Deloitte.

Manufacturing USA

A Third-Party Evaluation of Program Design and Progress

January 2017

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Background

The 21st century has seen dramatic changes in the way people create, communicate, commute, and conduct business. At the heart of these changes is the exponential growth of innovation embodied in the goods and services we use.

Technology-driven manufacturing is central not only to producing these goods and services but to securing American economic vitality as well. Advanced manufacturing helps maintain U.S. economic leadership across the globe. However, the U.S. is not the only nation that recognizes the value of this sector.

Countries worldwide see the economic benefits of a strong manufacturing base. These countries are committing significant and deliberate resources towards advanced manufacturing, with the hope of leading in the global competitive landscape.
To maintain its edge in this area of strategic significance, the U.S. took action. The federal government partnered with industry, independent experts, and academia; together they built Manufacturing USA.

Manufacturing USA: A "Whole-of-Economy" Approach

Manufacturing USA forms public-private, national Institutes that focus on critical advanced manufacturing technology areas with strategic impact on the economy. Through eight* Institutes, the Manufacturing USA Program provides matching federal funding to foster networking and mutually beneficial collaboration between key stakeholders (industry, academia, and government) in a "whole-of-economy" approach. The very existence of the Program is a strong signal to industry that encourages R&D investment and serves as a strategic impetus for action.

The Program's goals, as stated in the Program's Strategic Plan, 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 Institutes become stable and sustainable.

The origins of this Program and its uniqueness should be credited to the many dedicated leaders and pioneers from the Department of Commerce (DoC), Department of Defense (DoD), and Department of Energy (DoE), who organized the nation's focus and collectively set the foundational conditions for success in achieving the Program goals.

Program Assessment

This study found that Manufacturing USA is a valid approach grounded in a portfolio of technology-centric Institutes. The public-private partnership Institute-based model attracts significant and meaningful participation from industry (including large companies and small enterprises), academia, and local, state, and federal government. Institute members have made substantial joint investments in collaborative approaches to R&D and commercialization of cutting-edge advanced manufacturing technologies. Institutes are laying the groundwork for building the American manufacturing workforce's skills to meet the needs of 21st century employers.

Manufacturing USA Institutes*

*As of the beginning of the study (August 2016), eight Institutes had been awarded and started. Since then, additional Institutes have been announced.

Report Approach and Methodology

Study Context and Scope

Manufacturing USA commissioned Deloitte Consulting, LLP ("Deloitte") to conduct a third-party review and evaluation of the Program. The study emphasized the overall Program, not the detailed operations of any individual Institute; however, the Institutes and their members played a critical role in providing perspectives and information to assist in developing the Program-level analysis.

Research and analysis contributing to this report took place between August 2016 and January 2017.

Throughout the study, the team investigated key areas of the Program to respond to the following questions:

- Does the underlying design of the Manufacturing USA Program help the Institutes improve U.S. manufacturing competitiveness and accelerate the development of the advanced manufacturing workforce? Is the Manufacturing USA design valid, or does it need to be modified?
- What progress has the Program made towards its goals? Have there been demonstrable successes which can be qualitatively or quantitatively measured?
- How could the Program or Institutes evolve to further improve their performance and effectiveness?

Study Methodology and Approach

To answer these questions, Deloitte analyzed numerous sources of information and perspectives, using an "outside-in" approach to understand how customers and stakeholders nationwide view Manufacturing USA and its work. The approach included:

- **Stakeholder interviews** with the sponsoring Agencies, including the Department of Commerce, Department of Defense, and Department of Energy.
- **Site visits and interviews** at each of the eight currently-existing Institutes, including interviews with Institute Directors and leaders, technical directors, and workforce development leads.
- **Interviews with independent external experts** in manufacturing, including CEOs and leaders of Fortune 500 companies, experts from and leaders of prominent research universities, and industry groups.
- **Collection and analysis of Institute and Program documents**, including the 2015 Annual Report, 2015 Strategic Plan, Institute annual and quarterly reports, Institute internal strategy and execution materials, the Revitalize American Manufacturing and Innovation (RAMI) Act, the President's Council of Advisors on Science and Technology (PCAST) Advanced Manufacturing Partnership 2.0 reports, and many more.
- **Aggregation and analysis of Institute data** – including membership lists, participation in project calls and projects, and steering committees – to build a database of interactions facilitated by the Institutes, and development of visualizations to quantify the Institutes' ability to convene stakeholders.
- **Crowdsourcing perspectives and feedback** from more than 70 members across the eight Institutes – including large corporations, small businesses, research universities and community colleges, and federal, state, and local government – determining the value they receive from the Program and how it could better serve them.
- **Use of the DataUSA data and visualization engine** developed by Deloitte, the MIT Media Lab, and Datawheel to conduct analysis.
- **Analysis of open source reports, data, and documentation,** including government statistics (e.g., Bureau of Economic Analysis, Bureau of Labor Statistics) and committee reports, think-tank analyses, reports and information about competitor entities in the U.S. and abroad (e.g., UK's Catapult Centres, Germany's Fraunhofer), business and industry publications, and academic resources.

Executive Summary

Section Overviews

Introduction and Program Design: The U.S. Responds to the Global Manufacturing Competitiveness Challenge

- **Advanced manufacturing is a critical investment area for the broader domestic economy; support is needed to reverse slowing productivity growth and the trade imbalance.** The advanced manufacturing sector has a significant effect on job creation in other industries and contends with expanding foreign competition.
- **Manufacturing USA is a public-private partnership uniting academia, large companies, small business, and government to respond to these challenges.** This "whole-of-economy" design is intended to preserve and grow U.S. competitiveness in advanced manufacturing by creating Institutes that convene and coordinate member organizations.
- **Manufacturing USA's Institutes help spur R&D innovation and commercialization and prepare the 21st century workforce.** Institutes encourage mutually beneficial collaboration to catalyze R&D investment and overcome barriers to innovation. They solve collective action problems, enable members to tap into critically valuable and synergistic stockpiles of intellectual property, and provide access to shared assets. This enables innovation to occur more efficiently.

Note: More details can be found on pages 08-21.

Program Progress Section I: Facilitating Technology Innovation and Commercialization

- **Historically, investments are unevenly distributed across stages of manufacturing R&D and transitioning IP is difficult, inhibiting innovations from reaching the market.** Manufacturing USA addresses the "valley of death" between research and commercialization by convening members that conduct work along different parts of the R&D spectrum and de-risking investments.
- **Institutes decrease the cost of R&D experimentation by providing access to expensive equipment, pooling project costs, creating technology roadmaps, and promoting knowledge exchange.** Institutes deliver greater return on R&D spending for members than they could each achieve on their own. Co-development of technology results in cross-industry and cross-company sharing of information that accelerates technology transition and advancement.

Note: More details can be found on pages 22-27.

Program Progress Section II: Accelerating Manufacturing Workforce Development

- **U.S. advanced manufacturers are experiencing a growing talent gap.** Baby boomer retirements, the technical complexity of manufacturing work, a science, technology, engineering, and math (STEM) skills deficit among students, and persistent negative perceptions make it difficult for companies to fill critical roles in a timely manner.
- **Institutes help industry mitigate the talent gap by coordinating workforce activities conducted by members and external stakeholders.** Institute workforce efforts include industry assessments of worker supply and demand for technological areas, community engagement events, apprenticeship programs, and the coordination of employee credentials and certifications.

Note: More details can be found on pages 28-35.

Program Progress Section III: Promoting Sustainable Ecosystems for Advanced Manufacturing

- **The Program's portfolio of Institutes approach for managing and overseeing the Program is a deliberately designed strength.** The Program's portfolio approach provides enough oversight to ensure federal investments are being spent wisely to improve U.S. advanced manufacturing while at the same time affording each Institute enough autonomy to effectively meet the needs of its industry members.
- **Institutes are achieving high degrees of network connectivity and strong member recruitment, reaching respective "tipping points" that drive towards success.** The number of members and degree of member connectivity are key indicators of the sustainability of an Institute's network. There are early signs that Institutes are reaching "tipping points" where organizations see membership as necessary to their own success and seek out membership without being prompted.
- **Institutes are strengthening regional economic clusters, creating and reinforcing connections between firms that are geographically concentrated.** Institutes tap into existing regional clusters and strengthen them, tying innovation efforts to places with strong advanced manufacturing workforces and enabling R&D knowledge spillovers.

Note: More details can be found on pages 36-45.

INTRODUCTION AND PROGRAM DESIGN:

The U.S. Responds to the Global Manufacturing Competitiveness Challenge

PowerAmerica Institute member facility.

Section Takeaways:

- **Advanced manufacturing is a critical investment area for the broader domestic economy; support is needed to reverse slowing productivity growth and the trade imbalance.** The advanced manufacturing sector has a significant effect on job creation in other industries and contends with expanding foreign competition.
- **Manufacturing USA is a public-private partnership uniting academia, large companies, small business, and government to respond to these challenges.** This "whole-of-economy" design is intended to preserve and grow U.S. competitiveness in advanced manufacturing by creating Institutes that convene and coordinate member organizations.
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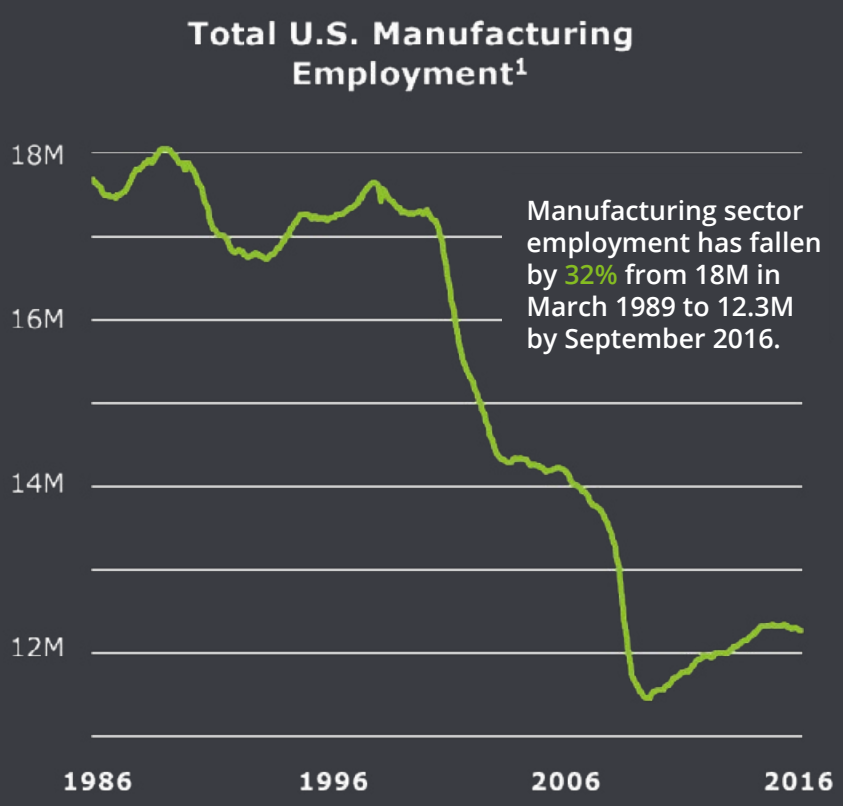
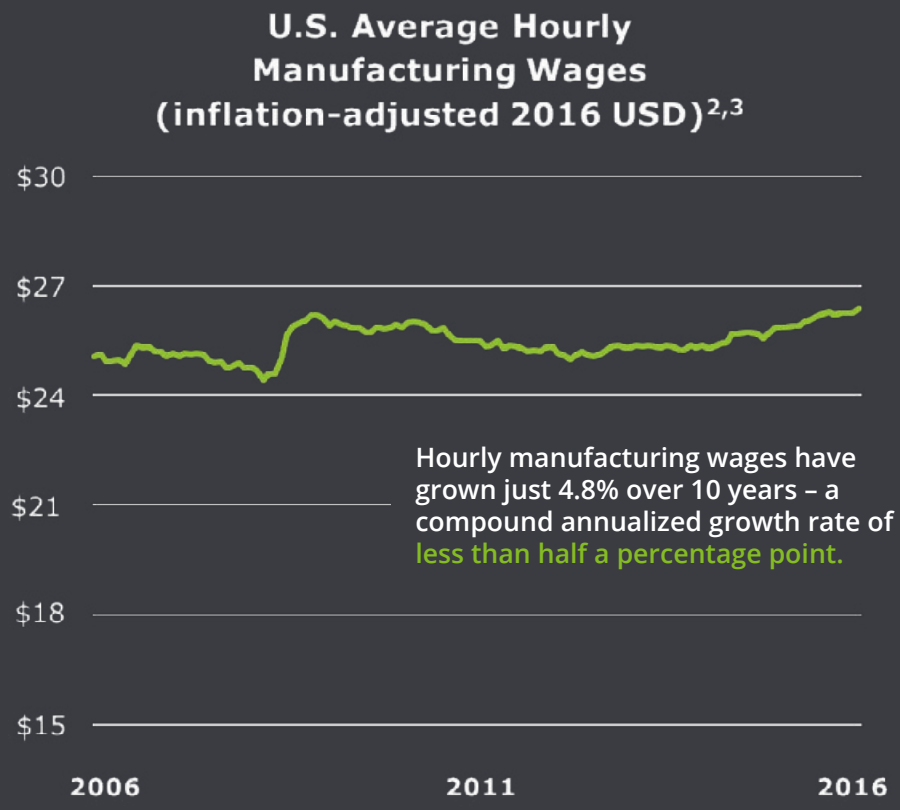
U.S. manufacturing has experienced significant employment losses, stagnant wages, and strong foreign competition in recent decades

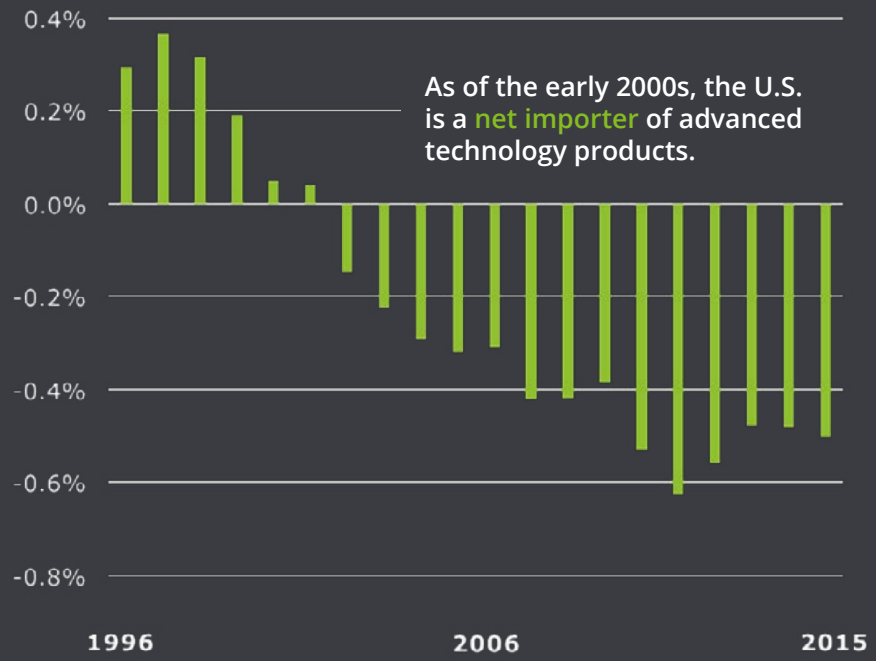




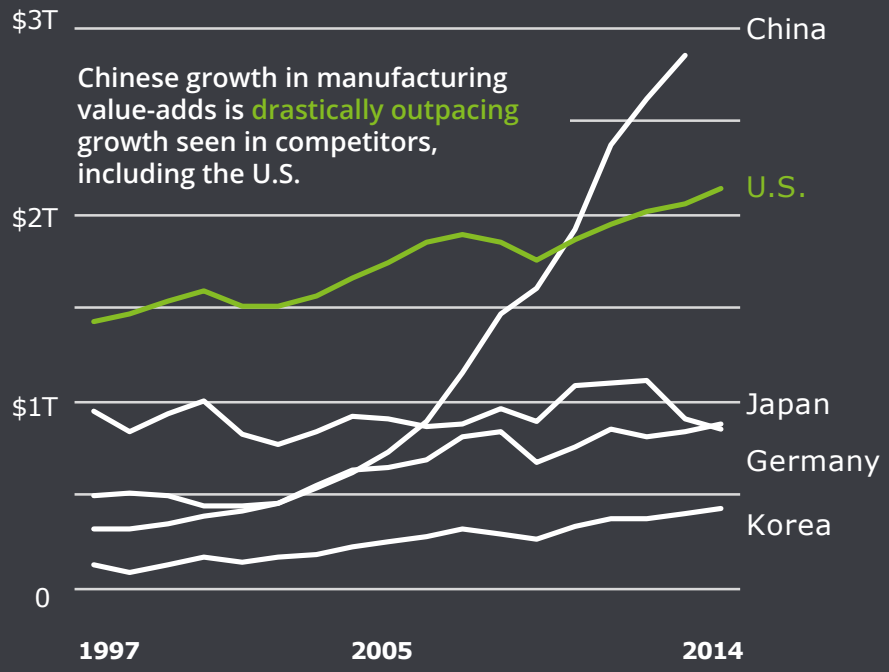
"The low-tech manufacturing of the… 60s, 70s, and early 80s – those days are gone forever to cheaper labor markets… [today's] discussion should be around state-of-the-art product manufacturing in the USA. All high-tech products going forward will require **sophisticated manufacturing technology**."

