutes serve as core resources for meeting the Manufacturing USA goals. DoD, DOE, and DOC established and oversee institutes that help develop technology ecosystems. The DoD Manufacturing Innovation Institutes (MIIs) have the additional mission to develop innovative technologies that aid the warfighter. The DOE Office of Energy Efficiency & Renewable Energy, Advanced Manufacturing Office also establishes Clean Energy Manufacturing Innovation Institutes to bolster U.S. energy efficiency and innovation.

Department of Commerce: NIST Office of Advanced Manufacturing



The NIST Office of Advanced Manufacturing (OAM) helps coordinate advanced manufacturing outreach by working with other federal agencies. OAM serves as the headquarters for the AMNPO, which is authorized by the Congress to collaborate with federal departments and agencies with missions that contribute to, or are affected by, advanced manufacturing.

OAM also sponsors the National Institute for Innovation in Manufacturing Biopharmaceuticals, or NIIMBL (the DOC-sponsored Manufacturing USA institute). The DOC institute's focus is exclusively on the U.S biopharmaceutical industry and economic competitiveness via manufacturing technology and workforce development.

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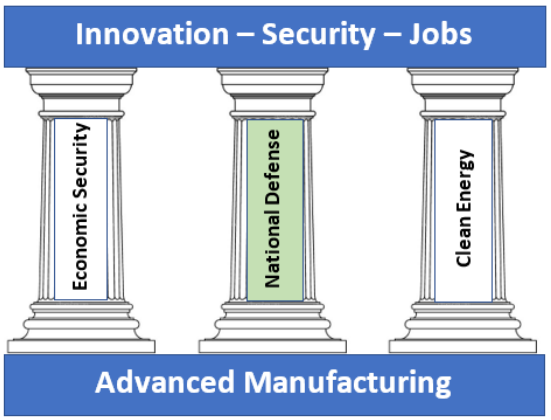
[4] *Manufacturing USA Strategic Plan*, Advanced Manufacturing National Program Office, p. 4 (November 2019), https://www.manufacturingusa.com/reports/manufacturing-usa-strategic-plan

[5] Ibid.

Department of Defense and the Defense Manufacturing Technology Program



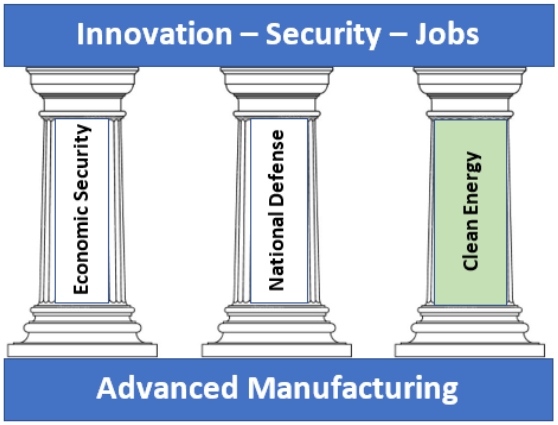
DoD provides a staffed, trained and equipped military force needed to deter aggression and protect the security of our nation. To transition DoD science and technology advances into production, the Department must have access to a robust and responsive U.S. industrial base equipped with advanced manufacturing 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 eight manufacturing innovation institutes through its Defense-wide Manufacturing Science and Technology program element within 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 Manufacturing Innovation Institutes address commercial and defense manufacturing needs via public-private partnerships and 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 modernization technology areas. Already, the institutes have shown progress in support of cybersecurity for manufacturing, micro-electronics, biotechnology, hypersonics, and autonomy, among other modernization 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 United States are manufactured in the United States.

In FY 2021, the DoD awarded a ninth institute, BIOMADE, focused on bioindustrial manufacturing of non-medical materials.

Department of Energy: Advanced Manufacturing Office



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

Functions, Governance, and Coordination

Manufacturing USA's four governance operating principles, outlined in the network charter, are:

1. "The network supports its member institutes in meeting the goals of the program and creates a collective impact greater than the sum of constituent parts. Individual institute governance is the purview of the lead funding agency and respective institute members. Legislatively mandated reporting on individual institute performance is the responsibility of the respective lead funding agencies."
2. "Network governance is a shared responsibility amongst the network membership. Mechanisms and structures are necessary to collect inputs and needs of key stakeholders, including those in the private sector."
3. "Decisions concerning inter-institute issues in the network should be made at the lowest responsibility level. In resolving issues, there should be a general preference towards empowering action at the institute level."
4. "The AMNPO is responsible for supporting network functions. The AMNPO, working with the lead funding agencies and other participating federal agencies, is also responsible for reporting to Congress on the Manufacturing USA program and related institutes." [6]

To ensure effective management and coordination of the network, federal agency members meet monthly to discuss policy decisions for defining and improving the network functions. The agencies coordinate through the AMNPO in support of the program's national purposes and in recognition that those national purposes are best realized by an integrated whole-of-government effort. The federal agencies embrace this unified effort, while ensuring that the value delivered by their respective institutes remains closely aligned with their agencies' statutory requirements and agency mission. Maintaining this balance between Manufacturing USA's national programmatic goals and each agency's needs helps ensure that all major stakeholder base requirements are addressed.

Collaboration is also important to the institute directors, who share best practices through their Institute Directors Council meetings. Formalized in the *Charter of the Institute Directors Council: Manufacturing USA*, the council directly supports the goals of the Manufacturing USA Program. The council facilitates collaboration among the institutes with advice, as needed, from the federal institute sponsors and other federal agencies, and from the AMNPO. [7]

Manufacturing USA has developed a powerful network brand and logo to help foster awareness of the institutes as applied manufacturing technology centers that belong to a larger network. The logo helps create instant awareness when furthering the cause of advanced manufacturing to nonmember entities, as well as to the media and public. ManufacturingUSA.com and the networks' social media pages boost agency and institute visibility with key stakeholders by offering regular updates on network activities. AMNPO also helps to coordinate with the agencies to release public materials and facilitate industry events.

Institutes within Manufacturing USA

The agency-sponsored manufacturing institutes are the core of Manufacturing USA. Each of the 14 institutes (16 including the two new institutes established in FY 2020 and 2021) focuses on a specific technology area of critical importance to the nation's ability to establish and maintain leadership in advanced manufacturing (see Table 1). The institutes connect member organizations, including large and small private companies, major research universities,

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[6] *Network Charter: Manufacturing USA Program*, Advanced Manufacturing Series (NIST AMS) - 600-4 Revision 1, Section D, Network Operating Principles, Department of Commerce, National Institute of Standards and Technology, p. 3 (October 2019). https://nvlpubs.nist.gov/nistpubs/ams/NIST.AMS.600-4r1.pdf.

[7] *Charter of the Institute Directors Council: Manufacturing USA*, NIST Advanced Manufacturing Series (NIST AMS) - 600-1, C. Blue, L. Brown, Y. Fink, N. Justice, M. Liehr, T. McDermott, E. Morris, pp. 1-2 (November 2016). https://www.nist.gov/publications/charter-institute-directors-council-manufacturing-usa.

community colleges, state and local economic development entities, and Manufacturing Extension Partnership state organizations.

Funds Expended by the Department of Commerce

This Report to Congress is required to state the funds expended by DOC on the program. FY 2020 appropriations to NIST were $16M; approximately $4.9M was used for operation of the AMNPO, network services supporting Manufacturing USA , and other legislative requirements; $3.3M was competed via grants to institutes to respond to the pandemic; and $7.8M in financial assistance was provided to the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) under the on-going cooperative agreement. An additional $10M of Coronavirus Aid, Relief, and Economic Security (CARES) Act funding supported Manufacturing USA institutes addressing the national emergency. No waivers of cost-share requirements for NIIMBL were requested.