— Small and Medium Enterprise

U.S. Trade Balance in Advanced Technology Products as share of GDP[4,5]



Manufacturing Value-Add* (inflation-adjusted 2016 USD)[6]



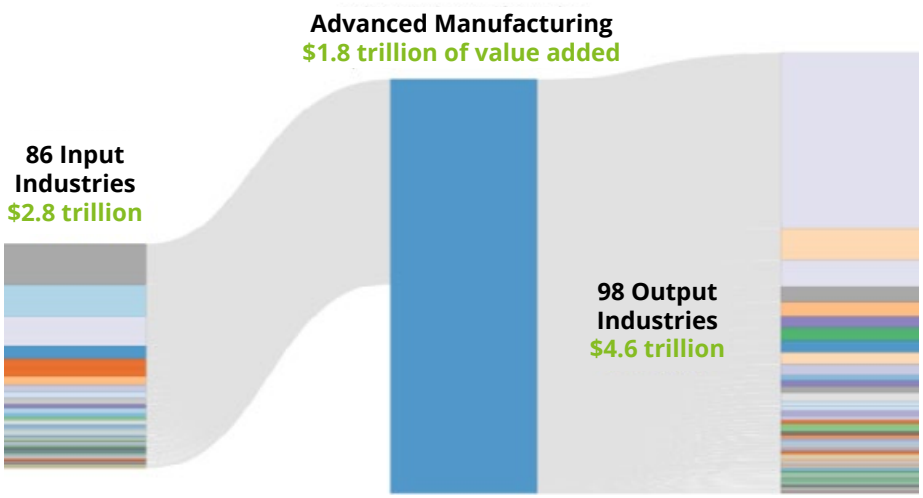
"Across the entire [U.S.] industrial landscape there are now gaping holes and missing pieces. It's not just that factories stand empty and crumbling; it's that **critical strengths and capabilities have disappeared that once served to bring new enterprises to life...** the danger is that as U.S. companies shift the commercialization of their technologies abroad, their capacity for initiating future rounds of innovation will be progressively enfeebled."

— Report of the MIT Taskforce on Innovation and Production, 2013[7]

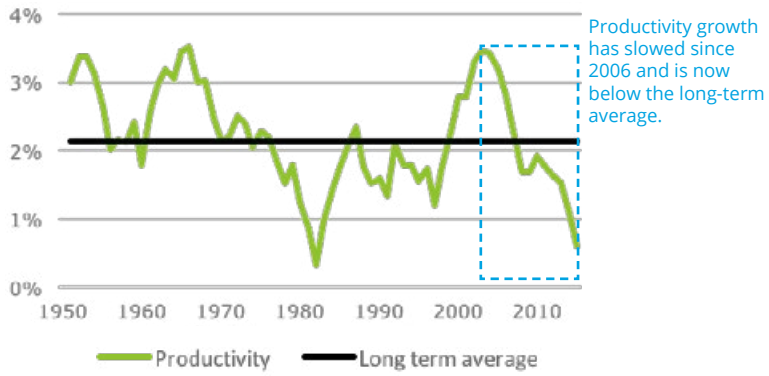
*Value-Add is an economic measure expressing the "value" (in terms of labor and capital input into a manufactured good) in each country. If a country begins to conduct more highly complex activities to manufacture goods, the "value-added" of that country will be higher. It typically requires increased productivity and more highly-skilled (and thus highly-paid) workers, and can lead to increased internal consumption and exports.

Advanced manufacturing has a multiplier effect on job creation and can counteract declining domestic productivity growth and increasing foreign competition

U.S. advanced manufacturing supports trillions of dollars of production.[8]



Advanced manufacturing is needed to reverse slowing productivity growth.[9]



Note: All productivity data is represented as the 5-year running average (i.e., each individual data point is the average of the five years previous). Endpoint of the data goes through 2015.

U.S. advanced manufacturing supports trillions of dollars of production in other parts of the economy by purchasing from and selling to over 80 other industries, ranging from transportation to education.[10]

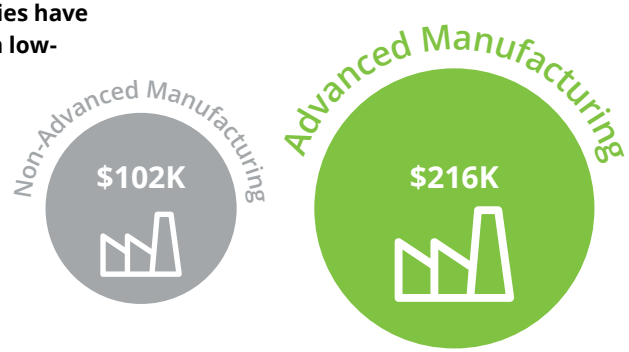
One of the main drivers of productivity growth is new innovations and inventions that allow workers to produce goods more quickly and cost effectively. Stronger connections between institutions conducting research and companies that commercialize new technologies could reverse the trend of slowing productivity growth.[11]

Technological advances have an incredible impact on the economy. **Workers today produce nine times more each hour than workers 100 years ago.**[12] Today, each job in advanced manufacturing supports up to an estimated 16 jobs in the rest of the economy, a much larger impact than traditional manufacturing (4.6 jobs) or retail (0.8 jobs).[13,14]

When U.S. workers are able to produce more goods, their companies are more competitive and worker wages have the potential to rise. New manufacturing techniques, advanced computing, and other innovations have increased productivity over the last 50 years, providing the foundation for continued economic growth.[15]

High-productivity industries have larger job multipliers than low-productivity industries.[16]

Manufacturing output generated per worker is twice as high in advanced manufacturing.[17]



The Manufacturing USA Program is designed as a strategic response to increasing global pressure on U.S. advanced manufacturing

Program Overview

The U.S. stands at an inflection point in manufacturing. The preeminence of the country's manufacturing heritage is being challenged by a rapidly evolving competitive environment. This evolution includes progress toward a future where competitor nations are investing significantly and strategically to define and defend their positions in the global advanced manufacturing industry.

Foreign competitor investments in advanced manufacturing programs

In June 2016, China announced $3B in funding for an advanced manufacturing program aimed at boosting high-end manufacturing and promoting modernization of traditional industry.[18]

In 2009, Japan invested more than 30 times as much as the U.S. as a share of gross domestic product (GDP) in small and medium enterprise (SME) support programs.[19]

The German Fraunhofer-Gesellschaft program's annual research budget is €1.9 billon in support of 67 institutes and research units.[20]

Given advanced manufacturing's impact on job creation, economic prosperity, and national security, strategic decisions on how the U.S. should invest and drive forward technological advancements can have substantial long-term implications.

Manufacturing USA is a U.S. national-level response to the increase in global pressure on U.S. advanced manufacturing. The Program, a collaboration of science and technology experts, industry, and academic leaders, encourages investment and innovation. The Program is designed to be an innovative public-private partnership, not a traditional federal grants office. As such, the Program is creating a portfolio of **networked Institutes** with facilities located across the country. These Institutes accelerate technology development by **convening and coordinating** members to:[21,22]

- **Catalyze** research and development projects through federal funding
- **Reduce** the costs associated with developing new technologies
- **Signal** the importance of advanced manufacturing to U.S. interests
- **Connect** industry members who would not normally come together to innovate through consortia that can tackle cross-sector challenges, and
- **Develop** workforce skills and build a pipeline of 21st century STEM talent.

As of November 2016, there were eight established Institutes and 753 members. In addition to convening critical stakeholders, the government has committed over $600M in investments, which has spurred $1.3B in "matching" investments from industry, state, local, academic, and not-for-profit stakeholders.

Report Structure

This report analyzes the Manufacturing USA Program's initial strategy and progress to date and presents opportunities to promote continued drive to success. The sections of this report provide the following:

- An assessment of Manufacturing USA's Program design,
- Visibility into the Program's progress and achievements across three areas: manufacturing technology innovation; preparing the workforce of the future; and creating sustainable, living, and thriving ecosystems of industry, academia, and government working together, and
- Recommendations to further improve Program performance and effectiveness.

This report is structured in the following manner, with an overarching focus on the Program's impact on U.S. competitiveness.

Program Design

Program Progress

I	**Facilitating Technology Innovation and Commercialization**
II	**Accelerating Manufacturing Workforce Development**
III	**Promoting Sustainable Ecosystems for Advanced Manufacturing**

Manufacturing USA Institutes deliver value to members through a common, but uniquely tailored, set of core value propositions

The Program enables the Institutes to accelerate technology development in order to increase U.S. competitiveness. While each Institute focuses on delivering two core value propositions to its members, it does so in different ways.

Leveraged Investment via Valuable Cost-Share

In response to foreign pressures and the significant challenges to the U.S. manufacturing industry, leaders within the National Economic Council, DoC, DoD, and DoE organized a collective action strategy designed to secure the United State's preeminent competitive edge in advanced manufacturing. Manufacturing USA is built on a foundation that leverages cost sharing between the federal government and key technology area players. The Federal government's commitment of over $600 million to eight awarded Institutes has been matched by over $1.3 billion in non-Federal resources from across industry, academia, and state governments. These resources are used to convene technology partners and to coordinate Institute projects around technologies critical to U.S. national security, energy, and the U.S. economy.

Convening Partners

The Program enables Institutes to *convene* in order to:

- **Organize various efforts** across industry and address collective action challenges
- Help a **diverse array of members** overcome a number of barriers to intra- and inter-industry collaboration
- **Improve visibility** between members for partnership opportunities
- Balance the competing business interests of similar organizations and **encourage collaboration for mutual benefit**

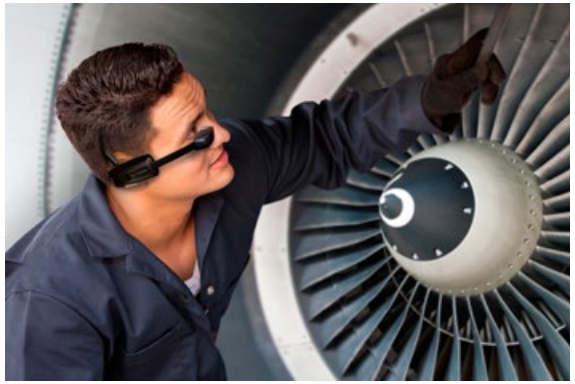
Coordinating Projects

Institutes *coordinate* project activities in order to:

- **Facilitate knowledge exchange** to speed innovation
- Drive stakeholder coordination to **provide access to shared pools of intellectual property**
- **Provide access to equipment** and/or technical support for equipment that is inherently highly expensive, complex, and/or rarely available
- **Align overarching member goals** through strategic planning and technology road-mapping
- **Signal market needs and viability**

Accelerate Technology Development

Manufacturing USA Institutes convene and coordinate partner organizations to bring next generation technologies to market



Investing in the Technology of Tomorrow – Wearable Devices with Augmented Reality[23]

A DMDII project is bringing together researchers from the Rochester Institute of Technology and partner businesses to commercialize emerging wearable technologies. This project aims to move shop floor instruction manuals into interactive, easy-to-use wearable technology. Using augmented reality technology, users will be able to see how to complete a physical task, with virtual guides showing them what—and what not—to do in real-time via a Heads-Up Display. At the same time, the system will collect valuable shop floor data that is not typically captured and harness it to improve future manufacturing processes. Together, DMDII's members are working to create cost-effective technology that could significantly improve manufacturing quality and maintenance.

Facilitating Breakthroughs in Creation and Commercialization of Cutting-Edge Technology[24]

With support from PowerAmerica, member AgileSwitch has applied a new patented switching technique to provide enhanced control in high-power silicon carbide applications. AgileSwitch's technology has been incorporated into the company's first silicon carbide gate drive assembly, which has applications for solar inverters, wind turbine technology, electric vehicles and other clean energy applications. PowerAmerica funding enabled AgileSwitch to implement its patented technique and test the capabilities of the drivers and switches – often one of the costliest and time-consuming parts of getting a new product ready for market. The Institute is also helping the company generate interest in the product from other companies due to connections it has facilitated. "PowerAmerica has helped us significantly with introductions to potential customers at the university, government lab and industrial levels," said AgileSwitch company leadership.

Institutes convene members to create mutually beneficial innovation partnerships

Institutes help organizations overcome barriers to creating new and lasting connections.

- **Reducing effort to make connections.** With many organizations in one place, it is easier for groups to find the best possible partners with the right resources.
- **Aligning shared interests.** Creating relevant partnerships and matching companies together is easier because each Institute's members are working on similar technological problems in the Institute's topic area.
- **Convening members as a neutral trusted party.** Institutes do the hard work of bringing industry, academia, and government together and often serve as an intermediaries to guide members' networking.
- **Sending a strong signal.** Since members pay to join an Institute, members are serious about collaborating, achieving milestones on projects, and deriving real value from Institute-based interactions.

Institutes solve collective action problems.

- **Creating technical standards.** Few companies have the breadth and industry coverage to drive stakeholders toward a technical standard. The Institutes promote early alignment and help companies avoid creating disjointed processes.
- **Building technology roadmaps.** When companies better understand the progression of technology from an industry-wide perspective, all involved parties invest their R&D budgets more effectively in a coordinated manner.

Breaking Down Barriers for Collaboration	U.S. textile manufacturers have traditionally been reluctant to collaborate due to IP leakage to foreign manufacturers. AFFOA serves as a trusted convener to connect companies who would benefit from technological collaboration and want to retain IP in the U.S. For example, through AFFOA, two small companies partnered with a larger industry partner, Bluewater Defense Inc., to work on a fabric upgrade that combined their specialty knowledge to meet a market need.[25]
Facilitating Unlikely Partnerships	Members gain connections that would otherwise take years to forge, or might never materialize. For example, an academic partner who recently visited DMDII and made a key connection said: "It'd have taken me years to get in the door with this company, now I talk to their C-suite on a weekly basis [about a joint manufacturing project]."[26]
Creating Standards for New Technology	The Institutes are at the forefront of advanced manufacturing and often operate in spaces without existing standards. America Makes, in partnership with the American National Standards Institute (ANSI), launched the Additive Manufacturing Standardization Collaborative (AMSC) to develop standards roadmaps for additive manufacturing to promote coordination, quality, and consistency across the industry.[27]
Organizing an Industry's Workforce Needs	Understanding workforce needs for future technologies is important for every Institute. NextFlex, in coordination with IACMI and LIFT, developed a list of 32 "next-generation" occupations that require a two-year degree for all three of their technology areas. The skills identified will be instrumental for the future advanced manufacturing workforce.[28]

Institutes coordinate member activities to address significant shared challenges

State-of-the-Art Facilities and Equipment Access	LIFT and IACMI are co-locating $50M worth of key manufacturing equipment in a joint facility in Detroit. Given the overlap in technology needed for each Institute's focus area, the Institutes' members benefit from having key equipment for lightweight metals and advanced composites available in close proximity in a state-of-the-art facility.[29]
Facilities that Speed Production	AIM Photonics members can leverage equipment capabilities that enable the development of new products and processes. Through money provided by New York state, AIM is building a new user facility in Rochester, NY, where members can work with state-of-the-art commercial tools to test, assemble, and package new products more quickly, increasing the speed at which new technologies can be scaled.[30]
Asset Pooling that Enables Small-Scale Production	Silicon carbide and gallium nitride are critical materials for the emerging field of power electronics. The silicon carbide and gallium nitride markets are dominated by relatively few players. There is a need for innovation from start-up entrepreneurs advancing disruptive technologies. However, dozens of smaller fabrication plants have closed their doors since 2001 because of competition. X-FAB, with funding from PowerAmerica, pools the production of semiconductors from small companies to achieve economies of scale. IP from each company is protected, but innovation is fostered because of X-FAB's ability to aggregate demand across customers.[31]
Access to Software, Hardware, and Expertise	IACMI provides small businesses, start-ups, and even some large companies access to resources they otherwise could not afford, including expensive modeling and simulation software suites that typically require licenses and advanced skills to operate.[32]

Institutes let companies innovate without the high costs of owning, staffing, and maintaining high-end advanced manufacturing equipment for R&D.

- **Providing equipment access.** Consignment agreements between Institutes and equipment manufacturers have enabled Institutes to provide members access to the equipment necessary to advance projects at much lower cost. This is especially critical for SMEs, for which advanced equipment is cost-prohibitive. Much of the equipment is state-of-the-art and not otherwise easily accessed and is made available to members via the Institutes.

Institutes allow members to collaborate through common agreements on IP and partnerships that would be prohibitively expensive and time-consuming to negotiate case-by-case. This enables safer and easier sharing of sensitive information.