Table 1. The 16 Manufacturing USA Institutes					
Institute	Technology Focus Area	Agency	Headquarter Locations	Date Estab.	*Agency Agreement
America Makes The National Additive Manufacturing Innovation Institute	Additive manufacturing	DoD	Youngstown, OH	Aug 2012	Follow-on
MxD Manufacturing times Digital	Digital manufacturing and design/ Cybersecurity in Manufacturing	DoD	Chicago, IL	Feb 2014	Follow-on
LIFT	Lightweight materials manufacturing	DoD	Detroit, MI	Feb 2014	Follow-on
PowerAmerica Next Generation Power Electronics Manufacturing Innovation Institute	Wide-bandgap power electronics manufacturing	DOE	Raleigh, NC	Jan 2015	Ending
IACMI Institute for Advanced Composites Manufacturing Innovation	Fiber-reinforced polymer composites manufacturing	DOE	Knoxville, TN	Jun 2015	Ending
AIM Photonics American Institute for Manufacturing Integrated Photonics	Integrated photonics manufacturing	DoD	Rochester & Albany, NY	Jul 2015	Original
NextFlex America's Flexible Hybrid Electronics Manufacturing Institute	Thin flexible electronics devices and sensors manufacturing	DoD	San Jose, CA	Aug 2015	Follow-on
AFFOA Advanced Functional Fabrics of America Institute	Sophisticated, integrated, and networked fibers, yarns, and fabric manufacturing	DoD	Cambridge, MA.	Apr 2016	Original
CESMII Clean Energy Smart Manufacturing Innovation Institute	Smart manufacturing, advanced sensors, and process controls	DOE	Los Angeles, CA	Dec 2016	Original
BioFabUSA Advanced Regenerative Manufacturing Institute	Engineered tissues and tissue-related manufacturing	DoD	Manchester, NH	Dec 2016	Original
ARM Advanced Robotics for Manufacturing Institute	Transformative artificial intelligence and robotic technologies for manufacturing	DoD	Pittsburgh, PA	Jan 2017	Original
NIIMBL National Institute for Innovation in Manufacturing Biopharmaceuticals	Biopharmaceutical manufacturing	DOC	Newark, DE	Mar 2017	Original
RAPID Rapid Advancement in Process Intensification Deployment Institute	Modular chemical-process intensification for manufacturing	DOE	New York, NY	Mar 2017	Original
REMADE Reducing Embodied-energy And Decreasing Emissions	Sustainable manufacturing	DOE	Rochester, NY	May 2017	Original
BioMADE Bioindustrial Manufacturing	Sustainable & reliable bioindustrial manufacturing technologies	DoD	St. Paul, MN	Oct 2020	Original
CyManII Cybersecurity Manufacturing Innovation Institute	Cybersecure and energy efficient manufacturing	DOE	San Antonio, TX	Sep 2020	Original

* The period of performance for the initial agency Cooperative Agreement or Technology Investment Agreement establishing the institute are usually for 5-7 years. The three DoD-sponsored institutes that have completed their original agreement either have a follow-on agreement or are in the process of establishing a follow-on agreement.

Response of the Institutes to the National COVID-19 Pandemic

Manufacturing USA institutes provide a national resource with state-of-the-art equipment and a wealth of the nation's science and engineering talent ready to quickly collaborate in response to national emergencies. Examples below show how the institutes worked together to immediately address the crisis as early as March 2020. In addition, Congress provided CARES Act funding to support the institutes, enabling additional projects at the institutes.

Reinventing the Supply Chain in the Face of COVID-19

The COVID-19 pandemic created a ripple effect for U.S. manufacturers that revealed not only a lack of redundancy in the supply chain, but also a lack of clarity as to the supply chain functioning. As the pandemic took hold, worldwide demand for personal protective equipment (PPE) dramatically increased and many material and product costs skyrocketed. It quickly became apparent that the PPE supply chain in the U.S. would need reinventing.

The immediate response to a PPE shortage was to find ways to make more. But several Manufacturing USA institutes quickly took an expanded view of the issues and asked questions that could fundamentally change the PPE supply chain:

- How can we empower U.S. manufacturers to make PPE?
- How do we match emerging PPE producers with purchasers who need it most?
- How do we test and validate the efficacy of new PPE coming on the market?

Early Workarounds in PPE Production: DIY Face Shields

PPE supply chain management was, and remains, largely a manual process. With so much of global production of PPE being in Asia, enormous gaps in the U.S. supply chain became apparent. U.S. manufacturers often made higher-value-add products and may not have had adequate backup sources or visibility into all layers of the supply chain, which means they were not able to mitigate disruptions. All of this combined to make workarounds difficult.

With the onset of the pandemic, the DoD's Manufacturing times Digital institute (MxD) quickly produced step-by-step instructions for manufacturers to make face shields for their employees and their communities. The responsiveness demonstrated the flexibility of digital manufacturing—recreating a supply chain and illustrating how to build products in places that traditionally do not produce them.

MxD's face shield initiative provided a venue for its 300 members to contribute to the greater cause. It also reinforced the institute's and members' agility and resolve. In many ways, a shift of operations to work on producing face shields was a "proof of concept" for the kinds of adjustments that many manufacturers will face in supply chain challenges.

Compliance Testing and Product Lifecycle Management

Manufacturers jumping into the PPE supply chain or expanding their presence need capital investment and are required to meet legal compliance standards, such as Centers for Disease Control and Prevention (CDC) or Food and Drug Administration (FDA) approval. DoD's Advanced Functional Fabrics of America (AFFOA) institute went to work with its partners to create a regional network of testing locations to meet this demand.

These locations provide compliance testing for N95 masks and evaluate the quality of foreign-sourced respirators. They also provide preliminary performance results to researchers seeking to develop new filter media for N95 respirators and surgical masks and evaluate the efficacy of various mask sterilization techniques.

AFFOA also helped develop the first product lifecycle management system specifically for PPE. This helps designers and developers capture specifications to recreate products moving forward. This pioneering work led to CARES Act funding for "Creating a Blueprint for Manufacturing During Periods of Surge Demand." The initiative will provide product management and oversight to produce additional certified medical PPE, facilitate rapid prototyping of PPE by non-traditional performers, and provide testing/certification capabilities to evaluate new designs.

In addition to testing and product management, AFFOA has created a blueprint for government-owned N95 mask production and distribution, an important safety net for the future.

Mapping the Supply Chain to Improve Efficiency and Mitigate Risk

DoD's America Makes collaborated with the Food and Drug Administration (FDA), Veterans Affairs (VA), and National Institute of Health (NIH) to quickly created an online repository of healthcare providers in need of medical PPE, manufacturers with 3D printing capabilities, and designers willing to share 3D print designs with the aim of connecting manufacturers with medical caregivers on the frontline of the COVID-19 pandemic. The institute then launched a new program connecting the additive manufacturing industry with the healthcare provider community to accelerate design and clinical review of 3D-printed PPE medical devices.

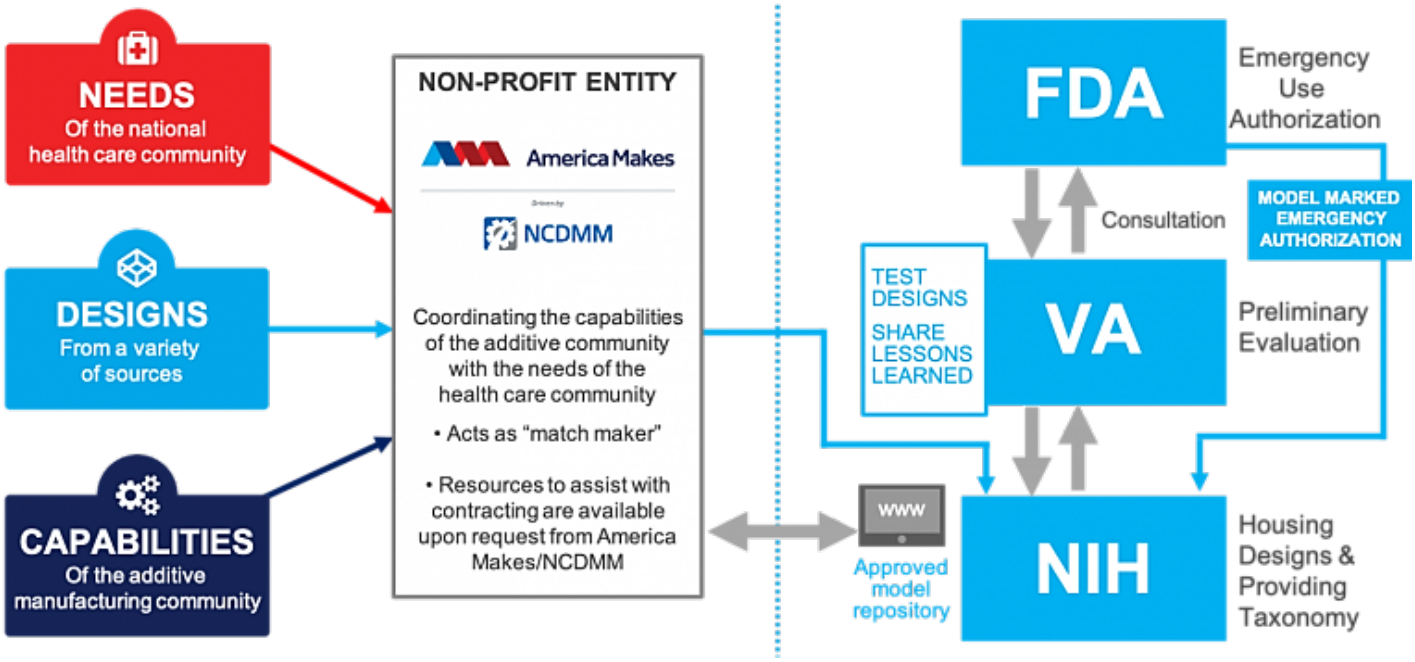

Figure 1. This America Makes project integrated the FDA, VA, NIH, and crowd-sourcing to quickly develop innovative designs for PPE, approve designs, and provide designs to manufacturers of all sizes across the country.