- **Creating standardized member and IP agreements.** Having members pre-sign standard agreements reduces partnership costs and increases speed, facilitating more net partnerships and faster R&D results.
- **Facilitating joint development of IP.** Institutes make it easier for companies to develop and test innovations together by creating solicitations for joint projects which can be bid on and completed by members.
- **Leveraging existing IP.** In addition to the shared and project-generated IP, Institutes also bring together pre-existing academic patents and other available IP to be combined, built upon, and shared across industries.

Manufacturing USA's Institutes and the Institutes' members are distributed broadly around the country, showing the national reach of the Program

The dense concentration of clusters of companies and organizations participating in Manufacturing USA is highlighted with selective call-outs on this map, to better illustrate the numbers of members in close proximity. See the example below. More than 700 members are represented on this point-in-time snapshot map.

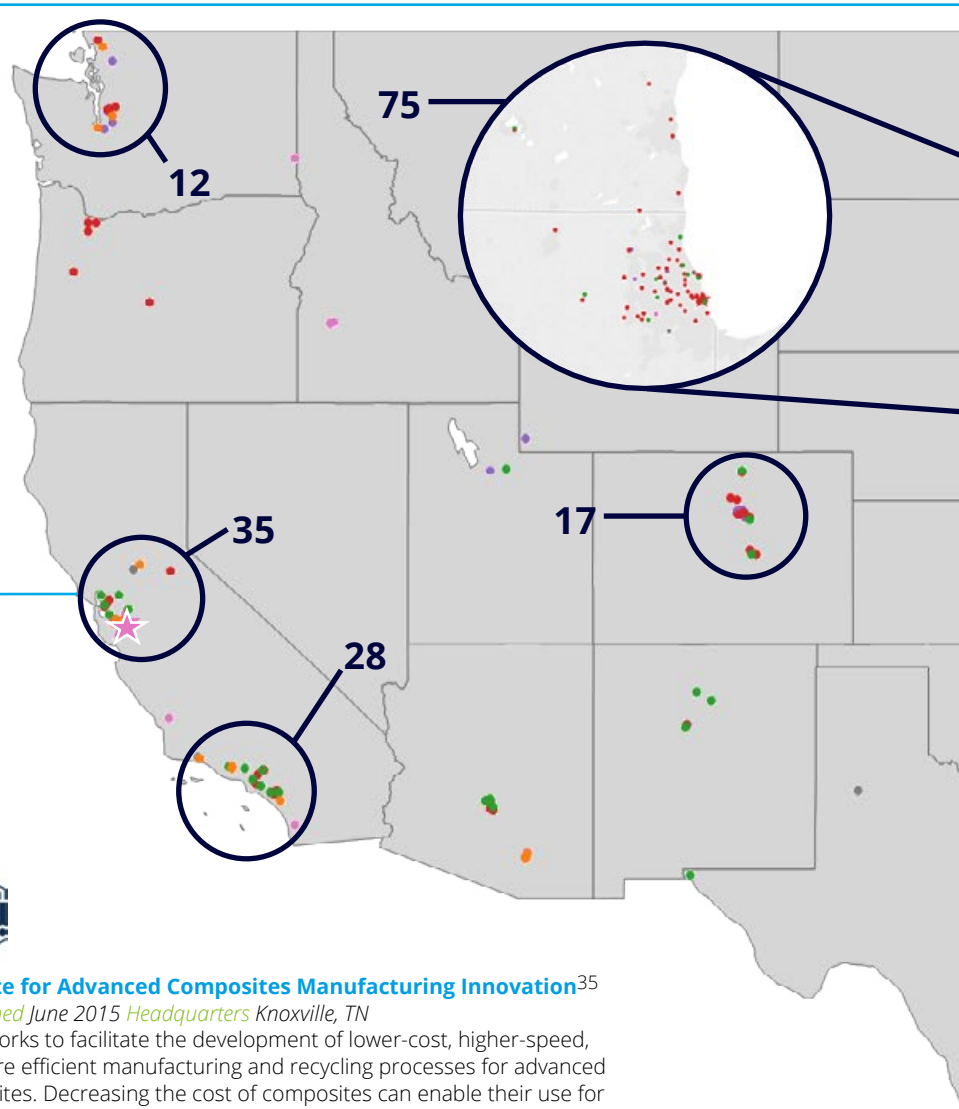
More Institutes are scheduled to be launched in the future, and each Institute will continue recruiting members across the country, resulting in progressively broader geographic representation over time.

A Note on Secondary Hubs

As can be seen on the map, Institutes have member participation across the U.S. In addition, Institutes are working to set up secondary hubs or satellite centers to continue expanding their national reach. One example is America Makes' satellite center created in partnership with the University of Texas at El Paso and its state-of-the-art Keck Center facilities.[36]

A Note on Methodology

Where available, Institute member data reflects specific company locations or the facility that most closely works with the Institute; where unavailable, markers represent company headquarters. It is likely that geographic reach of the Program is even broader than depicted here, as multiple company sites are connected to or impacted by the Program in the case of larger member organizations.



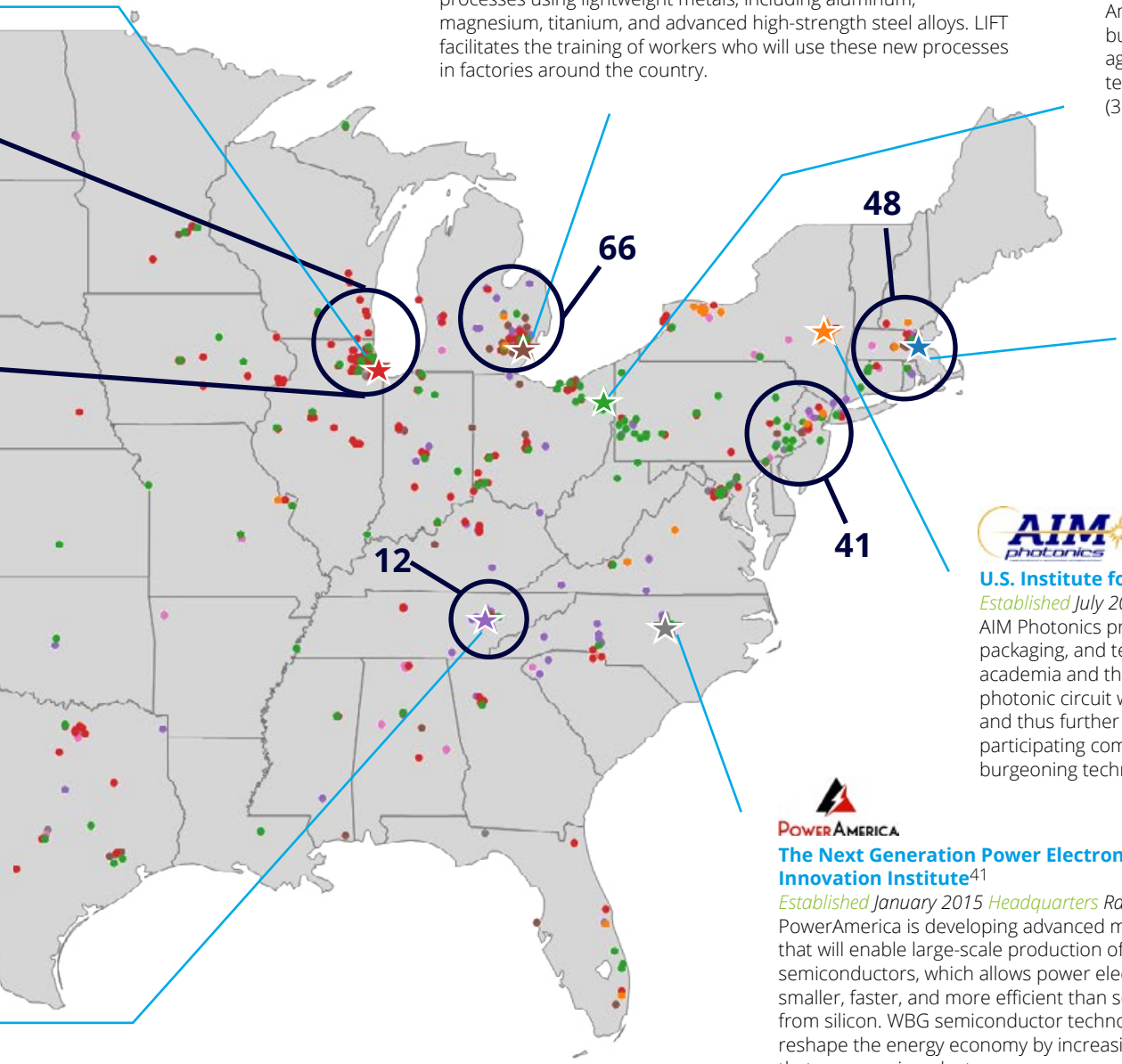
Digital Manufacturing and Design Innovation Institute[33]
Established February 2014 Headquarters Chicago, IL
DMDII works with factories across America deploying digital manufacturing and design technologies in order to connect different parts of the manufacturing life-cycle through data, and to utilize that information to make smarter, more efficient business decisions.

America's Flexible Hybrid Electronics Manufacturing Institute[34]
Established August 2015 Headquarters San Jose, CA
NextFlex catalyzes the U.S. flexible hybrid electronics (FHE) ecosystem to commercialize technology through investments in thinned device processing, device/sensor integrated printing and packaging, system design tools, and reliability testing and modeling.

Institute for Advanced Composites Manufacturing Innovation[35]
Established June 2015 Headquarters Knoxville, TN
IACMI works to facilitate the development of lower-cost, higher-speed, and more efficient manufacturing and recycling processes for advanced composites. Decreasing the cost of composites can enable their use for a broader range of products including lightweight vehicles with record-breaking fuel economy, lighter and longer wind turbine blades, high pressure tanks for natural gas-fueled cars, and lighter, more efficient industrial equipment.

KEY

- AFFOA
- AIM Photonics
- DMDII
- America Makes
- IACMI
- LIFT
- PowerAmerica
- NextFlex



Lightweight Innovations for Tomorrow[37]
Established February 2014 Headquarters Detroit, MI
LIFT increases the speed of development of new manufacturing processes using lightweight metals, including aluminum, magnesium, titanium, and advanced high-strength steel alloys. LIFT facilitates the training of workers who will use these new processes in factories around the country.

America Makes
National Additive Manufacturing Innovation Institute[38]
Established August 2012 Headquarters Youngstown, OH
America Makes facilitates collaboration among leaders from business, academia, nonprofit organizations, and government agencies, focusing on areas that include design, materials, technology and workforce and help our nation's three-dimensional (3D) printing industry become more globally competitive.

Advanced Functional Fabrics of America[39]
Established April 2016 Headquarters Cambridge, MA
AFFOA's mission is to transform traditional fibers, yarns, and fabrics into highly sophisticated, integrated, and networked devices and systems. The Institute makes fiber device intellectual property available for domestic manufacturers, links together a Fabric Innovation Network of producers and laboratories to rapidly execute prototypes and pilot production, and oversees a network of "advanced fabric" incubators connected to market-facing companies.

U.S. Institute for Manufacturing Integrated Photonics[40]
Established July 2015 Headquarters Albany, NY
AIM Photonics provides access to state-of-the-art fabrication, packaging, and testing capabilities for small-to-medium enterprises, academia and the government; creates an adaptive integrated photonic circuit workforce capable of meeting industry needs and thus further increasing domestic competitiveness; and meets participating commercial, defense and civilian agency needs in this burgeoning technology area.

PowerAmerica
The Next Generation Power Electronics Manufacturing Innovation Institute[41]
Established January 2015 Headquarters Raleigh, NC
PowerAmerica is developing advanced manufacturing processes that will enable large-scale production of wide bandgap (WBG) semiconductors, which allows power electronic systems to be smaller, faster, and more efficient than semiconductors made from silicon. WBG semiconductor technology has the potential to reshape the energy economy by increasing efficiency in everything that uses semiconductors.

The Program consists of an interconnected network of members that are linked to one another within and across Institutes

Organization-to-Organization

e.g., Company & University

Partnerships between organizations are formed to enable cost savings, foster more rapid development through information sharing, and reinforce organizational capabilities.

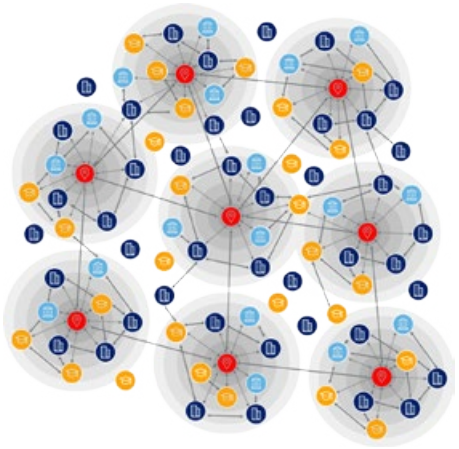
Advanced manufacturing companies have links to each other independent of Manufacturing USA. Institutes are not the source of all connectivity; they are a catalyst to increase it.

Institute Consortium

e.g., America Makes and its Members

Innovation consortia are dynamic and co-evolving communities of diverse organizations that create and capture new value through collaboration and competition.

The goal of a consortium is to achieve something that lies beyond the effective scope and capabilities of any individual actor.[42] Institutes are ecosystem conveners that exert a "gravitational pull" and create a common space of trust that promotes and spurs partnerships between actors.



Network

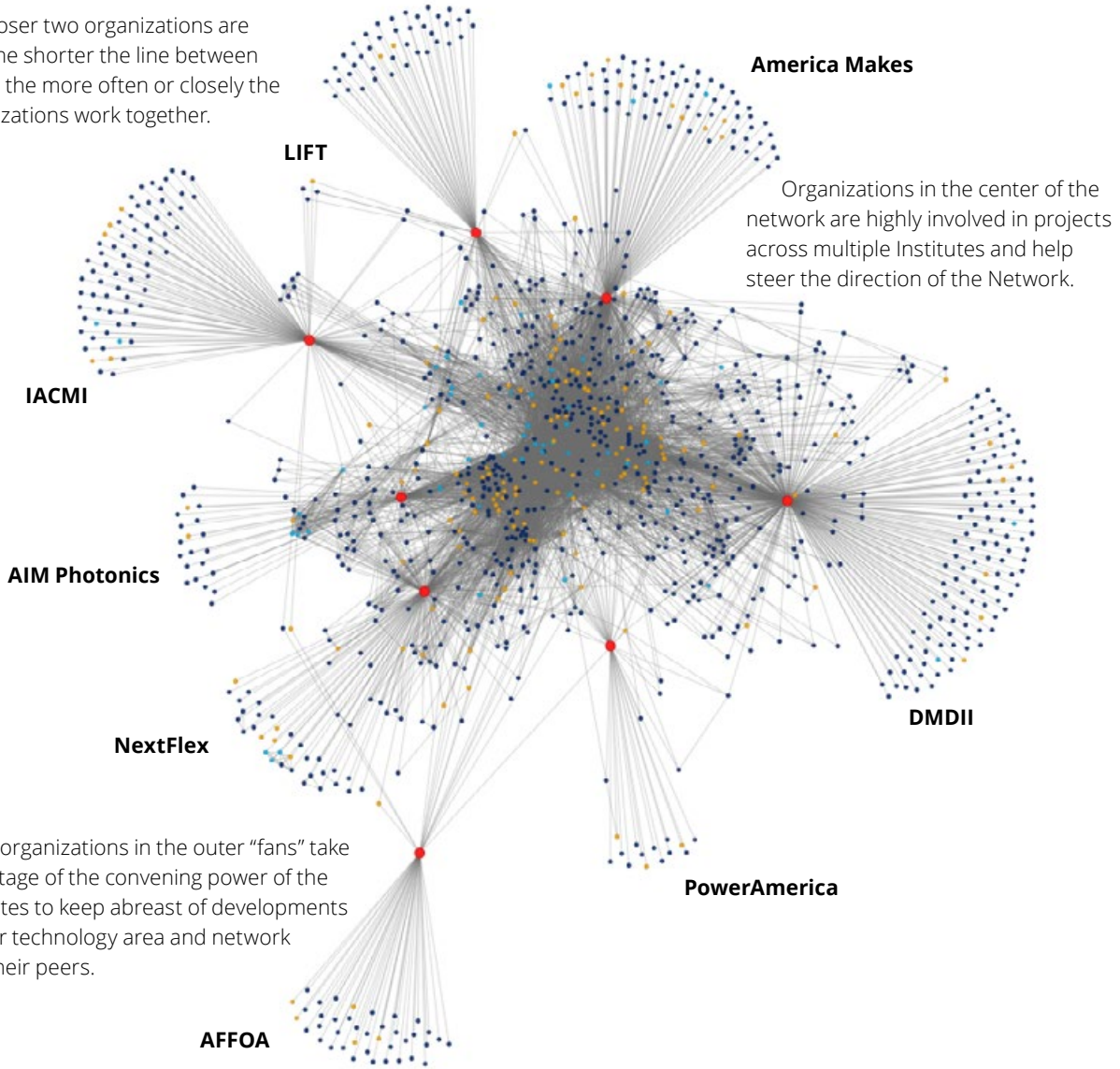
e.g., Manufacturing USA

A network is a decentralized structure that facilitates sustained interactions (1) between Institute consortia and (2) between individual members of different Institutes; the additional web of connections formed is mutually reinforcing and creates additional value for participating actors.