The initiative is one of several in the Manufacturing USA network that has been augmented by CARES Act funding from DoD and NIST with a focus on mapping the supply chain. Others include:

- AFFOA and partners are mapping the PPE supply chain by capabilities — documenting, for example, which manufacturers make gowns and masks.
- DoD's BioFabUSA is working on a "Demand Forecasting Dashboard for Medical Supplies." This project will implement an inventory forecasting dashboard to reflect PPE product demand and response time for requisitions.
- The Supply Chain Risk Alert Project, launched by MxD and partners prior to the pandemic, is developing machine learning/artificial intelligence capabilities to provide end-to-end visibility into a manufacturer's supply chain. It will help expand U.S. pharmaceutical manufacturing capacity while improving risk management.

Next-Generation Masks Are in the Pipeline

DOC's NIIMBL tapped into the NC State University "Nonwovens Institute's" newly developed "spunbond" technology to help develop next generation materials and manufacturing processes for face masks. These masks provide a significant level of protection and can be manufactured easily at industrial scale and were quickly put into use by students, faculty, and staff at NC State University. Researchers are determining if this new spun-bound mask can be sterilized for re-use. NIIMBL is also testing ways to produce disposable inserts for reusable surgical masks, extending the life of those products.

Additionally, DoD's ARM leveraged its ecosystem to enable 10 fast-start projects to manufacture diagnostic, medical care, medical countermeasure, non-medical PPE, and other supplies.

PPE Supply Chain Work Shows Promise of Advanced Manufacturing

There is a clear return on investment in manufacturing PPE in the United States, economically and societally. Manufacturers already were dealing with risks of outsourcing — such as poor quality, theft of intellectual property, shipping delays and a lack of control — so the pandemic may prove to be a tipping point for reshoring. Emerging technologies are converging with this demand to create new possibilities for domestic manufacturing. The work on reinventing the PPE supply chain demonstrates the value of the large-scale support for innovation that Manufacturing USA is providing to the U.S manufacturing sector.

CARES Act Funding Enabling Strong Institute Response

The CARES Act was signed into law on March 27, 2020, providing $10 M to NIST[8] to support institute work. The institutes developed numerous proposals, and the NIST CARES Act funding along with the agency's other appropriations supported five of these high-impact projects, summarized below. More details are described in a separate report[9].

NIIMBL

Eleven projects were funded to improve COVID-19 testing capabilities, including rapid in-house diagnostics; identify reliable domestic supply chains for the production of respirators and personal protective equipment; validate decontamination approaches for clinical spaces; determine the manufacturability of potential therapeutics; and build flexible manufacturing capabilities for the quick scale-up in production of biologic therapies and essential medical products.

America Makes

The "Advanced Manufacturing Crisis Production Response (AMCPR)" project, leveraging America Makes' initial COVID response, will establish a lasting strategic framework for additive manufacturing crisis response that includes regulatory awareness, access to validated designs, increased supply chain, and workforce readiness. This strategic framework will help prepare the U.S. for future crises and enhance overall national economic competitiveness and security.

BioFabUSA

The "National Technology Roadmap for Pandemic Response and Recovery" will guide stakeholders on the technologies, platforms, and infrastructure needed to accelerate their response and recovery from the COVID-19 pandemic. This effort will equip organizations with the necessary information to better coordinate activities that build capacity and resiliency against future pandemics in areas such as intentional regulatory and deployment frameworks, optimized predictive capabilities as well as stronger data infrastructure, manufacturing and supply chain networks that drive down response time on everything from PPEs and medical workforce to vaccine development and delivery.

LIFT

"Operation Next for the Pandemic" will validate a nationally replicable workforce development training model by leveraging the proven Operation Next accelerated curriculum in computer numerical control (CNC) machine operations, industrial technology maintenance, welding, and robotics to provide additional skills to small and medium manufacturers' employees in two regional economies (Pittsburgh, PA and Detroit, MI). This effort will leverage the unique assets of the proven Operation Next learning platform to provide higher level training in topic areas specifically aligned to each regional economy through a hybrid learning model – online, online and in-person, or completely in person post-pandemic.

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[8] The CARES Act provided funding to NIST and DOD for Manufacturing USA institute support. See page 10 of (p 10) - ''Coronavirus Aid, Relief, and Economic Security Act'' or the ''CARES Act'' (P.L. 116-136), https://www.congress.gov/116/plaws/publ136/PLAW-116publ136.pdf. DoD impacts are reported elsewhere.

[9] Manufacturing USA Rapid Response to COVID-19 Report: https://www.manufacturingusa.com/news/manufacturing-usa-rapid-response-covid-19-report

Advanced Robotics for Manufacturing (ARM)

The “Advanced Robotics for Manufacturing COVID-19 Recovery Program” will demonstrate a safer, scalable robotic system that increases hospital and university lab COVID-19 testing with an increased throughput of 300% without additional trained staff. The solution addresses one of the biggest challenges in COVID-19 testing: the lack of sufficient personnel to analyze samples and provide test results. The equipment to complete quantitative identification of nucleic acids from infective organisms exists at most hospitals and universities, but there are not enough technicians to operate at full equipment capacity. By automating this process with robotics, more people will have access to testing and the results of those tests can be made available sooner.

Measuring Manufacturing USA Program Performance

Manufacturing USA's performance metrics are revised over time, reflecting a better understanding of what can be measured and the maturation of the program. Manufacturing USA's leadership is committed to continuous improvement and additional metrics have been incorporated so that the program can be properly assessed over the long term. The quantitative performance metrics measure progress toward overall Manufacturing USA program goals, as shown in Table 2. Each metric category provides information for tracking progress toward four interrelated high-level goals[10] based primarily on the legislative program purposes.[11]

Currently there are 26 metrics (Tables 3 and 4), which are complemented by an additional 14 education and workforce metrics being piloted for a subset of institutes (Tables 5 and 6). Current metrics are compared with FY 2019 in this report.

In addition to the Manufacturing USA Program metrics reported here, each lead funding agency has established metrics relating directing to the agency's unique mission-specific requirements. Those additional metrics are separately collected and evaluated by the funding agency.

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

Institute Metric Category	**Goal 1** Increase competitiveness of U.S. manufacturing	**Goal 2** Facilitate the transition of innovative technologies into scalable, cost-effective, high-performing domestic manufacturing capabilities	**Goal 3** Accelerate the development of an advanced manufacturing workforce	**Goal 4** Support institute business models that help institutes become stable and sustainable
1. Impact to U.S. innovation ecosystem	●	●		●
2. Financial leverage		●		●
3. Technology advancement	●	●		
4. Development of an advanced manufacturing workforce	●		●	

[10] *Manufacturing USA Strategic Plan*, Advanced Manufacturing National Program Office, p. 6 (November 2019), https://www.manufacturingusa.com/sites/manufacturingusa.com/files/2021-01/2019%20MfgUSA%20Strategic%20Plan%2011-10-2020.pdf.

[11] 15 U.S.C. § 278s(b)(2). http://uscode.house.gov/view.xhtml?req=(title:15 section:278s edition:prelim).

Performance Metrics

Table 3 provides the aggregated performance metrics for the innovation ecosystem, financial leverage, and technology advancement for the 14 institutes operating in FY 2020.