The Manufacturing USA Program represents a "whole-of-economy" approach, and provides oversight and guidance to support Institute effectiveness. The Program represents the sum of all individual Institutes, the Institute consortia, and the Network.

The Institutes convene nearly 1,200 organizations in an inter-industry network comprising 9,000+ substantive relationships

The closer two organizations are (and the shorter the line between them), the more often or closely the organizations work together.



Organizations in the center of the network are highly involved in projects across multiple Institutes and help steer the direction of the Network.

Some organizations in the outer "fans" take advantage of the convening power of the Institutes to keep abreast of developments in their technology area and network with their peers.

The nearly 1,200 companies, government agencies, non-profits, and academic institutions shown are linked through Institute working groups, steering committees, and the process of planning and conducting research projects. The Program provides organizations the flexibility to join the one or many Institutes that offer the benefits most relevant to their needs.

9,424
Relationships between organizations

1,174
Organizations involved with the Program

753
Organizations with formal membership

203
Organizations with relationships with multiple Institutes

120
Organizations which are members of more than one Institute

PROGRAM PROGRESS: SECTION I

Facilitating Technology Innovation and Commercialization

This section describes how the Program and Institutes facilitate the transition of technologies from basic research to commercialization.

The section starts by describing market obstacles in the progression of critical advanced manufacturing technologies. It then details how the Program and Institutes' core activities are addressing these issues. Institutes are reducing the cost of experimentation and increasing the efficacy of R&D spending by members, enabling pre-competitive collaboration on technical projects and fostering focused relationships between members. Institutes do this by aligning federal funding to key technical areas and by developing shared resources such as technology roadmaps, which help companies appropriately prioritize and sequence spending.

DMDII Facility in Chicago, Illinois

Section Takeaways:

- **Historically, investments are unevenly distributed across stages of manufacturing R&D and transitioning IP is difficult, inhibiting innovations from reaching the market.** Manufacturing USA addresses this "valley of death" between research and commercialization by convening members that conduct work along different parts of the R&D spectrum and de-risking investments.
- **Institutes decrease the cost of R&D experimentation by providing access to expensive equipment, pooling project costs, creating technology roadmaps, and promoting knowledge exchange.** Institutes deliver greater return on R&D spending for members than they could each achieve on their own. Co-development of technology results in cross-industry and cross-company sharing of information that accelerates technology transition and advancement.

"Affiliation with Manufacturing USA provides access to **unique opportunities to bring together multidisciplinary teams to conduct impactful research**. The combination of research partners, industry members, and government interest all focused on advanced manufacturing **exists nowhere else**."

— Member Organization

"My affiliation provides me with an outstanding opportunity to see **basic science and technology discoveries translated into real-world applications and products**. It has facilitated connections between my research groups and a broad community that would be otherwise difficult to access."

— Research-Focused Academic Institution

"The most important value of participation in Manufacturing USA's Institutes is that it creates a highly respected venue to inform many relevant parties of newly developed technology. **Such truly effective opportunity is simply not available elsewhere.**"

— Small and Medium Enterprise

Manufacturing innovations can be slow to reach market viability due to barriers such as uneven R&D funding and the difficulty of transitioning IP among players

Within the manufacturing industry, gaps exist between research and the subsequent commercialization of new products. These gaps, common among many of the industry's technology areas, differ in magnitude and impact by technology, but are all traditionally the result of key factors such as an uneven distribution of R&D investments and challenges associated with transitioning IP between stakeholders with different priorities.

When viewed collectively at the industry level, these gaps are referred to as the industry's "valley of death" – a significant barrier to the maturation of advanced manufacturing technology.[43]

Progress along the technology innovation spectrum is defined by "Manufacturing Readiness Levels" (MRLs), which are used to assess technology maturity and are expressed as a 1 to 10 scale.[44] The "valley" spans MRLs 4 to 7 (dark green in the graphic below).

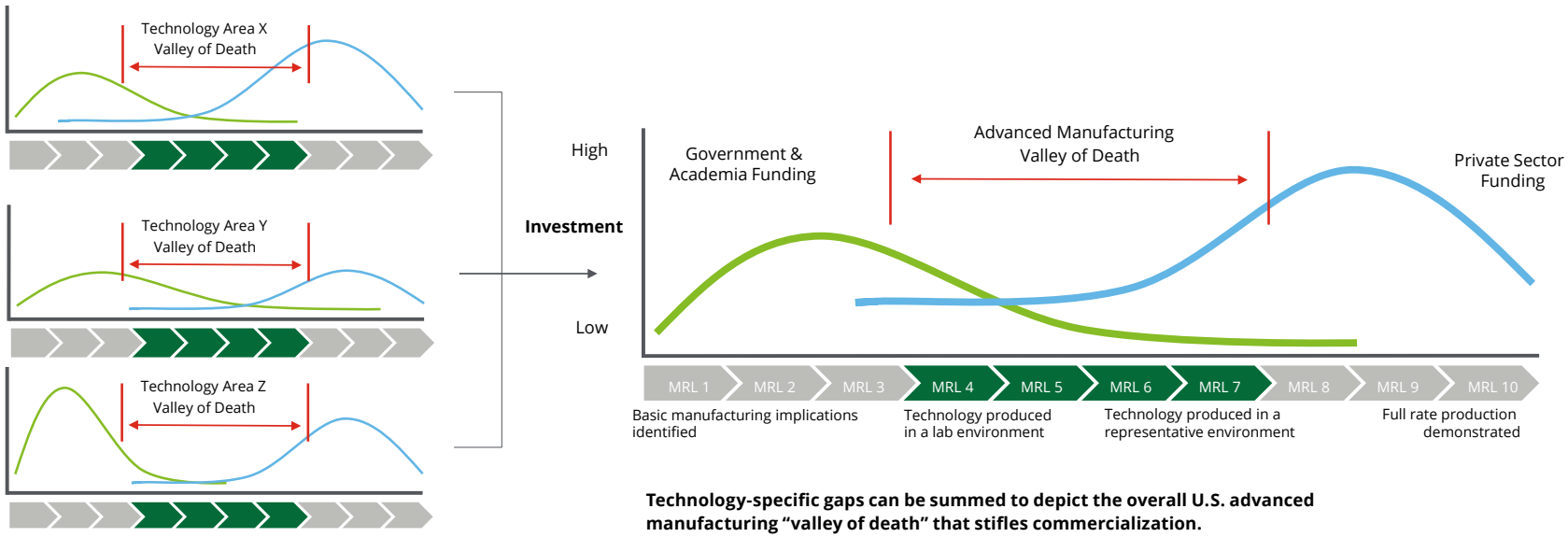
For both the aggregate (industry-level) and individual (technology-specific) valleys, the lack of investments and the inability to find the right partnerships causes many inventions to "die on the shelf," never maturing to commercialization.[45]

Manufacturing USA's program design answers these challenges by fostering the creation of Institutes that convene members from across the research-commercialization spectrum, pulling the two sides of the valley together to "bridge" the gap via collaboration.

In addition to convening the right players, the Program also commits critical government funding (via funding agencies such as DoE and DoD in the case of the existing Institutes) to jump-start and de-risk investment in these key areas.[46]

The selection of technical areas for Institute focus is driven by industry and independent experts. The initial selection of priority technology areas was obtained through a crowdsourcing effort, including a federally sponsored Request for Information (RFI) and regional workshops beginning in April 2012. Ongoing input on Institute topics is collected via workshops, new RFIs, and through open competition.

By breaking down market barriers in the right technological areas, the Program facilitates the acceleration of U.S. manufacturing R&D.



Technology-specific gaps can be summed to depict the overall U.S. advanced manufacturing "valley of death" that stifles commercialization.

Institutes combat the effects of the "valley of death" by decreasing the cost of experimentation for their members through access to critical equipment and facilities

Advanced manufacturing industries* represent some of the most capital-intensive parts of the economy. Influenced by how expensive it is to invest in small-scale production to test advanced manufacturing innovations, company executives sometimes shy away from the risk associated with investing in cutting-edge R&D projects.[47] The ability to access and "leverage" equipment from Institutes allows members to experiment with and subsequently scale new products and processes in a lower-risk environment. By providing members with the ability to validate the viability and value of innovative products or processes – as well as understand the associated costs and potential profits – Institutes improve companies' likelihood of making commercial-scale investments.

The reduction of financial risk increases the likelihood that a member will pursue valuable investments in advanced manufacturing technologies, including innovations outside the core R&D portfolio. Increasing the breadth and ambition of a member's R&D portfolio in turn increases the likelihood of major breakthroughs across advanced manufacturing.[48] By empowering members, Institutes encourage the pursuit of fundamental industry goals such as improved competitiveness, increased capability, and/or enhanced energy efficiency.

Multi-project wafer creates economies of scale for photonics experimentation	AIM Photonics' multi-project wafer program allows companies to produce photonics-enabled semiconductors at an extremely discounted cost compared to in-house production. Through the Institute, multiple member firms share a single silicon wafer for their projects instead of each producing its own. By pooling demand, AIM Photonics creates the economies of scale needed to efficiently produce photonics-enabled semiconductors, significantly decreasing the cost barriers to experiment with photonics.[49]
Open composite production line accelerates R&D cycle	IACMI provides U.S. industry access to a high- tech, fully open, end-to-end carbon fiber production line, one of only a few currently available in the U.S. It would be prohibitively expensive for SMEs and even large companies to recreate these facilities; without the resources at IACMI, members would either need to invest in their own facilities or slow down or repurpose active production lines for R&D. Having access to third-party facilities like IACMI's accelerates the R&D cycle for members, decreases risks, and allows additional products to be tested more rapidly.[50]

Empowering Small Business and Startups – Bringing in the "Benjamins"[51]

At DMDII's Goose Island facilities in Chicago, Benjamin Bullis, a young aspiring manufacturing innovator, was able to accelerate the development of his idea for a type of high-powered, ultra-flexible LED light. While his day job is in IT, Ben spends considerable time coming into DMDII's facilities and testing and refining his product prototypes for his manufacturing start-up, Frelux. Today, he has developed eight prototypes in production. Without DMDII and the thousands of dollars in equipment and skilled coaching it made accessible to Ben, he might have never been able to test his concept and drive the spirit of American small business innovation.

*Advanced manufacturing industries are defined by the Brookings Institution based on two criteria: R&D spending per worker and share of workers working in occupations requiring high STEM knowledge. Advanced manufacturing industries have R&D spending per worker above the 80th percentile of industries and more than 21 percent of their employees work in occupations requiring high STEM knowledge.[52]

Institutes let members pool R&D investments and gain broad access to results across the Institute's projects, delivering significant return on R&D spending

Each Institute offers members a positive leveraged return for R&D spending through projects. Instead of members individually investing all of the R&D dollars required to fund a project, Institutes enable members to participate in cost-sharing agreements to distribute the costs (and therefore the risks) associated with R&D projects. Despite costs being shared across industry and academic partners – with additional government dollars from the Institute defraying the cost – members receive the full benefits of the R&D. These include not only deepened understanding and learning in the technology area, but actual intellectual property including product and process improvements.

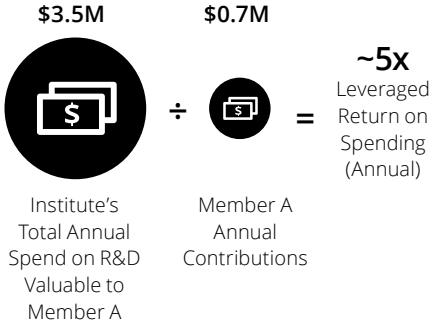
By collaborating in a pre-competitive R&D environment that lowers risk, members are empowered to pursue cutting-edge projects that would otherwise be out of reach. The resulting technological advancements can then be incorporated into products and processes that allow the members to compete commercially – while surpassing non-member foreign competitors which are not part of the Institutes.

While IP and R&D results sharing among members with direct project involvement is a consistent value proposition of all Institutes, some (such as DMDII) even have agreements allowing members to access IP from projects they do not directly support. This element of DMDII's IP agreement amplifies the R&D return realized by members.

Although each Institute has unique IP agreements, all have the ability to produce conservative calculations of their R&D portfolio and the value that is returned to members through participation in shared R&D costs and outputs. It is clear the Institutes provide value to each member through these mechanisms; calculating these with greater precision for potential new members could speed recruitment.

A specific example is detailed below to demonstrate the value delivered to members through joint R&D projects and IP sharing.

Representative Sample Calculation of DMDII IP Portfolio Value
(uses conservative assumptions based on Institute internal data)



Situation: DMDII has an IP agreement allowing Tier 1 members to access IP from all present and future projects and is persuading "Member A" to join as a Tier 1 member. The following example is based on Member A's unique profile:

Member A's Path to Returns: Assume Member A pays $400K for membership dues. Assume the average Tier 1 member spending per project is $150K and the average total project cost is $750K. Under these conditions the total "free" value Member A receives for participating in a project is $750K - $150K = $600K. This $600K represents other organizations' R&D budgets pooled together to produce results that benefit member A.

Assuming Member A participates in two projects per year, benefits and costs are:

- **Annual Benefits:** $750K * 2 = $1.5M in total R&D spend on projects as a benefit.
- **Annual Costs:** $400K dues + ($150K Member A project cost * 2) = $700K total costs.

Additionally, because Tier 1 members can access the full breadth of the Institute's project results – additional value is derived.

Assume that the total spend of the Institute's accessible project portfolio is $10M and conservatively, only 20%* of other projects are useful to Member A. In that case, the Institute's portfolio spend relevant to Member A is estimated as: $10M x 20% = $2M.

Adding the $1.5M in R&D spend from projects in which Member A is involved and $2M in other projects in which Member A is not involved yields $3.5M. Dividing that by their total costs for the year, $700K, suggests (conservatively) a 5x leveraged return on spending.

*The relevant portfolio percentage is likely to be higher for members that play an active role in Institute project selection processes.

Institutes enable collaboration and meet shared industry needs by creating roadmaps and promoting knowledge exchange

Market drivers rarely incentivize U.S. companies to collaborate.

The lack of collaboration that exists across U.S. advanced manufacturing technologies leads to unintentional and unnecessary overlap of effort among companies pursuing similar early-stage R&D programs. By design, the Program operates in the pre-competitive stage of research, limiting threats to industry competitive advantage. In this pre-competitive space, Manufacturing USA creates a mutually beneficial environment. Members participate because the collaboration makes them all more competitive against foreign rivals by eliminating (or at least limiting) costly duplication where it does not serve as a competitive differentiator.

Revolutionary technologies require collaboration.

The investments required to commercialize emerging technologies require highly specialized skills from diverse stakeholders. Institutes align players that are not typically partners, such as industry and academia, or semiconductor manufacturers and traditional printers, in a forum where they can license and leverage others' processes, technologies, and insights. In this environment, companies capitalize on their own strengths while harnessing the capabilities and assets of others. This co-development of technology results in cross-industry and cross-company pollination of ideas that strengthens final results.[53]

Reducing overlap of effort with technology roadmaps	The industry, academic, and government members of each Institute collaborate to create a technology roadmap laying out their common technical problems and developing a project strategy to guide the Institute's project awards. The technology roadmap, and ensuing projects, reduces overlap of effort across a technology by signaling where pre-competitive collaboration will occur and where members should still invest independently.
Convening textiles and electronics expertise	AFFOA integrates technology from multiple industries including textiles, semiconductors, telecommunications, and data storage to create a future-oriented product that changes the way businesses and consumers interact with clothing. Linking large industry leaders to small businesses and start-ups, AFFOA facilitates relationship building and increases the speed at which new products are designed and prototyped.[54]
Connecting the semiconductor and printing industries	NextFlex connects the Silicon Valley-based semiconductor industry with the traditional printing industry in the Midwest. Many of the underlying technical issues facing flexible hybrid electronics have previously been solved by printing companies. NextFlex helps the semiconductor industry tap into that expertise and provides a vehicle for the printing industry to expand into a new advanced manufacturing technology.[55]

Pioneering a Greener Future for Vehicles – Making Advanced Composites Supercars[56]

Ford and IACMI are working together to produce pioneering processes that will use carbon fiber and other advanced composites to improve fuel economy and reduce emissions, making the next generation of vehicles even better for the environment. The Ford GT supercar is a low-volume test bed for Ford's work with composites such as carbon fiber, cutting the weight of parts by as much as 60 percent compared to steel. Ford's Letter of Intent includes a $5 million commitment to IACMI over five years, leveraging significant federal, state, and industry investment dollars totaling $250 million.

PROGRAM PROGRESS: SECTION II

Accelerating Manufacturing Workforce Development

This section overviews current challenges with the development of a skilled and adaptive U.S. workforce for advanced manufacturing, leading to the development of a "talent gap" that negatively impacts U.S. employers and national economic competitiveness.

The section highlights effective Institute and Program initiatives designed to reduce the talent gap. Some of the Institutes' most effective activities include industry workforce assessments, community engagement events, post-secondary apprenticeship programs, and coordination on the creation of effective industry- and skill-based credentials.