Table 3. Technology and Program Development Performance Metrics – 14 Institutes			
Specific Metric	**Unit of Measure**	**FY 2019**	**FY 2020**
Metric Category 1 – Impact to U.S. Innovation Ecosystem			
Organizations with institute membership agreements	Total number of memberships	1,920	**2,013**
Diversity of member organizations	Number of large manufacturers (more than 500 employees)	369	**355**
	Number of small manufacturers (500 or fewer employees)	805	**895**
	Number of academic members (universities, community colleges, etc.)	463	**459**
	Number of other entities (government members, government laboratories, not-for-profits, etc.)	283	**304**
Metric Category 2 – Financial Leverage			
Federal investment	Federal base funding in the fiscal year	$133M	**$163M**
Co-investment	Cost-share expended and federal funding not part of the base federal funding in fiscal year	$355M	**$262M**
Metric Category 3 – Technology Advancement			
Active research and development projects	Number of ongoing projects	561	**534**
	Total institute expenditures in fiscal year	$488M	**$425M**
Key project objectives met	Percentage of key project milestones met	80%	**79%**

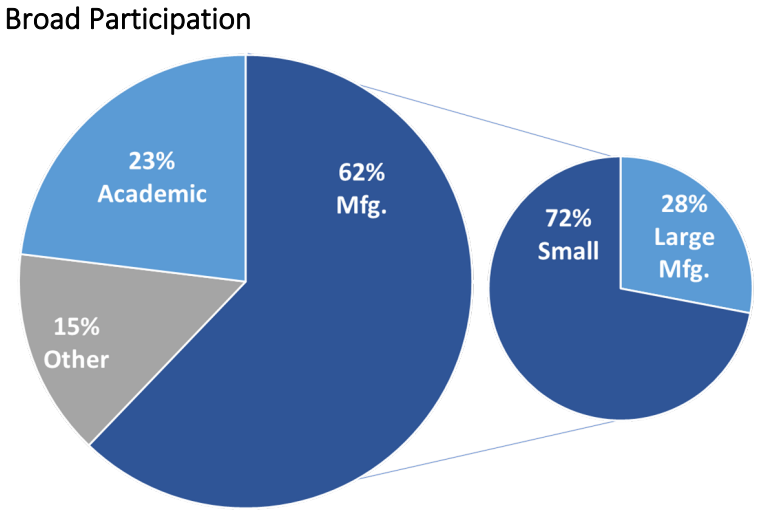

Figure 2. Institute membership demographics.

In FY 2020, the institutes had 2,013 member organizations, including large and small manufacturers, community colleges, major research universities, and state and local economic development entities. Of these, 62% were manufacturers (industry), and 72% of those manufacturers were small and medium-sized manufacturing companies with 500 or fewer employees. Universities, community colleges, and technical training schools made up 23 % of member organizations. The remaining 15% of other organizations included federal laboratories, regional economic development

agencies, not-for-profit organizations, and state and local governments. Compared to 2019, these numbers reflect year-to-year growth in membership, largely associated with small manufacturers.

Financial Leverage: Program Co-Investment Exceeded Federal Program Funds by 2-to-1

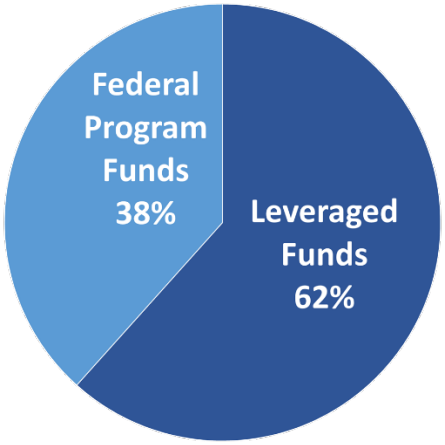

Figure 3. Leveraged funding vs. federal program funding for the Manufacturing USA institutes in FY 2020.

As in previous years, institutes significantly exceeded the program target of a 1-to-1 match of non-federal resources to federal base program support, leveraging federal base program funds by 1.6 to 1. Nonprogram matching expenditures totaled $262M and federal program funds totaled $163M, bringing total annual institute expenditures to $425M. Matches from industry, academia, competitive government grants and contracts, and regional organizations totaled $1.60 for each $1 in federal base funding. The total funding expended decreased somewhat from FY 2019, primarily due to the impact of the Covid-19 pandemic on the institutes' work.

Technology Advancement: Advancing Technology and Improving the Innovation Ecosystem

During FY 2020, the institutes managed 534 technology projects that included manufacturing-process research, proof-of-concept development, early system prototyping, and manufacturing demonstrations. While R&D projects have inherent risks, an average of 79% of key technical milestones were met, which is consistent with previous years.

Critical to each institute's success is a rigorous and broadly inclusive approach to selecting project topics, and stakeholders from industry, academia, regulatory agencies, and end users develop roadmaps for key technologies and manufacturing processes. The subsequent R&D projects are selected based in part on their linkage to the roadmaps' time-based technical requirements. The institutes' procedural transparency and the wide acceptance among members of the importance of the institutes' technology roadmaps have helped generate highly qualified teams of industry and academic members doing high-quality collaborative technology development.

Advanced Manufacturing Workforce

Workforce is the key enabler of America's leadership in advanced manufacturing, and our supply chains and innovation ecosystems have suffered from insufficient availability of trained workers. Shortages of qualified workers have become critical. A 2.4M worker shortfall is projected between 2018 and 2028, putting $454B of manufacturing GDP at risk annually by 2028. Worker training and availability have risen to the top of manufacturing CEO's list of needs. The institutes have organized programs to provide additional training to existing workers and to create a pipeline of new skilled workers.

Table 4 summarizes Education and Workforce metrics from all 14 institutes active in FY 2020.

Table 4. Education and Workforce Development (EWD) Performance Metrics – 14 Institutes			
Metric	**Units of Measure**	**FY 2019**	**FY 2020**
STEM activities	Total number of students participating in institute projects or internship programs and training	32,951	55,478
	Workers completing a certificate, apprenticeship, or training program	6,120	9,284
Educators & trainers	Teachers or trainers completing institute-led training	805	5,411
	Total number of EWD participants	**39,876**	**70,173**
Source of funding for Institute EWD projects or activities	Base-funded projects: base federal funding from the original cooperative agreement or technology investment agreement	96	83
	Commercial-funded projects: support provided from industry, regardless of membership status	9	7
	Federal agency-funded projects: resourced from federal funding outside the base Cooperative Agreement (CA) or Technology Investment Agreement (TIA) funding	17	16
	State- or locally funded projects: resourced from state or municipal government funding	19	14
	Other funded projects: resourced from philanthropic organizations, nonprofits, foundations, or associations	9	9
	Total number of EWD projects and activities operated by institutes*	**121**	**117**
Funding amount expended for EWD projects and activities	Base funding expended: resourced by institute using base federal funding from the original CA or TIA	$9.42M	$10.51M
	Commercial expenditures: provided by industry, regardless of membership status	$0.86M	$0.41M
	Federal agency expenditures: resourced from federal funding outside the base CA or TIA funding	$2.13M	$4.50M
	State or local funding expended: resourced from state or municipal government funding	$0.46M	$2.17M
	Other expenditures: resourced from philanthropic organizations, nonprofits, foundations, or associations	$2.66M	$5.06M
	Total expenditures for EWD projects and activities	**$15.53M**	**$22.65M**

* This represents individual EWD projects and does not represent a summary. The information above illustrates EDW projects may be funded by multiple sources. Therefore, the total EWD projects is less than the sum of the projects funded by each source.

The institutes worked together with federal agencies (DOC, DoD, DOE, NSF, DOL, NASA, USDA, FDA, and ED) to share best practices in the education and workforce development areas. In FY 2020, the cross-institute EWD team launched an effort to identify needs and opportunities of interest for the institutes, including access to data and analysis. A NIST-funded study is synthesizing this information for the institutes, providing an actionable plan for workforce-related activities.

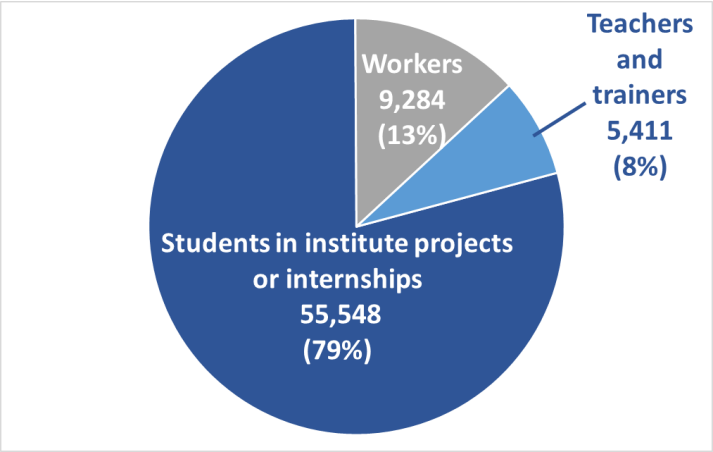

Figure 4. Number of individuals who received training in FY 2020.

The metrics indicate significant developments in the program in addition to the increase in participants. The funding for EWD increased year over year by more than 35%. However, particularly noteworthy is that direct commercial funding of EWD activities is small, supporting fewer than 6% of the projects and less than 2% of the funding. Also, there was a large increase in training of teachers already linked to existing educational programs, ensuring that knowledge of work-relevant technologies reached larger total numbers of students, allowing incorporation of emerging manufacturing developments into curricula.

Expanded Metrics – Reaching Learners at Different Depths of Participation

Additional metrics with data from a subset of institutes are provided in Table 5 and Table 6. This data expanded previous EWD metrics to focus on targeted groups and depth of learning. These expanded metrics demonstrate that the institutes have been increasingly effective at reaching the targeted groups, with substantial increases in post-secondary students and those already in the manufacturing workforce seeking additional training.

The institutes emphasize cost-effective approaches by leveraging existing community-based educational institutions, including local public schools. Furthermore, exposing K-12 students to emerging high-technology career opportunities in manufacturing before the students make formative career decisions can strengthen the pipeline of manufacturing workers for future years. Knowledge of these career options is critical for college-bound students and for the 33.8% of high school graduates who do not immediately go to college, and advanced manufacturing provides them with better-paying job opportunities in fields where high demand is anticipated. Additionally, advanced manufacturing provides career opportunities for those with industry credentials, two-year degrees, four-year degrees, and advanced degrees. It is a sector with career opportunities for all.

Table 5. Aggregated Institute Education and Workforce Development Refined Performance Metrics Assessment of Nine DOC and DoD Institutes			
Specific Metric	Unit(s) of Measure	FY 2019	**FY 2020**
Individuals participating in institute EWD projects or institute-led EWD activities	K–12 participants: students enrolled full-time in primary or secondary schools and GED candidates not employed full-time in current workforce	22,179	19,376
	Postsecondary participants: postsecondary students (full- or part-time) not employed full-time in the current workforce (e.g., college student or worker taking a career and technical education class to prepare for a new career)	2,983	12,751
	Manufacturing workforce participants: individuals employed full- or part-time in the manufacturing workforce, whether or not their participation eventually leads to a credential	7,265	22,839
	TOTAL – individuals participating in institute EWD projects or institute-led activities	32,427	**54,966**
Individuals completing an institute-aligned professional development certification, apprenticeship, or training program	Certification: Include substantive certifications recognized or otherwise valued by industry. Does NOT include certificates for minor courses	150	757
	Apprenticeships: Include arrangements in which someone has completed learning an art, trade, or job under another expert in that field	11	14
	Other Training Programs: Include other substantive training programs that would be recognized or otherwise valued by industry	4,313	3,711
	TOTAL – individuals completing an institute-aligned professional development certification, apprenticeship, or training program	4,474	**4,482**
Teachers and trainers completing institute-led training	K-12 educators who completed an institute-led training activity	546	4,613
	Postsecondary educators who completed an institute-led training activity	9	29
	Manufacturing Workforce teachers and trainers who completed an institute-led training activity	60	14
	TOTAL – teachers and trainers completing institute-led training	615	**4,656**

In 2019, the Manufacturing USA Education and Workforce Development (EWD) Working Group finalized an additional metric to complement the other EWD metrics, some of which did not distinguish between the different levels of participation equally, e.g., a one-day manufacturing facility tour counted the same way as a two-year apprenticeship or a four-year college degree.

Table 6, with data from the nine DOC and DoD institutes, differentiates the "intended learning depth" of planned activities. It measures the number of participants in EWD, distinguishing shallower, shorter interactions from deeper, longer-term engagements, in order to determine how the entire spectrum of learning is being supported. The concept of learning depth uses a depth of engagement scale, from first topical awareness through advancement of technological frontiers, to recognize the value of the attained competency or advancement. The metric is not intended to measure a participant's success towards attaining the learning objectives.

Progress is seen in increasing the depth of learning, with a substantial majority of participants engaged in quite substantive education (e.g. concept, skills, or application learning). Given the focus of the institutes on bridging the mid-

range gap in the Manufacturing Readiness Levels (MRLs), more of the institute activities are focused on applied skills learning and application activities, rather than on concept learning activities.

Notably, there was a striking jump in some categories, including Concept Learning and the highest level of training, high-level hands-on creation and innovation with potential to advance the state of the art in advanced manufacturing. The agency and institute Education and Workforce Development working group is looking forward to using such data to understand the changing trends in the institutes' education and training programs.

	Table 6. Participation in Education and Workforce Development Activities by Intended Learning Depth Assessment of Nine DOC and DoD Institutes		
Metric	Unit(s) of Measure	FY 2019	**FY 2020**
Individuals participating in EWD activities	1. Awareness: Presentation of information with or without accompanying recall questions *Examples: a short class, presentation, demonstration, or event*	19,468	16,953
	2. Concept Learning: Learners understand facts and ideas by classifying, summarizing, comparing, or explaining principals, theories, or models *Example: introductory-level (101) course*	3,420	25,857
	3. Skills Learning: Practically oriented learning to apply conceptual knowledge and develop manufacturing-related procedural or process knowledge *Example: intermediate-level (201) course with significant interactive, laboratory, or hands-on components*	4,361	4,304
	4. Application: Learners solve problems, identify connections and relationships and how they apply in practical situations *Examples: long-term internship or apprenticeship, or through work-based or project-based learning*	5,178	6,305
	5. Creation: Original research or innovation activity that might advance the state of the art. Students critique and evaluate accepted procedural knowledge or create novel methods or combinations of accepted methods *Examples: graduate or post-doctoral research project, novel product design, or an R&D project*	0	1,547
	TOTAL – individual EWD participants (sum of DOC and DoD Institutes)	32,427	**54,966**

Activities Reinforcing the Manufacturing Ecosystem

In addition to the COVID-19 response described above, the institutes continued their mission in advancing U.S. manufacturing technology and workforce development. Highlights are described below in both areas.

Training the Workforce of the Future

The COVID-19 pandemic has changed the way manufacturers recruit and train their workforce. This shift will work in manufacturers' favor in the long term as online learning is key to widespread development of skills enabling the manufacturing economy of the future.

Ensuring manufacturers have the trained workers they need means more than having machine operators transfer the "art of the craft" – i.e., filling *present-day* manufacturing jobs. It also means recruiting more people into manufacturing by raising awareness of the career possibilities in technology and programming — i.e., the manufacturing *jobs of the future*.

To this end, the Manufacturing USA institutes have developed specialty online learning initiatives to develop career pathways to higher-skilled positions needed for advanced manufacturing, offering:

- Competency-based vs. time-based learning, which allows for more individualized curricula and targeting of specific skills; this approach usually results in higher student engagement.
- Flexibility that expands the pool of participants.

The latter consideration is especially important for many underrepresented populations for whom traditional classroom training programs may pose attendance challenges due to lack of transportation and inflexible time constraints.

Many of the online offerings are free and open to anyone; others are available to institute members. The programs range from targeting high school students to undergraduates, as well as prospective entry-level employees and tenured workers seeking opportunities for career advancement. The following are examples of online learning initiatives from the institutes and Manufacturing USA Agency partners.

DOC-SPONSORED INSTITUTE

The NIIMBL eXperience

The NIIMBL eXperience is a program linking underrepresented students to the biopharmaceutical manufacturing industry to improve recruiting and retention of a talented, diverse workforce. College students from Historically Black Colleges and Universities connect directly with biopharmaceutical companies and federal agencies to learn about the industry and its role in patient health and well-being.

When the pandemic hit, NIIMBL took the program online in collaboration with the National Society of Black Engineers. A dozen organizations engaged with 13 rising sophomores and juniors during the virtual eXperience, understanding the students' interests and sharing opportunities within their companies. Participating organizations included AstraZeneca, Amgen, Genentech, Merck, RoosterBio, and NIST.

DoD-SPONSORED INSTITUTES

AIM Academy

AIM Photonics has built an online learning portal that allows instructors to download teaching materials and offers free online college-level EdX courses. EdX is a non-profit created by founding partners Harvard and Massachusetts Institute of Technology. The courses focus on integrated photonics which use light for applications traditionally addressed through electronics. It dramatically improves the performance and reliability of electronic integrated circuits while significantly reducing size, weight, and power consumption.

NextFlex's Flex Factor

When the pandemic shut down most in-person activities, NextFlex transitioned its FlexFactor educational program from classroom-based to online in concert with the participating manufacturers, public school systems and community colleges. The month-long program now operates in four ecosystems through these sponsoring community colleges, with about 700 students completing the program in its first six months:

- Evergreen Valley Community College, California.
- Lorain County Community College, Ohio
- Drake State & Colhoun Community Colleges, Alabama.
- Midlands Technical College, South Carolina.

AFFOA's MITxFIT Program

AFFOA partnered with the Massachusetts Institute of Technology (MIT) and the Fashion Institute of Technology (FIT) to create the Advanced Fiber and Fabric Workshop. This two-week workshop introduces undergraduate students to advanced fiber and fabric technologies and the common competencies necessary for engineers and designers to successfully innovate and prototype in the advanced textiles industry. Further, students gain exposure to industry needs and how to design products that meet these needs. AFFOA has partnered with industry member, New Balance to provide students with an industry challenge to address. This model of project-based learning ensures students are not only participating but applying knowledge gained in this workshop towards a real-world challenge, which only enhances participant engagement and excitement.