Department of Commerce Leadership visiting a U.S. Nanofabrication Lab.

Section Takeaways:

- **U.S. advanced manufacturers are experiencing a growing talent gap.** Baby boomer retirements, the technical complexity of manufacturing work, a science, technology, engineering, and math (STEM) skills deficit among students, and persistent negative perceptions make it difficult for companies to fill critical roles in a timely manner.
- **Institutes help industry mitigate the talent gap by coordinating workforce activities conducted by members and external stakeholders.** Efforts include industry assessments of worker supply and demand for technological areas, community engagement events, apprenticeship programs, and the coordination of employee credentials and certifications.

"My unit at the community college is focused on supporting business growth, and much of that work takes place at **the intersection of advanced technology and talent development…** the value of the Manufacturing USA [Program] is [the] tools or investments that help us serve as a resource to our local employer base."

— Academic Institution

"It is my belief that [advanced manufacturers] **cannot succeed if the appropriate pipeline of workers is not available**, so a well-thought-out [workforce] plan with short- and long-term goals that match the growth and need in each sector is an important component of the Institutes."

— Member Organization

"Our university has seen value in engaging with [an Institute] on a whole host of activities, from pre-competitive projects to participation in road-mapping exercises to workforce development endeavors. In our mind, **the true value of the engagement with [the Institutes] comes from the interactions.**"

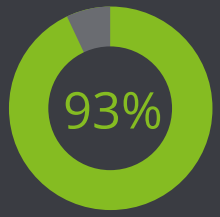
— Academic Institution

U.S. advanced manufacturers are experiencing a growing talent gap – an insufficient number of skilled workers to meet employers' existing and future needs

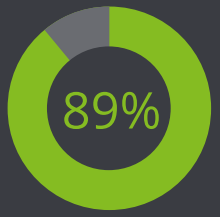
Increasing baby boomer retirement, higher talent demands due to growing technical complexity of manufacturing work and automation, a STEM skills deficit, and negative perceptions prevent companies from filling key roles.

Baby boomer retirement in skilled positions

As the existing manufacturing workforce nears retirement (2.5M expected retirees by 2025), industry faces challenges in re-training workers and building workforce pipelines. Skilled production workers account for 50%+ of the manufacturing workforce and represent some of the most acute shortages.[57]



93% of industry executives say baby boomer retirement will have a moderate to significant impact on the skilled production worker shortage.

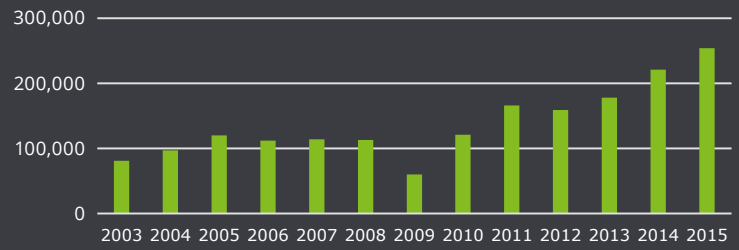


89% say it will have a moderate to significant impact on the engineer, researcher, and scientist shortage.

Technology-driven technical complexity of work

As simple processes become automated and the skill requirements to effectively operate technology increase, the gap between employer needs and existing worker skills grows. Machines are often complementary assets in the field (augmentation rather than automation), meaning workers need to learn to work effectively using robots and software.[60]

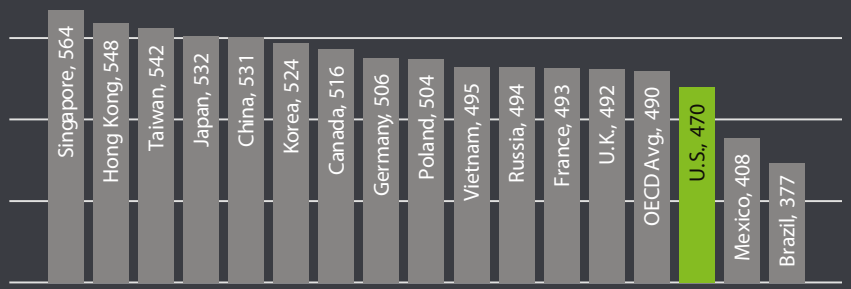
New Worldwide Installations of Industrial Robots (Est., 2003-2015)[61]



STEM skills deficit in the existing workers and students

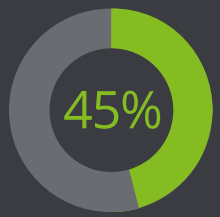
Industry leaders worry about U.S. students' STEM skills; U.S. students consistently underperform those in competitor countries' on standardized exams (e.g., PISA).[58]

U.S. PISA 2015 Performance in Math Against Select Countries[59]

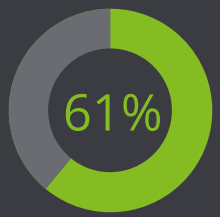


Negative perceptions of manufacturing careers

Though perceptions have improved, outdated stereotypes about manufacturing persist; there is a need to overcome these views to obtain new workers. Currently, barely more than a third of parents would encourage their children to pursue careers in the field.[62]



45% of people agreed or strongly agreed with the statement: "U.S. manufacturing jobs have limited career prospects."



61% of teenagers not considering a job in manufacturing believe manufacturing is a: "dirty, dangerous place that requires little thinking or skill... and minimal opportunity for personal growth."

Institutes enable industry to overcome the talent gap by coordinating members and external stakeholders across a spectrum of workforce development activities

The following initiatives occur across the network to various degrees, each of which can be replicated by every Institute across the network.

Industry assessments

Institute members get value from detailed workforce supply/demand analyses on specific advanced technology fields. Members use this to refine their own growth plans and talent strategies. The Program uses this data to assess its impact on talent pipelines, and better allocate resources to workforce initiatives.

Community engagement events

Institutes engage with the community to educate and change perceptions of manufacturing careers. In one example, following an IACMI event, participants contacted the Institute and indicated that the event made a significant impact on the students' career choices.[63]

Manufacturing USA Institutes

Post-secondary apprenticeship programs

Apprenticeship programs link industry partners with students where they can learn about and work with new technologies in advanced manufacturing. Institute programs designed to engage post-secondary students are creating a talent pipeline that benefits their member organizations.

Credentialing coordination

As advanced technologies become more prevalent and the need for skilled workers increases, industry-driven credentials are important signals for employers to identify future employees and ensure a baseline level of skill.

Connecting Students to Modern Manufacturing Work-Study Programs[64]

LIFT is working with a local community college in Ohio to facilitate a work-study program that will provide high school students with the ability to earn college credit towards their associates degree in Electro-Mechanical Engineering Technology. Graduating students will become employed full time or have the option of enrolling in a bachelor's degree after completion of the program. "We are working to fill the pipeline of talent for the advanced manufacturing industry," said Emily DeRocco, LIFT director of education and workforce development.

Institutes conduct job and skill demand analyses, enabling educational programs to align content with existing employer needs

Skill needs assessments provide snapshots of industry trends and provide insights for Institutes to provide more specific workforce programming and community engagement.

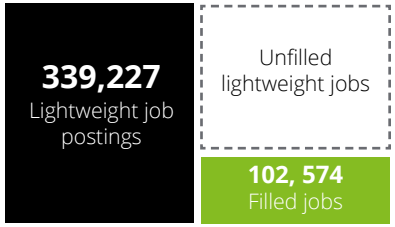
LIFT has partnered with the Workforce Intelligence Network (WIN) to perform a skills-gap analysis based on their five state partners (MI, OH, IN, KY, TN). The analysis provided LIFT a comprehensive report of all professions related to their technology area and the current levels of employment. The reports are published quarterly to enable members and partners to anticipate skill gaps and strategize on how to leverage other workforce development programs. Replicating LIFT's work, IACMI and NextFlex also generated WIN reports for their own technology areas. Because the Institutes used the same standard methodology and analysis, 32 overlapping professions were identified.[65]

DMDII partnered with ManpowerGroup to conduct an analysis of the specific needs in the field of digital manufacturing. This assessment, designed to establish a baseline to inform future workforce develop initiatives, began in March 2016 and is planned to continue to run through 2017. The initiative involves identifying roles required within the digital manufacturing environment, developing descriptions of those roles, and mapping potential career pathways in advanced analysis and intelligent machining.[66]

AIM Photonics conducted focus groups and industry surveys to inform and align their educational and workforce development activities to industry needs. The surveys demonstrated two major focal-points:

- The need to bridge the skills gap for advanced specialized skills at the Ph.D. and M.S. level, and
- The importance of developing skills at the technician level (community college/ undergrad).[67]

During 2015, within LIFT's region, there were over 200,000 unfilled jobs in lightweighting[68]



There are **three unfilled job postings** for every one graduate in advanced composite jobs in IACMI's region[69]

Institutes host community engagement events designed to increase awareness of advanced manufacturing, combat misperceptions, and inspire future workers

Community Engagement

FabLab and NextFlex[70]

FabLab TV is a series that promotes STEM awareness and reaches nearly two million kids a week. NextFlex collaborates with FabLab to incorporate Institute/ member content into targeted series segments to increase exposure to new and exciting technologies.

Community Manufacturing Day & IACMI[71]

In October 2016, IACMI partnered with the Visionary Center for Sustainable Communities (VCSC) to hold a Community Manufacturing Day in Knoxville, Tennessee. The goal was to introduce students to industry professionals, demonstrate the types of technologies used in advanced manufacturing work and promote interest in the field as a career.

Digital Days & DMDII[72]

DMDII provides hands-on experiential education and learning to high-school student in digital manufacturing through its Digital Days program. This program has also been included in Manufacturing Day activities and involves partners such as the National Institute of Standards and Technology (NIST) and the State of Illinois.

Pathways to Jobs and LIFT[73]

LIFT partnered with and provided start-up funding to Pathways to Jobs in Detroit, to create a series of training programs aimed at inspiring interest in regional manufacturing career opportunities. Launched in the summer of 2016, the programs' goal was to provide technical training, work readiness, and upskilling for incumbent workers and disconnected youth.

Institutes link industry and academia through apprenticeship programs to create a pipeline of top student talent

Institute programs focused on secondary student pathways foster careers by linking highly trained students with industry.

Internships and apprenticeships provide students with opportunities to explore and learn about advanced technologies, meet industry specialists, and gain exposure to technological advances driving U.S. economic growth.

Manufacturing USA has the ability to aggregate Institute-level internships and ensure that the opportunities are widely understood.

Defense Innovation Unit Experimental

NextFlex provides a unique forum to connect government to nontraditional partners and innovators. As part of the Defense Innovation Unit Experimental (DIUx) program, NextFlex brought together a team of Stanford students to prototype a unique underwater communications device for Navy SEAL divers, the Aqualink.[74]

AIM Photonics Research Apprenticeship

A 10-week internship run by AIM Photonics and UC Santa Barbara gives undergraduate students the technical and professional training to prepare for entry into the photonics workforce. The work students perform in the program focuses on exposing them to the specific technical areas that will be critical to their future employment in the photonics industry.[75]

Composite Institutes Internship Program

IACMI provides undergraduate and graduate interns an opportunity to conduct research at one of its five partner sites (Detroit, MI; Golden, CO; Dayton, OH; Knoxville, TN; West Lafayette, IN) around the country. Students have an opportunity to work with manufacturing equipment and interact with leading scientists and researchers.[76]

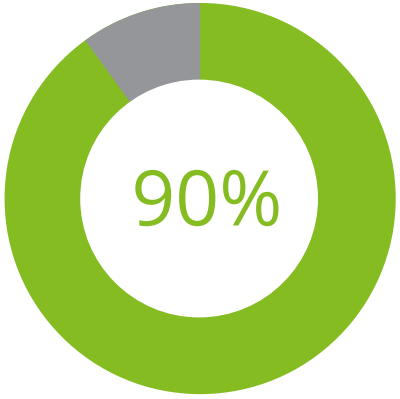
LIFT: Transitioning Veterans to Skilled Employment with Upward Mobility[77]
In Indiana, LIFT has partnered with Vincennes University to launch a Right Skills NOW program to train veterans to transition to become machinists and quickly enter full-time employment. Veterans in the program train at the newly built, state-of-the-art Gene Haas Training Center just outside Indianapolis. The program includes a national credential from the National Institute for Metalworking Skills (NIMS) and features partner companies that connect with trainees ahead of time, mentor them through the program, and assist in placing them in paid positions upon program completion.

Institutes build consensus around portable and stackable standardized credentials, reducing the difficulty of hiring candidates with the right skills

By establishing industry standards, credentials ensure that a regional economy is supported by an educational system that reflects the manufacturing jobs in that location.

A limited number of manufacturing workers (approximately 11.5%) have licenses or certifications – one of the lowest measures across a range of industries.[78] Credentials signal competence in an industry-specific skill set and are useful for employers when looking to fill open positions.

Manufacturing USA can help overcome coordination problems through the Institutes, bringing together members to convene and discuss industry needs in promoting workforce certifications.



of manufacturing executives surveyed indicated that standard credentials made a positive difference in validating the workforce's knowledge and skills.[79]

Benefits of Credentials/ Certifications

- Decreased on the-job training time/cost
- Improved company performance
- Enhanced workplace safety
- Increased employee engagement
- Improved hiring practices
- Enhanced quality practices

PowerAmerica

In partnership with the training organization EPTAC, PowerAmerica offered an IPC Designer Certification to students and faculty at North Carolina State University. The first module to be presented was a course on Certified Interconnect Designer (CID), a professional certification valued among printed circuit board (PCB) designers and in the electronics industry.[80]

LIFT

LIFT worked with 125+ industry, education, and workforce development experts to develop the first-ever industry standards for educating and training the lightweight materials workforce. Ivy Tech Community College in Indiana launched a new instructor training facility to prepare 50 instructors to deliver the training and NIMS-created certifications in fall of 2016.[81]

America Makes

America Makes developed an Additive Manufacturing Certificate Program in collaboration with the nonprofit SME and the Milwaukee School of Engineering developed an Additive Manufacturing Certificate Program. The Program includes a review course and exam and results in a certification that serves as a high-value portable career credential.[82]

PROGRAM PROGRESS: SECTION III

Promoting Sustainable Ecosystems for Advanced Manufacturing

Like any network-based platform, company, or program, Manufacturing USA must develop and sustain a thriving community of members – a requirement to generate desired Program outcomes in technology development and innovation.

This section discusses three key success factors for network sustainability which the Program has achieved: customer value through a tailored portfolio approach, critical masses of members and connectivity (which encourages others to join and remain as members), and alignment to and stimulation of regional economic clusters.

Section Takeaways:

- **The Program's portfolio approach to managing and overseeing the Institutes is a deliberately designed strength.** The Program's portfolio approach allows each Institute enough autonomy from government to effectively meet the needs of its industry members, but enough oversight to ensure federal investments are being spent wisely to improve U.S. advanced manufacturing.
- **Institutes are achieving high degrees of network connectivity and strong member recruitment, reaching respective "tipping points" that drive success.** The number of members and degree of member connectivity are key indicators of the sustainability of an Institute's network. There are early signs that Institutes are reaching "tipping points" where organizations see membership as necessary to their own success and seek out membership without being prompted.
- **Institutes are strengthening regional economic clusters, creating and reinforcing connections between firms that are geographically concentrated.** Institutes tap into existing regional clusters and strengthen them, tying innovation efforts to places with strong advanced manufacturing workforces and enabling R&D knowledge spillovers.

"[Manufacturing USA provides us] the opportunity to have **greater voice and influence in determining the direction of the manufacturing community**, and collaboration opportunities that we wouldn't otherwise have access to with the other center members."

— Large Corporation

"There is great value in establishing **a collaborative network** to tackle barriers to growth that are **beyond the reach of one company or institution**."

— Economic Development Organization

"[The Institute to which my company belongs] is really just getting started... however, I am hopeful that [the Institute] will **help solve ecosystem issues that are beyond the scope of any one company or institution**."

— Large Corporation

Institute effectiveness and network sustainability are driven by a portfolio of Institutes approach, growth in connectivity, and alignment to regional clusters

This section analyzes key success factors behind each Institute's design that help drive Program effectiveness and sustainability (a critical component of any network-based program). These attributes are indicators of value and suggest that the Institutes will retain members and continue to grow and deliver results.

Tailored Customer Value (Portfolio Approach)

Manufacturing USA's portfolio of Institutes approach positions the Program to set overarching goals and direction and to deliver Program-wide support to the Institutes.

This Program model empowers the Institutes with autonomy to tailor their business models to the needs of their membership and unique technology areas.

Network Connectivity and Critical Mass

Successful ecosystems mature to a point where member volume and connectivity reaches a point of "critical mass." At this stage, non-member industry stakeholders see participation as critical to their own success.

When this point is reached, active recruitment activities by the Institutes will become less necessary as a steady flow of new members seeks to join.

Regional Economic Clusters

Institutes strengthen and broaden regional economic clusters. This impact furthers geographic-based competitive advantage in a given technology area.