LIFT's IGNITE Program

LIFT is rolling out its IGNITE: Mastering Manufacturing curriculum across the country after completing test pilots at high schools in Illinois, Michigan, and Ohio. IGNITE is a three-year foundational competency-based educational program to train multi-skilled technicians. High school students learn through project-based experiences and graduate with skills and knowledge needed for entry level manufacturing positions. They are also exposed to career paths for engineering technicians, technologists, and engineers.

MxD's Cybersecurity for Manufacturing

MxD, in partnership with University of Maryland, Baltimore County, has developed a series of certificate-level cybersecurity courses that integrate instruction on manufacturing-focused job roles, career pathways, and success profiles. Cybersecurity is a critical skill set needed for the long-term success of manufacturers that are increasingly reliant on connected factories, machine learning and artificial intelligence.

America Makes' Additive Manufacturing Classes

America Makes has partnered with Tooling U-SME to offer more than a dozen online classes specific to additive manufacturing and 3D printing technology. Tooling U is an online training repository of more than 500 interactive courses that range from a high school career and technical education program to college classes and certificate programs. Classes use computer-aided-design software and 3D object scanners to 3D print what previously was made by removing material from a larger workpiece through milling, machining, carving, shaping, and other means.

ARM Lowers Barriers

The AmSkills Apprenticeship Recruitment Initiative demonstrated success in FY 2020 with previously unemployed participants accepting job offers after attending an employer-supported training program sponsored by the ARM Institute. The AmSkills Manufacturing Career Discovery Workshop and Bootcamp was created as a fast-track program to recruit and assess candidates for manufacturers to hire into entry-level positions. Several of the workshops are in a community center within low-income communities. The program teaches industry-identified skills with 80% hands-on activities and projects to demonstrate ability. Manufacturers are invited to conduct on-site interviews in a "speed dating" format to improve the candidate's interviewing skills and to determine if the manufacturers would be interested in the candidate for hire. Most of the unemployed individuals completed the first two-weeks and were offered jobs. These hired individuals had varied backgrounds including a homeless veteran and several with a criminal record, all

looking for a second chance and a way to have a life-sustaining career. Continued success is expected as more AmSkills bootcamps roll forward.

Ensuring that a skilled manufacturing workforce is in place to meet pandemic-related needs, the ARM Institute began the development of a unique, comprehensive asset map of robotics education providers and robotics career pathways. This solution will be made available through the public website www.roboticscareer.org in FY 2021.

BioFabUSA Online Gaming for BioFabrication

BioFabUSA developed the "TEMPtation" game to introduce students in grades 7-12 to the world of Tissue Engineered Medical Products (TEMP) and biomanufacturing, challenging students to learn about the industry while winning prizes. The goal was to enable students to discover the world of regenerative medicine and tissue engineering while they are still choosing high school and college course work. Forty BioFabUSA members were featured. This activity helps BioFabUSA meet their goal of addressing the need for workers trained in tissue and organ manufacturing by providing training opportunities to non-college bound youth.

DOE MANUFACTURING INSTITUTES

RAPID's eLearning Courses

The RAPID institute is focused on breakthrough technologies to boost energy productivity and energy efficiency in oil and gas, pulp and paper, renewable bioproducts and domestic chemical manufacturers. In addition to its virtual internship program, RAPID has made numerous professional development online courses available to its members through AIChE Academy, which focuses on modular chemical process intensification (MCPI). MCPI is the underpinning science and technology that will be required for innovative manufacturing processes and applications that will lead to smaller and more efficient chemical processing plants, among other benefits.

IACMI

IACMI has had more than 100 interns graduate in the composites program, more than 7,000 K-12 students in STEM programs, and more than 2,000 participants at hands-on training workshops. IACMI is establishing a composite technician training program at community colleges across the U.S. strategically located within the national manufacturing industrial base's supply chain. With its National Learning Provider Network, IACMI provides access to a wide range of delivery and distribution points across the supply chain.

PowerAmerica enables training partnerships

The Texas Tech and X-FAB Educational Partnership developed classes in silicon carbide power device simulation, processing, and characterization to train undergraduates and graduate students in power device design and fabrication. These classes enable a workforce knowledgeable in the manufacturing of cutting-edge devices in a modern semiconductor foundry production setting. In FY 2020, PowerAmerica trained 106 students in 47 applied academia/industry collaborative projects, 488 professionals attended tutorials, and 88 attended short courses organized by PowerAmerica. Over the lifetime of the Institute, 410 students were trained in over 110 university/industry projects, over 1700 professionals participated in PowerAmerica organized tutorials, and 154 attended PowerAmerica wide bandgap power electronics short courses. These courses are taught by experts in the field and draw professionals with varying experience from around the country, providing training in silicon carbide and gallium nitride semiconductor technologies.

REMADE Training Certificates

REMADE has launched two Awareness Level Certificate pathways in response to industry need. First, Fundamentals of Remanufacturing and Fundamentals of Mechanical Recycling of Plastics is a multi-part short course series are designed for manufacturers new to the industry, skilled engineers and technicians, and incumbent remanufacturers and recyclers looking for a deeper, technical dive. Second, REMADE Institute, in partnership with New York State and the Rochester Institute of Technology, also offered a five-part online Remanufacturing Bootcamp. Totaling over seven hours of training from seven subject matter experts, the bootcamp was designed for manufacturers new to the remanufacturing industry and skilled engineers and technicians seeking industry updates. The training covers an introductory overview to

remanufacturing, cleaning technology, condition assessment, additive repair technology, and design for remanufacturing.

CESMII Expands Smart Manufacturing Training

CESMII has grown the library of recorded knowledge in smart manufacturing, sharing videos with professionals and experts of all industries, and engaging with over 3,000 viewers. The virtualized CESMII workshops and educational webcasts FY 2020 educated over 500 people on the value, multiple dimensions, and fundamentals of smart manufacturing, including the impact on sustainability, energy productivity, and supply chain resiliency. CESMII has partnered with Pennsylvania State University and the Massachusetts Institute of Technology to develop an instrumented, small-scale fiber extrusion tool kit that models real-world practical manufacturing scenarios along with smart manufacturing software applications and supporting educational modules, such as labs, projects, and sample data sets. This tool is designed for the classroom setting, lets students work with use cases and makes smart manufacturing education immediately adoptable in a broad range of engineering, non-engineering, and cross-discipline educational programs.

The tool was tested with 10 engineering students and seven business students as part of an Industry 4.0 overview. The created educational toolkit is available to educators in the CESMII network to leverage it in their own curriculum.

Other Agency Collaborations

National Science Foundation Support

In FY 2020, the NSF gave its first Future Manufacturing awards[12], to support fundamental interdisciplinary research and education of a workforce that will enable manufacturing methods that do not exist today. Four of the projects, accounting for over $7.6M of funding, feature collaborations with Manufacturing USA institutes, on topics ranging from bio-based electronics to production resilience to collaboration of humans and artificial intelligence.

Over the past five years, the NSF provided over $12.8M in funding for projects stimulated by three Dear Colleague Letters[13] that encourage researchers and educators to submit proposals that foster collaboration with the institutes and the DOC Investment in Manufacturing Communities Partnerships. In FY 2020, one of these awards supported (along with a grant from NIST) a workshop at NSF to promote and sustain research and educational collaborations between the faculty and students of Historically Black Colleges and Universities and participants in the Manufacturing USA Institutes. NSF's Dear Colleague Letter also provided a path of support for NSF researchers to use AIM's $1B foundry for research.

Support Provided Jointly by the Departments of Education, Defense, and the National Science Foundation

In 2020 the U.S. Departments of Education, Defense, and the National Science Foundation continued their collaboration to assist the institutes to amplify the impact of institute education and workforce programs. Specifically, this technical assistance effort, "Moving from Programs to Strategies through Career and Technical Education," focused on building from the smaller-scale targeted programs that most of the institutes are conducting and expanding those programs into sector strategies that engage high schools and community colleges in creating a skilled workforce for advanced manufacturing.

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[12] NSF announces investment in future of manufacturing (Oct. 2, 2020). https://www.nsf.gov/news/special_reports/announcements/100220.jsp.