When clusters exist, employees of different firms interact more readily, leading to innovation-boosting knowledge spillovers. Clusters also attract high-skill workers from other geographies in a virtuous cycle.[83]

Institute Effectiveness and Sustainability

When Institutes achieve these key success factors, they can be seen as sustainable network-based organizations. As long as members continue to receive value they remain affiliated with the Institute and continue to pay dues. This virtuous cycle keeps the Institutes operational and in a position to invest in new resources, staff, or other means to provide continued and enhanced value to members.

Program-level effectiveness and network sustainability are tied to and derived from the holistic portfolio of Institutes (though not dependent on any one Institute in particular). The Program supports advancement through cross-pollination and collaboration across Institutes and members of different Institutes.

The Program's portfolio of Institutes approach effectively balances federal oversight requirements with the Institutes' need to operate with autonomy

Manufacturing USA's portfolio approach is an intentionally designed strength that grants each Institute enough autonomy from government to effectively meet the needs of its industry members. This approach balances empowerment with the necessary oversight to ensure federal investments are being spent effectively to improve the state of U.S. advanced manufacturing.

What is the portfolio approach?

Institutes act as stand-alone business units within the Manufacturing USA portfolio, with the **independence to create customized business models that fit the specific needs of their technology areas**. This autonomy allows Institutes to structure Institute activities and allocate resources in ways that best fit their customers' needs. Institute leaders value the flexibility the government agencies give them to run independent organizations, as this flexibility allows the Institutes to respond more rapidly and appropriately to achieve U.S. advanced manufacturing goals.

Why is the portfolio approach successful?

Some of the most innovative companies promote decentralized decision-making and provide autonomy to all functions. Autonomy allows company teams to personalize their approach to customers, industries, and other relevant variables, which increases efficiency, strengthens accountability, and speeds up the pace of innovation.[84] Similarly, Institutes are able to be more responsive and adaptable to changing industry needs due to the autonomy and flexibility the Program provides.

Two examples of distinctive individual approaches Institutes are taking to deliver on common Institute value propositions are below:

A Unique Approach to IP: Tapping Into Existing Pools affoa	Throughout the U.S., thousands of patents sit unused at universities due to a lack of funding or capability to scale the technology commercially. AFFOA is aggregating patent data on textile-related IP that has not yet been licensed for commercial use. With members from academia and industry, AFFOA is linking already-developed technology on the shelf to industry partners that can use the initial IP to launch new products into the market.[85]
Creating a Digital Environment for Effective Collaboration DMDII	Through its online collaboration platform (the Digital Manufacturing Commons), DMDII fosters joint development and analysis of new products and processes. Coordinating member work in an open-source site encourages new partnerships and creates alignment among standards developed throughout the community. The platform also serves as an innovative "app marketplace" for peer-built software and tools for advanced manufacturing – sharing simple solutions to common problems.[86]

Institutes are sponsored by government agencies but are industry-focused, led by executives with decades of experience and leadership in manufacturing

Department of Energy Institutes – Executive Directors

Bryan Dods
IACMI

Bryan joined IACMI from GE Power. As Chief Engineer of Manufacturing, he was responsible for overall product manufacturability and manufacturing technology. In GE Power & Water he established GE Power's Advanced Manufacturing Works technology facility. Dods previously worked with Boeing, where he led composite assembly efforts for aircraft such as the 787 and F/A-18.

Nick Justice
PowerAmerica

Nick is a retired Major General from Army Research, Development and Engineering Command (RDECOM). He previously led the Program Executive Office Command, Control and Communications Tactical at Fort Monmouth, New Jersey. Justice earned the Legion of Merit and the Bronze Star. He was inducted into the Officer Candidate School Hall of Fame in 2009.

Department of Defense Institutes – Executive Directors

Ed Morris
America Makes

Before joining America Makes, Ed was the Director of Mechanical Engineering & Manufacturing at Lockheed Martin. Ed is a member of the National Academies' National Materials and Manufacturing Board and a founding member and past chair of the National Defense Industrial Association's Manufacturing Division. He has a B.S. in Aeronautical Engineering from Purdue University and an MBA from the University of Texas at Arlington.

Tom McDermott
DMDII

Prior to leading DMDII, Tom worked as a strategy and operations engagement manager with McKinsey & Company, where he worked on manufacturing and logistics topics. He was previously a submarine officer for the U.S. Navy, responsible for directing ship and nuclear power plant operations. Tom has a B.S. in Ocean Engineering from the U.S. Naval Academy and an MBA from the Kellogg School of Management.

Larry Brown
LIFT

Larry has more than 30 years of experience in materials joining in the aerospace and marine industries. He most recently served as Edison Welding Institute's Director of Government Technology Programs. Previously he was Project Management Office Director, Director of Engineering, and Director of the Navy Joining Center. He has a M.S. from Indiana Wesleyan.

Michael Liehr
AIM Photonics

Michael currently serves as the Executive Vice-President for Innovation and Technology at CNSE at SUNY Poly Institute. He previously served as General Manager of the Global 450 Consortium and held various positions at IBM from 1983-2009. He received a Ph.D. in physics from RWTH Aachen University in Germany.

Malcolm Thompson
NextFlex

Malcolm has over 25 years experience in the display industry and is a recognized worldwide authority. He previously served as Chief Technologist at Xerox PARC, President and CEO of dpiX, Inc., and was the founder and Chairman of the Board of the FlexTech Alliance. He has over 100 patents and publications.

Yoel Fink
AFFOA

Yoel is the Director of the Research Laboratory of Electronics and Professor of Materials Science and Electrical Engineering at MIT. He is a co-founder of OmniGuide Inc. and served as its CEO from 2007–2010. He received a B.A. in physics and B.S. in chemical engineering from Technion, and a Ph.D. in materials science from MIT.

Institutes attract more members to the network over time in pursuit of connectivity "tipping points," driving Institute-level sustainability and effectiveness

Ecosystems are **dynamic and co-evolving communities of diverse actors…**	Ecosystems bring together multiple players of different types and sizes in order to create, scale, and serve markets in ways that are beyond the capacity of any single organization – or even any traditional industry. The diversity – and collective ability of ecosystems to learn, adapt, and, innovate together – are key determinants of their longer-term success.
which **create and capture new value…**	Enabled by greatly enhanced connectivity across specialized capabilities and resources, ecosystems develop new, co-created solutions to address critical market needs.
through **both collaboration and competition.**	Competition remains a critical element of the ecosystem environment, but participants are additionally incentivized by shared interests and goals. Members also find collective synergies and benefits through the need to collaborate to meet increasing customer demands and to invest in the long-term health of their shared ecosystem, from which all parties can derive benefit.[87]

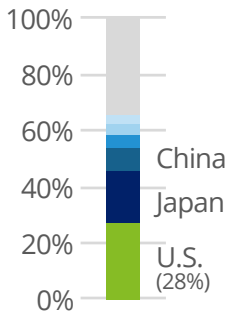
Gravitational Pull

In a formally organized and hierarchical structure, there is one central governing entity that marshals and allocates resources. This is not the case in an ecosystem approach, which is often characterized by peer-to-peer connections.

Ecosystem "conveners" such as the Institutes exert a "gravitational pull" that attracts "orbiting" organizations closer to the convener and closer to each other. In this case, gravitational pull consists of opportunities for collaboration and interaction (e.g., project calls and events). As organizations (represented by individual nodes) participate in more Institute activities, they become closer to other ecosystem entities. This network-based connectivity reinforces an organization's ties as well as strengthening the ecosystem itself.

Influential Players

One way to determine whether Institutes are achieving member recruiting success is by investigating their "market share" of key companies over time. At the moment, 15% of the 280 U.S.-based companies in the top 1,000 global manufacturers are already members of one or more Institutes, an indicator that bellwether influencer companies are seeing value and joining.[88]



28% of the global top 1,000 manufacturing companies are U.S.-based.

Of those 280 U.S. companies, **42** are already members of one or more Institutes.

Ecosystem Connectivity Tipping Point

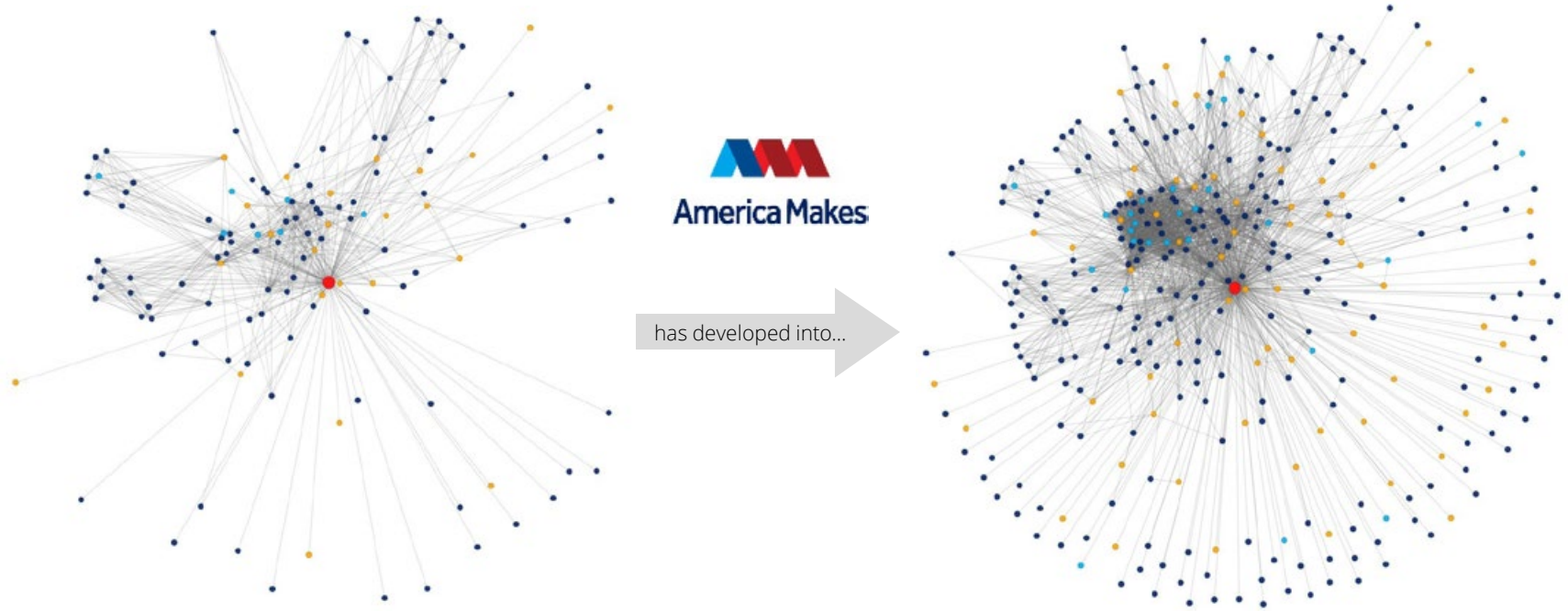
Institutes may reach a tipping point when industry players and academic institutions naturally seek out membership without being prompted by active pitches from the Institute. When this occurs, Institutes have reached a highly desired state — organizations see membership as a necessity to their own success.

America Makes serves as a strong example of this tipping point starting to take effect. From 2013 to 2016, the connectivity among members of America Makes increased five-fold.

During this time, America Makes engaged diverse actors, convened members, and created new value for participants. This led to increased collaboration and connections. America Makes' ability to grow so quickly is a strong sign of the value it provides and the likelihood that members will continue to be involved.

As each Institute increases membership, and the members connectivity increases, the value delivered to each members' is enhanced via the network effect

America Makes, the first Institute established, has grown membership and member connectivity over time by convening members through working groups, steering committees, and the project process. As more-recently established Institutes generate additional data, similar demonstrations of growth will likely be measurable.



2013

135 organizations connected through
652 relationships

2016

345 organizations connected through
3,634 relationships

The Program's goal is to strengthen regional economic clusters by boosting innovation and collaboration through increased connectivity

Clusters allow companies and academic institutions to build off each other's research and expertise, which furthers an area's competitive advantage in a given technology area and its economic growth and prosperity.

What are economic clusters?

A "cluster is a geographic concentration of firms, suppliers, coordinating entities and related institutions in a particular field" that derives mutual benefits from geographic proximity and the ability to share knowledge, mutual access to skilled labor pools, or the use of shared public goods.[89]

Clusters promote economic growth and prosperity.

Clusters generate new businesses and products as industries interact and build stronger ties to one another and adjacent regions. Clusters help regional economies as participating industries have higher levels of employment and higher wages. This enhances growth opportunities for the region and for industry.[90,91]

The U.S. has a strong tradition of economic clusters spurring new innovations.

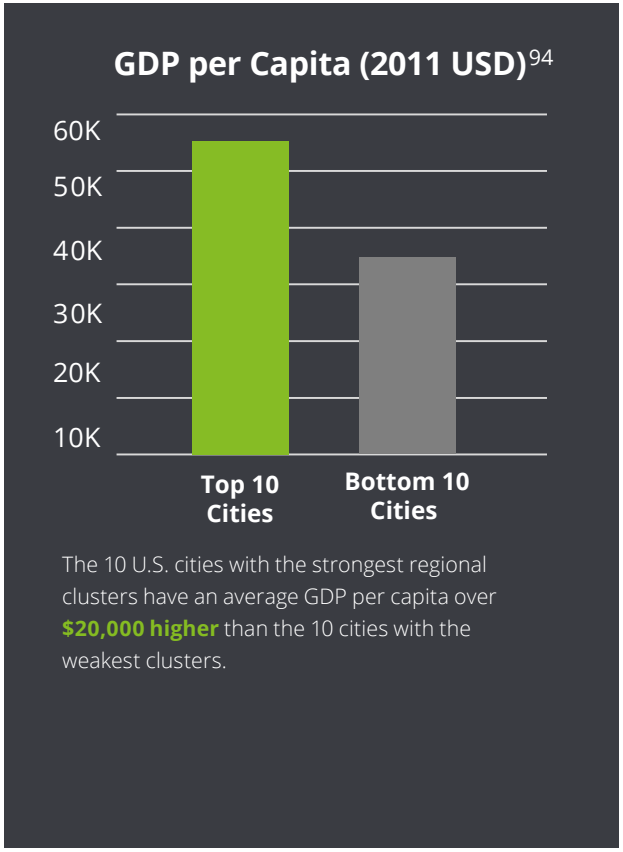
In the 20th century, regional clusters led to the creation of entire industries, having a tremendous impact throughout the world:

- **U.S. automobile industry.** In Detroit, a concentration of engine technology experts and early builders of the automobile led to a transportation revolution.
- **Computer technology industry.** Nearly half a century later, Silicon Valley emerged around the development of hardware and software, driving the creation of new cutting-edge industries.

These examples demonstrate the positive impacts of active economic clusters on productivity, local entrepreneurship, and employment growth. The Manufacturing USA Institutes build upon existing clusters and serve as conveners that support growth in new advanced manufacturing industries.[92]

Foreign competitors are also attempting to incubate their own regional clusters that will support the industries of the future.

Countries around the world are directing funding toward the creation and bolstering of economic clusters. The U.S. benefits from a historically strong base and has an opportunity to build and expand existing clusters to align more closely with the needs of advanced manufacturing industries and remain highly competitive vis-a-vis foreign alternatives.[93]

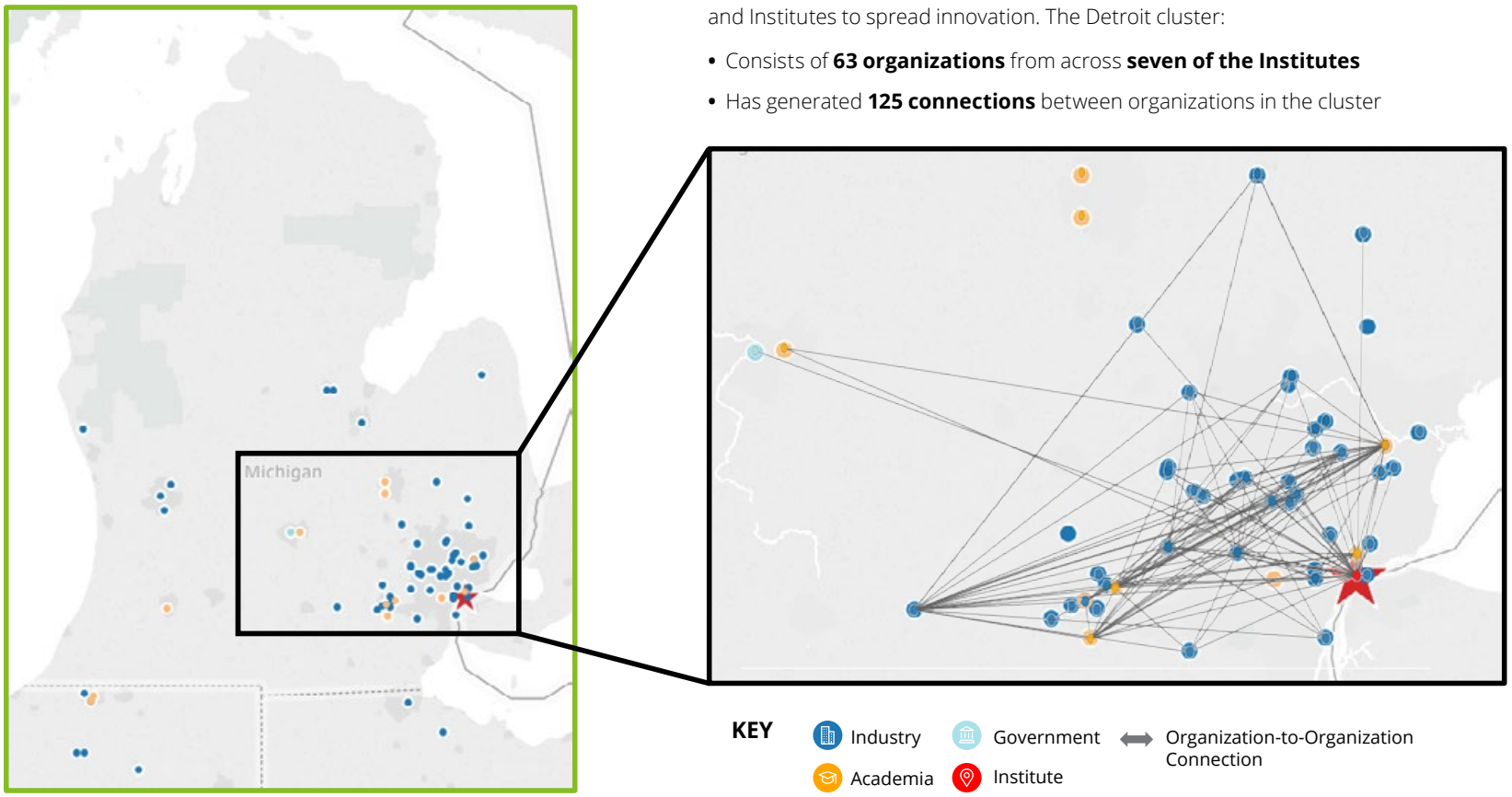


The 10 U.S. cities with the strongest regional clusters have an average GDP per capita over **$20,000 higher** than the 10 cities with the weakest clusters.