[13] Dear Colleague Letter: Advanced Technological Education (ATE) Program Support for Manufacturing Innovation Institutes and Investing in Manufacturing Communities Partnerships (IMCPs), National Science Foundation (NSF 16-007), Susan R. Singer (October 9, 2015). https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf16007; Dear Colleague Letter: Supporting Fundamental Research to Enable Innovation in Advanced Manufacturing at Manufacturing USA Institutes, National Science Foundation (NSF 17-088), Barry Johnson (May 25, 2017). https://www.nsf.gov/pubs/2017/nsf17088/nsf17088.pdf; and Dear Colleague Letter: Research on Integrated Photonics Utilizing AIM Photonics Capabilities, National Science Foundation (NSF 18-095), Dawn M. Tilbury (July 20, 2018). https://www.nsf.gov/pubs/2018/nsf18095/nsf18095.jsp.

In summary, the development of learning across the spectrum of high school students to early career professionals to providing additional training to current workers is an example of the large-scale support for innovation that the Manufacturing USA network is providing to the U.S manufacturing sector.

Manufacturing Technology Impacts

Technical accomplishments and impacts to the ecosystem are highlighted below.

DOC-SPONSORED INSTITUTE

NIIMBL Targets Lowing Vaccine Cost

NIIMBL brought together nearly 1,000 individuals from 302 organizations across the biopharmaceutical manufacturing ecosystem to collaborate on the innovations needed to strengthen domestic manufacturing for gene therapy, antibody-drug conjugates and bispecific antibodies, and vaccines. Complementing this effort was the first NIIMBL collaborative project call for the Bill and Melinda Gates Foundation's Global Health Fund to lower costs and increase speed-to-market of vaccines.

DoD-SPONSORED INSTITUTES

LIFT Strengthening Armored Vehicles

LIFT supported the development of an iron-manganese-aluminum alloy for use as armor on military ground vehicles. The steel is expected to reduce armor weight by more than 10% while matching or exceeding the ballistic performance of rolled homogeneous armor. Through this project, LIFT is optimizing processing conditions to produce affordable, high quality armor plate in large volumes.

NextFlex Printing NASA Cortisol Sensor Electrodes

NextFlex has printed multiple cortisol sensor electrode samples using commercially available graphene and silver-chloride inks on various commercially available substrates. This print capability is the first step in a National Aeronautics and Space Administration-funded project that is developing a human-wearable sensing system that will monitor multiple physiological markers such as cortisol. The intent is to test prototype devices in space flight by 2022.

AFFOA Rapid Tech Integration, Prototyping and Small Batch Production of Army Clothing System

AFFOA worked with US Army PEO Soldier Program Manager-Soldier Clothing and Individual Equipment (PM-SCIE), DEVCOM-Soldier Center (SC), and its ecosystem, to rapidly produce 200-300 (1,900 units) ensembles of the next-generation Cold Temperature Arctic Protection System (CTAPS) which is a multi-layer, complex extreme cold weather clothing system. The team sourced and selected performers who were able to rapidly produce the units within 5 months, in time for a Limited User Evaluation in Alaska in January 2021. As part of the rapid prototyping effort, the team was asked to integrate a powered moisture expulsion technology (Hydro- Bot), developed by Osmotex, into 20 units of an existing cold/wet weather jacket in time for the same Limited User Evaluation. For this effort, AFFOA customized the electronics and added sensing capabilities to the Hydro-Bot, in order to track movement, temperature, and humidity while the soldier is using the system.

America Makes Safer Football Helmets

For a second year, America Makes partnered with the National Football League (NFL) for a Play Safe, Play Smart Helmet Challenge. America Makes members connected with current helmet manufacturers and NFL health and safety scientists and engineers to leverage new technologies like additive manufacturing to produce and test a safer helmet. In FY 2020, the NFL Helmet Challenge announced the winning teams of the initial phase, including multiple America Makes members who participated on the selected teams. America Makes will continue to partner with the NFL to address Health & Safety needs using additive manufacturing.

MxD Manufacturing Readiness Assessment Tool

Development work continues on Docent, an app for Manufacturing Readiness Level Assessment (MRA) execution, collaboration, and assessment first developed in FY 2019. MRA is a standardized process to help de-risk and evaluate new defense acquisitions to improve outcomes. In FY 2020, MxD successfully stood up a collaborative industry and government working group to help shape the future of the tool. The team utilized input of working group members to prioritize further feature development on Docent. MxD will launch a series of pilot programs with DoD contractors which

will ultimately result in full adoption of Docent by the Manufacturing Readiness Level Working Group. Docent provides a digital tool that offers flexibility, collaboration, and scalability across the enterprise.

BioFabUSA Deep Tissue Characterization

As of 2020, BioFabUSA's Deep Tissue Characterization Center (DTCC), funded by the Defense Health Agency, is operational and houses sophisticated instrumentation needed for the multi-"omic" characterization of cells for Tissue Engineered Medical Products (TEMPs) developed by DoD investigators across the country. The DTCC informs the design of sensors specific to the monitoring of cells and tissues in-process on Tissue Foundry manufacturing lines. In FY 2020, BioFabUSA formalized a collaboration with the Cardiovascular Cell Therapy Research Network and the Texas Heart Institute to perform deep analysis of samples from 207 patients in 2 clinical trials to gain a deep understanding of the relationship between cell therapy manufacturing and efficacy of the therapy in patients.

AIM Photonics Multi-Project Wafer Run

The AIM Photonics silicon photonics fabrication facility in Albany, NY has developed a cost-effective way for organizations of any size to use the advanced node chip facility. AIM's silicon photonics Multi Project Wafer (MPW) allows customers to use standard elements developed and optimized by AIM, shortening design time and improving 1st run success. AIM also offers access to its electronics and photonics Test, Assembly, and Packaging facility in Rochester, NY. AIM Photonics' MPW prototype vehicle remains the most advanced integrated photonics wafer processing available.

AIM also offers indium phosphide MPW services through the Infinera Corporation. Infinera plans to send the photonic integrated circuits and other photonic materials to the International Space Station, as part of the Materials International Space Station Experiment (MISSE) Program. In another noteworthy collaboration, Infinera fabricated an on-chip micro-gyroscope as they explore applications of interest to DoD.

ARM Advanced Robotics in Seafood Handing

A great challenge of industrial robotics is the identification, handling, and manipulating of irregular slippery objects. ARM's FISH (Fostering Innovation in Seafood Handling) Project aimed to re-shore processes within the fishing industry through the development of robotics that can reliably identify, grasp, & place seafood or other slippery, non-rigid items while working collaboratively with human workers in a factory environment. New perception and gripping algorithms and other robotic technologies of the FISH Project could amount to $20B in economic impact each year within the next 5-10 years, with potential impact extending into numerous other defense applications such as explosive ordinance inspection, handling and logistics, and resupply. The ARM FISH project has received two additional grants from the National Science Foundation to study the adoption of new technology in the seafood industry while considering COVID-19's impact on worker and food safety concerns.

DOE-SPONSORED INSTITUTES

IACMI Tools for High-Volume, High-Speed Inspection of Structures in Automotive Manufacturing

Michigan State University (Lansing, MI) established a non-destructive evaluation (NDE) cell to enable air-coupled ultrasound testing (ACUT) to efficiently evaluate composites components integrated into automotive structures. ACUT technology is currently used in the aerospace industry but has not yet been adapted to high-rate use of high-volume products, such as needed in the automotive industry. The ability to inspect every part with NDE will enable increased use of carbon fiber reinforced polymer in auto body structures, leading to significant lightweighting and improved strength for fuel efficiency and crashworthiness. The project is continuing to scale-up the technology. The other members of the project include American Chemistry Council (Troy, MI), and Vanderbilt University (Nashville, TN).

Power America Simplified Chip Production

Silicon carbide is a more efficient material for high power devices, but it is more expensive to produce than standard silicon devices widely used in today's power electronics systems. PowerAmerica and X-FAB (Lubbock, TX) have standardized processes for customers of their silicon carbide foundry, eliminating technical and logistical complexities arising from different design processes. XFAB can now fabricate silicon carbide power devices with economy scale approaching that of silicon power devices. Five PowerAmerica members are utilizing XFAB capabilities in FY 2020 as fabless semiconductor companies or using XFAB capacity to complement their internal manufacturing efforts.

CESMII Reducing Energy Consumption in Cement Manufacturing through Smart Manufacturing Technologies

University of Louisville constructed a scale model of a rotary cement kiln. The lab scale model of a cement clinker production kiln, equipped with sensors and control system, combined with multi-physics (flow, heat transfer) predictive model was developed to optimize operating parameters for reduced energy consumption. The project also validated multi-physics predictive models that will lead to optimized operating conditions contributing to up to 15% reduction in energy usage in production kilns. The goal of data analytics approach is to use quality control and process operation information provided by the Argos Roberta Cement Plant to develop machine learning tools that allow the use of these data to improve energy efficiency of the process.