The map on the following page demonstrates the regional cluster that has grown around one Institute. The Institutes convene existing networks and knowledge centers to foster the creation of new technology development.

Manufacturing USA shows signs of early success with regard to its ability to strengthening existing regional economic clusters

Advanced Manufacturing Ecosystem in Detroit, MI – Anchored by the LIFT Institute (As of Dec. 2016)



The Institutes strengthen regional clusters by fostering hundreds of connections in their communities.

The Detroit cluster around LIFT, for example, brings together members across industries and Institutes to spread innovation. The Detroit cluster:

- Consists of **63 organizations** from across **seven of the Institutes**
- Has generated **125 connections** between organizations in the cluster

CONCLUSION

Manufacturing USA is convening U.S. advanced manufacturers, spurring R&D innovation, and laying the groundwork for workforce progress

In response to significant challenges to the U.S. manufacturing industry, Manufacturing USA has created true public-private partnerships that are successfully uniting academia, industry, and government across the country, itself a notable achievement. The Program's Institutes are designed to be highly responsive to U.S. industry's needs and are led by manufacturing experts and leaders to ensure this remains a priority. The Institutes have attracted hundreds of members, including influential U.S. companies such as Boeing, GE, Johnson & Johnson, Lockheed Martin, Ford, and others. Within the Program network, these members are densely connected within and across Institutes, strongly implying cross-pollination across companies, industries, and technology areas is taking place. Qualitatively, there are numerous examples of companies connecting and working together in ways that would not have occurred independent of the Institutes.

This indicates the Program is poised for continued success in spurring R&D innovation and commercialization.

The efforts Manufacturing USA is undertaking are necessarily long-term, and downstream results (e.g., patents, trade balance shifts in advanced goods) will take years to manifest. Nevertheless, initial activities and industry's reactions are encouraging. Preliminary calculations on return on R&D spending indicate there are strong reasons for companies to work together on pre-competitive projects via the Institute framework. Access to expensive equipment reduces experimentation costs (and is particularly valuable for small businesses), and coordination through roadmaps moves entire U.S. industries in the right direction. In terms of workforce development, the Program and Institutes have many foundational elements in place–such as workforce supply/demand analyses, credentialing, and apprenticeship programs. The key is to move beyond efforts focused on increasing Institute and Program awareness and investing more heavily in high-value, high-need workforce initiatives. Striving for outcome-oriented metrics would help focus the Program's workforce investments.

The Program is meeting its goals (or is on track in the case of longer-term objectives), but additional support across U.S. government initiatives may be needed to promote U.S. global manufacturing competitiveness. One relevant consideration is whether the scale of current efforts (the Program and other government initiatives) is sufficient given the competitive context and the significant investments being made by other nations. This will require subsequent macro-level analysis of other nations' activities to address.

Additionally, the Program will face strategic challenges managing the growth of existing Institutes and the establishment of new ones, as well as continuation issues related to keeping Institutes focused on U.S. national goals after the initial period of federal funding. Appropriately measuring the Institutes, especially mid-term and long-term outcomes, will be key to successful portfolio management.

Now is the time to anticipate and respond to these emerging challenges to promote the Program's continued success and to continue the U.S. manufacturing renaissance.

"The [U.S.] is poised to lead this manufacturing innovation by leveraging regional strengths throughout the country. However, to do so, the [U.S.] must implement a sustained and coordinated national effort to grow our lead in innovation, to develop the skills needed in today's advanced manufacturing plants and to increase the competitiveness of our environment for manufacturing that recognizes the stiff competition from other nations…"

— President's Council of Advisors on Science and Technology, Oct 2014 report, "Accelerating U.S. Advanced Manufacturing"[95]

APPENDIX A

Recommendations for Building on Early Program Successes

Manufacturing USA's underlying approach and design is valid and logical, and appears to be generating significant preliminary successes in the early years of the Program.

As with any organization, there are a few key opportunities for enhancement over and above this success. These are provided in this Appendix to enable the Program to build on its success and continue to accelerate the growth of U.S. advanced manufacturing innovation.

Summary of Recommendations

#	Recommendation	Recommendation Context
1	The Program should develop and execute an overarching strategy for the Institute portfolio, accounting for new Institute formation, member overlap, and competition	• Plans are already in motion to establish additional Institutes. The Program, however, has an opportunity to lead the way in developing a more cohesive, data-driven strategy that will inform which technology areas to focus on for the next Institutes. • Manufacturing USA should establish additional Institutes within technology areas that have preexisting ecosystems and where there is minimal or strategic overlap with current efforts. The Program should focus on limiting technology overlap that could transform Institutes from being complementary partners to competitors.
2	Manufacturing USA should facilitate further connections to relevant organizations and resources – first and foremost, other Institutes – to elevate Program impact	• Further development of value-adding mechanisms at the Program level can promote intra-network efficacy and relationship-building between members of Institutes to further expose the benefits of inter-Institute partnerships. • Manufacturing USA can leverage its position as an organization at the intersection of government, industry, and academia to facilitate forums for information sharing between industry leaders, Institutes, and government entities.
3	The Program should enhance its role in providing shared services and Program advocacy to encourage Institute success by promoting quality of operations	• The Program – and in particular AMNPO, which oversees it – is positioned to provide capabilities, services, and support mechanisms in areas of Institute overlap. • Opportunity areas include increasing public awareness through strategic communications, facilitating cross-government advocacy, and further developing shared tools such as membership agreements, IP-sharing agreements, project call processes, and cybersecurity frameworks.
4	The Program needs to develop a deliberate approach to ensure an enduring focus on U.S.-centric goals is maintained at the Institute-level post cooperative agreement	• Institutes are devising their own continuation plans to maintain operations after initial Program funding ends. Their plans span a variety of approaches, some of which mean Institutes will cease to be true public-private partnerships and pursue U.S.-centric program goals. • The Program should create more robust plans for maintaining U.S. government involvement with and support of the Institutes. Multiple levers are available to accomplish this, including giving additional funding, referring Institutes to other government customers, and providing high-value support services.
5	Institutes' work on technology development should emphasize transition and deployment activities to increase commercialization and sync efforts	• By design, the Program is supposed to focus on transitioning technologies from Manufacturing (MRL) and Technology (TRL) Readiness Levels 4 through to 8. However, the federal agencies funding the Program have tended to heavily focus the Institutes on developing technologies, which happens at MRLs 4-5. • This approach will create a gap in the Institutes' ability to deliver on technology commercialization goals. Additionally, by focusing Institute efforts on technology development, the Program risks creating non-strategic overlap with peer entities such as the national labs and operating in conflict with member priorities.
6	Funding agencies should encourage less restrictive contracting and membership agreements to enable Institutes to better move at the speed of industry	• Given that government and academia tend to make decisions more deliberately and, as a result, in an often less time-sensitive manner, ensuring that industry can continue moving quickly is a key priority for the Institutes. • Institutes are faster and more responsive than traditional government contracting and research processes but lag industry standards. Manufacturing USA, in coordination with the funding agencies, should encourage a less restrictive approach to contracting and membership agreements within the Institutes.
7	The Program should further align Institute workforce programs with existing federal, state, and local government resources and strategies	• While many Institute-level workforce initiatives are promising, there remain opportunities to strengthen Institute impact. Manufacturing USA can increase the impact and return of workforce development programs by placing activities into a framework that truly aligns actions, emphasizes high-impact efforts, coordinates inter-Institute activities across the national Program, and integrates with cross-governmental initiatives on federal, state, and local levels. • For instance, Institutes sometimes focus on high-visibility, (but low-impact programming, and the Program and agencies at times measure simple inputs and outputs that reinforce this approach e.g., counting the number of workshop engagements and student attendees to determine Institute progress).

RECOMMENDATION #1

The Program should develop and execute an overarching strategy for the Institute portfolio, accounting for new Institute formation, member overlap, and competition

Plans are already in motion to establish additional Institutes. The Program, however, has an opportunity to lead the way in developing a more cohesive, data-driven strategy that will inform which technology areas to focus on for the next Institutes.

Manufacturing USA should establish additional Institutes within technology areas that have preexisting ecosystems and where there is minimal or strategic overlap with current efforts. The Program should focus on limiting technology overlap that could transform Institutes from being complementary partners to competitors.

Along with industry input, the Program should take into account the following considerations when developing a growth strategy.

Which technology areas will future Institutes support? Which technologies are industry priorities?

How many Institutes will be established in total?

How should Institutes deal with foreign entities?

In 2014, 73% of all manufacturing foreign direct investment in the U.S. ($98.9B) was in advanced manufacturing.[96]

Foreign companies are members of some Institutes and many members have plants and other facilities both in the U.S. and abroad. Given the Program's goals to increase U.S. economic competitiveness and support the U.S. workforce, the Program needs to establish clear guidance to protect U.S. interests while accounting for the impact that foreign stakeholders play in domestic advanced manufacturing activities. This Program needs to assess the unique role (and potential threat) of foreign involvement in each of the Institutes before developing a Program-wide stance on foreign involvement within the Institutes.

How should the Program address technology overlap?

Due to similarities in technical scope, there are meaningful overlaps between some existing Institutes that serve to strengthen the Program. However, these overlaps must be strategically balanced across the Program. Institute leaders suggest that some members that belong to multiple Institutes feel "Institute fatigue" and are reluctant to invest in new ones, in some cases citing a lack of notable technological difference.

Managing overlap while competing with foreign and domestic Program rivals requires a high-level view of all activities within advanced manufacturing R&D, as well as tracking and comparing over time which members are participating in competitor programs and why.

Many of the U.S.'s closest foreign competitors are investing heavily in technological innovation centers.[97] There are also numerous examples of domestic programs, such as EWI's Additive Manufacturing Consortium and Carnegie Mellon's NextManufacturing Center. The Program must continue to focus on delivering unique value to its members, maintaining ease of participation, and effectively balancing institute volume vs. quality to effectively manage the impact of competing ecosystems.

Membership Overlap by Institute[98]

	AFFOA	AIM Photonics	America Makes	DMDII	IACMI	LIFT	NextFlex	Power America
AFFOA		1	5	5	3	2	6	2
AIM Photonics			4	3	2	2	7	2
America Makes				51	17	27	17	5
DMDII					19	19	10	6
IACMI						13	7	2
LIFT							7	2
NextFlex								4
Power America								

RECOMMENDATION #2

Manufacturing USA should facilitate further connections to relevant organizations and resources – first and foremost, other Institutes – to elevate Program impact

Institute-to-Institute Connectivity

Institutes collaborate and partner together to advance areas of shared interest, align on overlapping or converging technologies, and jointly use or invest in mutually-beneficial equipment and facilities.

A project at LIFT required additive manufacturing capabilities. LIFT pursued a partnership with America Makes splitting the project into two separate efforts, that harnessed expertise from both Institutes to deliver the project.[99]

Given the overlap between flexible hybrid electronics and advanced functional fabrics, AFFOA and NextFlex are actively exploring opportunities to conduct joint project calls in the future.[100]

Collaboration between Institutes occurs organically as Institutes uncover the benefits of partnering with one another. The Program strives to facilitate some of this "matchmaking" through Institute-to-Institute connectivity and collaboration via forums, a leadership council for Institute directors, and leading-practice sharing.

Further development of value-adding mechanisms at the Program level can promote intra-network efficacy and relationship-building between members of Institutes to further expose the benefits of inter-Institute partnerships.

> "**Broad public-private partnerships enable new technology in manufacturing much faster** than if addressed solely by individual corporations."
>
> — Large Industry Organization

Manufacturing USA's Convening Power

Manufacturing USA can leverage its position as an organization at the intersection of government, industry, and academia to facilitate forums for information sharing between industry leaders, Institutes, and government entities.

For **industry leaders** that are members of separate Institutes, convening promotes cross-pollination of ideas and identification of previously unknown resources (e.g., existence of useful SMEs/start-ups).

For **government entities** conducting acquisitions (e.g., through BAAs), there are opportunities for those government needs and technical challenges to be answered by Institute activities, utilizing the Institutes as a national asset.

Federal, state, and local governments have extensive pre-existing programs focused on advanced manufacturing and workforce training. In addition to continuing to develop their relationship with the Manufacturing Extension Partnership (MEP) Centers, the Program can help Institutes and members identify additional relevant programs with which to connect.

RECOMMENDATION #3

The Program should enhance its role in providing shared services and Program advocacy to encourage Institute success by promoting quality of operations

The 2015 National Network for Manufacturing Innovation Strategic Plan states that the Advanced Manufacturing National Program Office (AMNPO) was established to foster interagency collaboration in identifying and addressing challenges and opportunities across all Institute technology areas. This includes coordinating the efforts of all federal agencies involved in U.S. manufacturing, including the DoC, DoD, DoE, NASA, ED, USDA, NSF, FAA, and FDA.

The Program – and in particular AMNPO, which oversees it – is positioned to provide capabilities, services, and support mechanisms in areas of cross-cutting Institute activities. As the glue that binds the Institutes together, **Manufacturing USA and AMNPO have the ability to set overarching strategic objectives, coordinate across government agencies, and recognize common needs of all Institutes and members.** By doing so, AMNPO can unite various efforts across the government for Program-wide benefit.

Increase Public Awareness through Strategic Communications

Building national awareness of the Manufacturing USA Program and advanced manufacturing's role in the U.S. economy serves the interests of the Program, the Institutes, and Institute membership.

Positive sentiment for, and public awareness of, the Program are significant factors contributing to success at the Program and Institute levels. These factors are likely to influence future Program direction and potentially sources of continued Institute funding. Most importantly, they will also influence the career decisions of the next generation of U.S. advanced manufacturing engineers, designers, and technicians.

Manufacturing USA cannot rely solely on awareness within the government and select academic and industry circles. Fostering greater buy-in from the public through strategic communications is necessary to position the Program for success as it explores long-term development options.

Facilitate Cross-Government Advocacy

Manufacturing USA, with the support of AMNPO, is positioned to work across government entities to promote public policies and trade policies that will positively influence advanced manufacturing innovation and the goals of the Program. By serving as a representative of the Institutes and their members and facilitating connections where needed, the Program can improve the flow of industry feedback to other government agencies.

Advocating for policies complementary to Program efforts related to advanced manufacturing on behalf of the Institutes is a valuable service that the Program can provide to Institutes, which would otherwise need to advocate for themselves on a piecemeal basis.

Further Develop Shared Tools: Membership Agreements, IP-Sharing Agreements, Project Call Processes, and Cybersecurity Frameworks

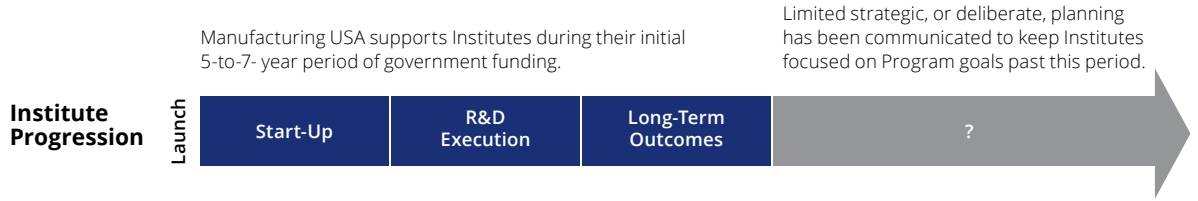
As the Institutes mature or as new Institutes are formed, the Program has an opportunity to facilitate the scaling of best practices, templates, preexisting platforms, (e.g., DMDII's Digital Manufacturing Commons) and techniques (e.g., or project call methods). While each Institute's independence and operational flexibility is a key feature of the Program's success, more services can be provided in this regard. For instance, the Program could set up a common website or platform with different pages or sub-sections for each Institute, where ideation about or voting on future Institute-funded projects and priorities could occur.