RAPID Conversion of Waste Biomass to Sugars

Iowa State University (Ames, IA) is scaling up a modular process for conversion of woody and agricultural biomass to fermentable sugars and other value-added products at or below current market prices. The new process uses less process heat than existing processes, is expected to double energy productivity, and is well suited for distributed processing in modular units designed to fit in standard shipping containers. Other project partners include Stine Seed (Adel, IA).

REMADE Transition to a Circular Economy

A team from Michigan Technological University, Idaho National Laboratory, and their industrial trade association partner, the American Chemistry Council, have developed and validated a framework for systems analysis of polyethylene terephthalate (PET) and olefin polymers in a circular economy. The project was guided by an Advisory Board of Experts from the plastics recycling value chain including Resource Recycling Systems, The Recycling Partnership, Titus MRF Services, Ravago, Association of Plastics Recyclers, 4RSustainability, BASF Corporation, Dow Chemical Company, and Unilever. The model evaluated how the manufacturing and recycling processes can be configured to minimize energy consumption and greenhouse gas emissions, and provide the greatest benefits economically, predicting that it is possible to reduce greenhouse gas emissions by 24%.

Summary and Assessment of the NIIMBL Report to the Secretary of Commerce

NIIMBL is the only institute funded under Manufacturing USA's legal authority. NIIMBL is therefore required to submit an annual report to the Secretary of Commerce. A summary and assessment of that report must be included in the Manufacturing USA annual report to Congress.[14] This is a summary and assessment of the NIIMBL 2019-20 Annual Report to the Secretary of Commerce.

NIIMBL launched operations on March 1, 2017. Its annual report, submitted to the Secretary of Commerce in 2020, covers its third year of performance, and describes the institute's financial standing, key performance metrics, and accomplishments as of February 28, 2020. A public version of this report, without the financial reporting data was released in September 2020.[15]

NIIMBL's seeks to promote U.S. global leadership in biopharmaceutical manufacturing innovation and to ensure that U.S. inventions become products made in America. The institute's success will promote economic development, with additional impacts on national security and public health, by strengthening the domestic supply chain and advancing the rapid scale-up of bio-manufactured therapies.

NIIMBL's mission is "to accelerate biopharmaceutical manufacturing innovation, support the 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."[16] In alignment with this mission, NIIMBL's report presents activities, goals, plans, and accomplishments that support the statutory purposes of the Manufacturing USA program.

NIIMBL reports that, in its third year, the institute:

- Expanded its technical and workforce portfolio by more than 20%, to 58 projects with a cumulative value of over $53M;
- Grew its membership by 37% to 155+ members including the addition of industry leaders GlaxoSmithKline, Eli Lilly, and Janssen R&D, along with 17 new Small and Medium Manufacturers (SMMs);
- Brought together nearly 1,000 individuals from 302 organizations across the biopharmaceutical manufacturing ecosystem to collaborate on the innovations needed to strengthen domestic manufacturing for gene therapy, antibody-drug conjugates and bispecific antibodies, and vaccines;
- Issued the first NIIMBL collaborative project call for the Bill and Melinda Gates Foundation's Global Health Fund to lower costs and increase speed-to-market of vaccines.

Assessment of NIIMBL's Performance

The NIST assessment of NIIMBL's report on its third year of performance, on behalf of the Secretary of Commerce, addressed the institute's financial standing, key performance metrics, and accomplishments. The assessment is positive as indicated in the impacts summarized in Table 7. It is evident that Manufacturing USA's statutory purposes[17] form an important guide to institute decision-making and activities and that the institute showed progress in all areas. NIIMBL fully accomplished the activities and actions identified to NIST in its Year 3 Operating Plan.

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[14] 15 U.S.C. § 278s(i). http://uscode.house.gov/view.xhtml?req=(title:15 section:278s edition:prelim).
[15] *NIIMBL 2019-20 Annual Report*, The National Institute for Innovation in Manufacturing Biopharmaceuticals (2020). https://niimbl.org/Downloads/NIIMBL_Annual_Report_2019-20_FINAL.pdf
[16] Ibid., p. ii.
[17] 15 U.S.C. § 278s(b)(2). http://uscode.house.gov/view.xhtml?req=(title:15 section:278s edition:prelim).

Table 7. NIIMBL FY 2018-2019 Performance Snapshot						
Manufacturing USA Statutory Purpose	**Strategic Objective**	**Institute Performance Goals**	**Performance Measures**	**Performance Indicators**	**Explanation** (data as of February 29, 2020)	**Value or Descriptor**
A) Improve the competitiveness of U.S. manufacturing and to increase the production of goods manufactured predominately within the United States	Foster diverse membership base to facilitate an end-to-end advanced manufacturing ecosystem	Secure partnerships with critical US stakeholders	Growth in membership	# of members	Total members	**155**
				Growth over year	Yearly Increase	**37%**
			Membership diversity evident (size, type, and geographic distribution)	Percentage of members signed in each key stakeholder group	Industry members	**41%**
					Academic members	**40%**
					State and local non-profit entities	**19%**
				Geographic diversity	Number of states with NIIMBL members	**25**
B) Stimulate U.S. leadership in advanced manufacturing research, innovation, and technology	Provide leadership in activities that require industry sector-wide engagement to support advanced biomanufacturing	Convene and lead an ecosystem to industrialize advanced manufacturing technology	Prioritization and project call execution for technical investments	Technical workshops convened	Number of technology workshops since institute launch	**35**
C) Facilitate the transition of innovative technologies into scalable, cost-effective, and high-performing manufacturing capabilities	Establish and support a robust technical portfolio to advance biomanufacturing capabilities	Demonstrate capabilities for establishing and maintaining a robust technology portfolio	Technology portfolio growth	Project calls designed and executed	Total number of technology project calls completed since institute launch	**6**
				Number of technical projects awarded	Technical projects awarded since institute launch	**37**
				Value of technology portfolio	Total value of technology portfolio	**$41.6 M**
D) Facilitate access by manufacturing enterprises to capital-intensive infrastructure	Develop a shared facilities network of biomanufacturing pilot facilities for testbeds, training	Establishment of NIIMBL HQ facility (non-federal funding)	NIIMBL HQ occupancy	1Q 2020 Occupancy of NIIMBL HQ	(Met or unmet)	**Met**
E) Accelerate the development of an advanced manufacturing workforce; and H) Create and preserve jobs	Establish a robust and industrially relevant workforce development portfolio to increase pipeline and skills	Demonstrate capabilities for establishing and maintaining a robust WFD portfolio	WFD portfolio growth	Number of WFD project calls executed	Total WFD project calls executed since institute launch	**5**
				Number of WFD projects awarded	Total number of WFD projects awarded since institute launch	**21**
				WFD portfolio value	Total portfolio value	**$12.0 M**

F) Facilitate peer exchange of the documentation of best practices in addressing advanced manufacturing challenges	Facilitate sharing and documentation of best practices for addressing advanced biomanufacturing challenges	Develop substantive mechanisms to foster knowledge sharing among ecosystem	Use of NIIMBL website and community portal	Public and member-only access to portal resources	Number of individuals using portal resources since institute launch	**469**
			Ecosystem participation in technical activities	Individuals participating in technology-focused meetings	Individuals participating in NIIMBL technology and roadmapping workshops since institute launch	**750**
				Unique organizations participating in technology and roadmapping workshops	Unique organizations (member and non-member) participating in NIIMBL technology and roadmapping workshops since launch	**196**
G) To leverage non-Federal sources of support to promote a stable and sustainable business model without the need for long-term Federal funding	Support membership structures that promote sustainable cost-sharing towards institute activities	Demonstrate non-federal leverage to fund institute activities	Meet and exceed Federal award requirements for NIIMBL non-federal cost-share	Non-Federal investment	Ratio of non-Federal to Federal investment reported for fiscal year ending February 29, 2020	**3.2 to 1**

It is also evident that industry is embracing this institute through membership and participation in NIIMBL technical and workforce activities. The high financial leverage indicates a consistently strong commitment by partners.

NIIMBL is the sole institute established under the Manufacturing USA authority given to the DOC. As such, the alignment of NIIMBL's mission and activities is more intentionally governed by the statutory purposes of the Manufacturing USA program than the Manufacturing USA institutes established by the DoD and the DOE under different authorities. This summary and assessment are an accurate reflection of the institute's significant accomplishments for the reporting period. The Secretary of Commerce has determined that NIIMBL's standing after its third-year positions NIIMBL to create the impacts for the U.S. economy intended by Congress for Manufacturing USA institutes and that NIIMBL continues to provide a successful model for any future institute funded under the same authority.

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