Additionally, the Program should promulgate guidance for managing the security and cybersecurity of any IP generated, the IT networks it sits on, and the mediums through which collaboration occurs.

RECOMMENDATION #4

The Program needs to develop a deliberate approach to ensure an enduring focus on U.S.-centric goals is maintained at the Institute-level after initial funding expires

As Institutes transition past the period of initial funding and plan for continuation, they will reach decision points that carry implications for whether U.S. government goals remain a focus and are achieved.



Institutes are devising their own continuation plans to maintain operations after initial Program funding ends. Their plans span a variety of approaches:

- **Creating new long-term cooperative agreements** with Manufacturing USA or other government entities, such as America Makes' agreement with the Air Force Research Laboratory (AFRL).[101]
- **Merging into the operations of a founding partner** (often the keystone academic entity – e.g., University of Michigan, Ohio State University, and EWI for LIFT, N.C. State for PowerAmerica, and MIT for AFFOA).
- **Merging with other Institutes,** or optimizing recruitment and pricing to become viable independent competitors.

Some of the plans mean Institutes will cease to be true public-private partnerships. If Institutes break off U.S. affiliation and stop taking funding, they are not required to pursue U.S.-centric Program goals, such as developing domestic workforce or innovation capacity. They may even start to advance the interests of competitor countries.

The Program – the agency sponsors (i.e., DoC, DoD, DoE), as well as AMNPO – should create more robust plans for maintaining U.S. government influence over the Institutes. Multiple levers are available to accomplish this, including giving additional funding, referring Institutes to other government customers, and providing high-value support services.

These plans may vary based on the Institute topic area and agency – for instance, DoE may want energy efficiency technology to rapidly spread worldwide to achieve its goals, while there may be different implications of foreign companies quickly advancing in technology areas critical to DoD and national security.

Not all foreign participation in the Institutes is necessarily negative, especially when companies have significant U.S. production presence. But if the Institutes are highly effective at boosting innovation, the U.S. government cannot passively accept whatever continuation plans the Institutes decide upon, and should instead proactively manage those determinations.

CASE STUDY

A Lesson from SEMATECH[102]

SEMATECH was founded in 1986 to boost the U.S. semiconductor industry after significant market share losses to Japanese chipmakers. U.S.-based semiconductor manufacturers (including IBM, Intel, HP, Micron, and Texas Instruments) joined the public-private consortium and the U.S. government provided $100M annually to spur R&D and encourage companies to join. SEMATECH pooled member R&D efforts to develop new technologies and combat Japan's lead in both the chip and fabrication equipment segments.

By the 1990s, SEMATECH had largely accomplished its goals - experts acknowledged that SEMATECH had reestablished U.S. competitiveness in microprocessors and memory chips. However, in 1996, the SEMATECH Board of Directors voted to end matching federal funding and shifted their focus to serving the international semiconductor industry. As a result, SEMATECH was no longer focused on strengthening U.S. competitiveness.

RECOMMENDATION #5

Institutes' work on technology development should emphasize transition and deployment activities to increase commercialization and sync efforts

Manufacturing USA's Current Focus

By design, the Program is meant to focus on transitioning technologies from Manufacturing (MRL) and Technology (TRL) Readiness Levels 4 through 7. However, the federal agencies funding the program have tended to heavily focus the Institutes on developing technologies, which happens at MRLs 4-5. Overly concentrating on technology development and deprioritizing scaling and commercialization has significant implications, detailed below.

SMEs Can Engage More Significantly in Later MRLs/TRLs

Implication #1: The majority of Institute developed technologies are still far from industry implementation. While focusing heavily on technology development may be inevitable due to the nascent nature of the technologies, over time, this approach will create a gap in the Institutes' ability to deliver on technology commercialization goals. De-emphasizing commercialization also carries the risk of operating in conflict with profitability goals of Institute members.

Without more process technologies, to include demonstration, testing, and feedback systems, the Institutes may limit their ability to bring in small and mid-sized manufacturing firms which seek, or participate in, later stages of manufacturing innovation. These later stages are where the SMEs thrive by pushing technologies toward commercialization. Institute leaders understand this well, but the dilemma merits attention.

Avoid Competition with Analogous Entities (e.g., National Labs, DoD Labs, DoD Warfare Centers)

Implication #2: Technology development straddles the boundary between basic and applied research, which is directly where the national labs, DoD Labs, and DoD Warfare Centers currently focus their time, effort, and resources. Using the national labs as an example, the national labs conduct primarily basic, as well as applied research; while some have specific focus areas like renewable energy, others carry out multifaceted R&D work. Manufacturing USA was designed, in part, to complement the national labs and propel their work through the manufacturing innovation process. In practice, however, by focusing Institute efforts on technology development, the Program risks creating non-strategic overlap with these peer entities.

Manufacturing Readiness Level (MRL) Definitions	
1	Basic manufacturing implications identified
2	Manufacturing concepts identified
3	Manufacturing proof of concept developed
4	Capability to produce the technology in a lab environment
5	Capability to produce prototype components in a production relevant environment
6	Capability to produce a prototype system or subsystem in a production relevant environment
7	Capability to produce systems, subsystems, or components in a production representative environment
8	Pilot line capability demonstrated; ready to begin low rate initial production
9	Low rate production demonstrated; capability in place to begin full rate production
10	Full rate production demonstrated and lean production practices in place

"The commercialization and scale-up phases of the technology lifecycle… are critical because they set firms on **a path of sustainable job creation and profit generation**."

— National Science and Technology Council
A National Strategic Plan for Advanced Manufacturing[103]

RECOMMENDATION #6

Funding agencies should encourage less restrictive contracting and membership agreements to enable Institutes to better move at the speed of industry

What is Speed of Industry?

Businesses make decisions, change plans, and adjust strategies constantly in order to keep up with market demands and threats from competition. A successful public-private partnership is one in which business is able to continue moving at the speed required to remain competitive. Given that government and academia tend to make decisions more deliberately, and as a result in an often less time-sensitive manner, ensuring that industry can continue moving quickly is a key priority for Manufacturing USA's Institutes.

Institutes' Current Efforts

Manufacturing USA Institutes attempt to create environments for faster research and development of new products while fostering cross-industry relationship-building.

Institutes are faster and more responsive than traditional government contracting and research processes but lag industry standards.

Moving Forward

Despite documented Institute successes, the Manufacturing USA Program has developed a reputation for being administratively cumbersome at times. As such, the Program should expedite processes to correspond to Institute and industry requirements. Specifically, Manufacturing USA, in coordination with the funding agencies, should encourage a less restrictive approach to contracting and membership agreements within the Institutes.

Institutes that have more restrictive contracting and membership processes (especially those tied to executing and awarding project call) continue to have members express that while Institutes move faster than typical government processes, they still move too slow for the demands driven by industry in these ever-evolving technology areas.

By improving Institutes' speed to value, Manufacturing USA will help encourage industry's involvement, which is critical to long-term Institute efficiency and sustainability.

Simple Agreements 	Recognizing that member connections drive product innovation, AFFOA's membership approach is purposefully simple (two pages long and requires no NDAs), reducing traditional barriers to joining an Institute.[104]
Faster than Government 	NextFlex prides themselves on being a faster contracting vehicle than government. They are able to perform contracting functions to connect government with institute members faster than traditional government processes.[105]
Internal Contracting 	LIFT performs all contracting internally and strategically includes an IDIQ (Indefinite Delivery Indefinite Quantity contract-like arrangement in all of their membership agreements. The IDIQ arrangement allows them to execute subcontracts with their members much faster compared to other Institutes.[106]

"**Excessive paperwork discourages large and small companies alike from engaging in projects** despite the value proposition and potential benefits of developing advanced/innovative technologies."

— Large Industry Organization

RECOMMENDATION #7

The Program should further align Institute workforce programs with existing federal, state, and local government resources and strategies

Cohesive Workforce Strategy

While many Institute-level workforce initiatives are promising, there remain opportunities to strengthen Institute impact. Manufacturing USA can increase the impact and return of workforce development programs by placing activities into a framework that truly aligns actions, emphasizes high-impact efforts, coordinates inter-Institute activities across the national Program, and integrates with cross-governmental initiatives on federal, state, and local levels.

For instance, Institutes sometimes focus on high-visibility but low-impact programming, and the Program and agencies at times measure simple inputs and outputs that reinforce this approach (e.g., counting the number of workshop engagements and student attendees to determine Institute progress). Institutes can strategically invest in their comparative advantages or differentiators, those things they can do especially well.

There are three core workforce development comparative advantages for Institutes, which they should emphasize:

- **Broad industry supply and demand assessments should be conducted across the network in a systematic and standardized way.** Institutes can use this information to identify regional and topical skills gaps and facilitate the creation of focused curricula to meet the market needs.
- Building off of industry skill supply and demand analyses, **Institutes can facilitate coordination of developing stackable and transferable credentialing programs across industries.**
- **Institute efforts should target post-secondary students** with a focus on apprenticeship programs that identify promising talent, close the gap between students and manufacturing employers, and improve perceptions of advanced manufacturing careers.

The Program should also foster stronger links between Institutes and government programs for this issue set.

- Leveraging convening power to **gather stakeholders** to advance a 21st century workforce strategy.
- **Creating pathways to resources** for federal funding opportunities.
- **Reducing instances of duplication** and informing Institutes of existing government programs/resources, such as the Manufacturing Extension Partnerships (MEPs), or facilitating collaboration so all Institutes are fully taking advantage of all opportunities.

Manufacturing USA can build on many existing government programs to achieve its goals.

"Skills on Purpose – Creating the Next Generation of Manufacturers" – an initiative by the Departments of Education and Labor that includes a six-webinar series serving as a resource for academic and industry partners.[107]

2014 Workforce Innovation and Opportunity Act – promote the newly formed career pathway definitions to encourage adoption across the network of Institutes and to use in developing secondary and post-secondary training programs for advanced manufacturing careers.[108]

Apprenticeship USA – a Department of Labor initiative that provides funding opportunities for states to expand their apprenticeship strategies with the goal of doubling and diversifying Registered Apprenticeships by 2019.[109]

> "It has long been apparent… that the efficiency and effectiveness of federal support of STEM-focused education programs has been limited by a **lack of inter-agency coordination and collaboration**."
>
> — National Science and Technology Council[110]


APPLI

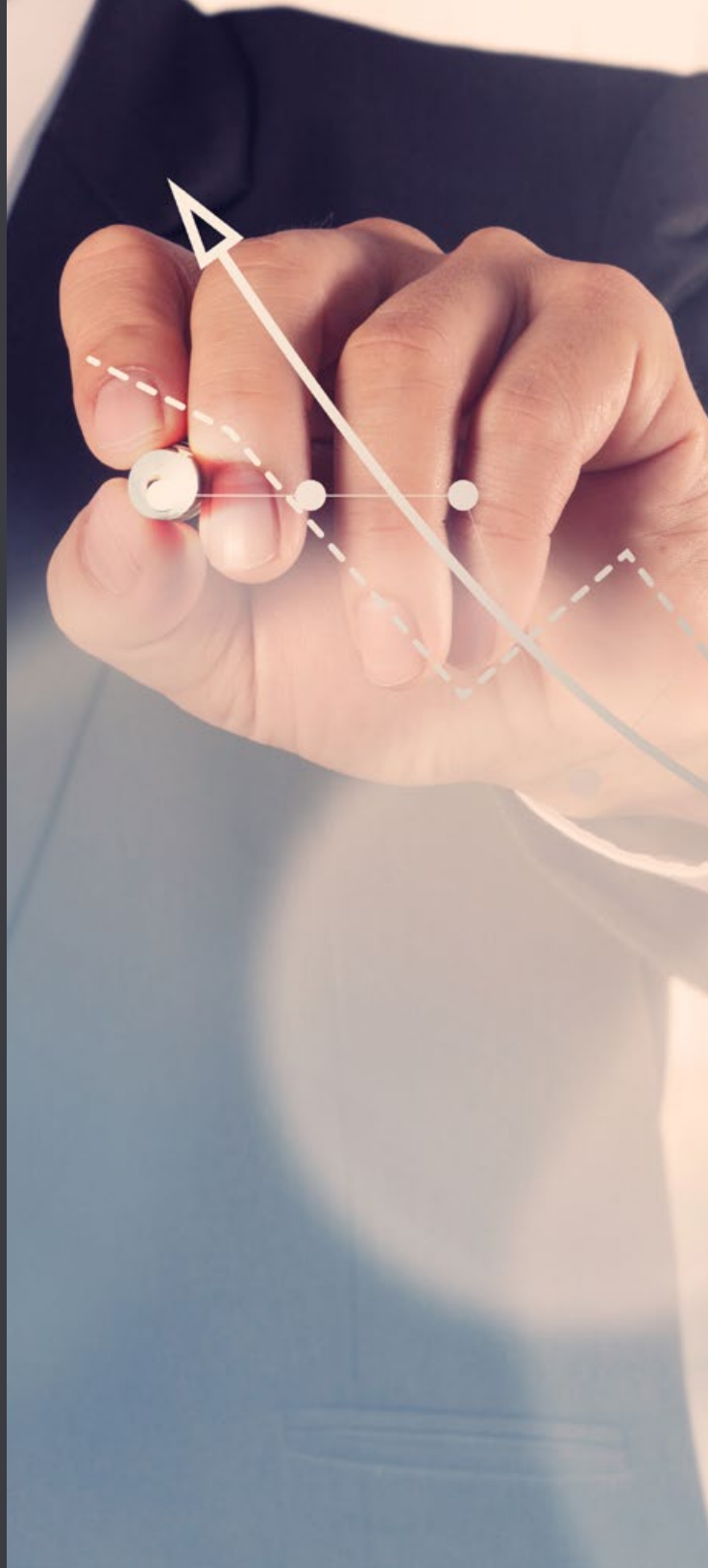
APPENDIX B

Insights on Performance Evaluation

This section provides insights on how to best evaluate Manufacturing USA and the Institutes' performance. The section begins with an assessment of the challenges facing the Program's evaluators and a review of the current approach. It then presents the recommendation to adopt a phased approach to metrics, followed by key principles that drove the development of metrics insights.

Section Takeaways

- **Variety of Challenges to Evaluating Performance.** Measuring Program performance is challenging due to its ambitious scope of impact, the diverse suite of Institutes, the inherently uncertain and risk-based nature of R&D, long lead times particular to advanced manufacturing R&D, and the Institutes' ecosystemic nature, where value is often generated through collaboration, which can be harder to measure.
- **Recommendation to Emphasize Phases of Evaluation.** Manufacturing USA should adopt phased metrics on two levels – Institute and Program. Due to the nature of the Institutes' work, long-term results such as innovative processes and products or company ROI will not be observable for several years after the formation of the Institutes. In the meantime, the Program should track Institute metrics around start-up activities (including establishing initial operating capability and growing membership) as well as preliminary R&D results.



Manufacturing USA's legislative goals are complex, but the Program, Institutes, and Agencies have invested considerable effort into measuring progress

Evaluation is already tied to the Program's strategic goals, but the many difficulties inherent in this complex effort mean there are opportunities for refining and enhancing the evaluation approach.

> "If you don't know where you're going, any road will take you there."
>
> — Institute Director, quoting Lewis Carroll[111]

Challenge and Overview

This pithy saying popular in performance management is a reminder of the importance of taking a goals-first approach to evaluation. Of course, the scale and complexity of the Manufacturing USA's ambitions – to propel America into renewed global leadership in manufacturing – can make it difficult to determine appropriate metrics. This is exacerbated by the fact that the Program consists of a diverse suite of Institutes, each of which operates in a unique way, complicating standardization. Additional factors present challenges to metrics, including:

- The inherently uncertain and risk-based nature of R&D
- The long lead times particular to advanced manufacturing (e.g., capital equipment and tooling)
- The ecosystemic, non-traditional nature of each Institute, where value is consistently generated through collaboration, which is hard to identify and track

The Program will face an additional challenge in the future when cooperative agreement funding ends. At that point, Institutes will have made decisions regarding the continuation of their operations and will have varying degrees of willingness to share data on a voluntary basis. Institute with strong federal relationships (likely driven by new funding agreements) will have greater incentive than others.

In response to this reality, the Program, Institutes, and the governing agencies put considerable effort into developing evaluation strategies with a vision for the future.

Manufacturing USA's Existing Approach

Manufacturing USA has conducted evaluation planning activities and has devised a set of activity metrics that frame the Program's progress. There are four categories of common metrics the Program uses for Institutes. These are aligned to DoE and DoD's framework pillars and were agreed upon as of September 2016.[112]

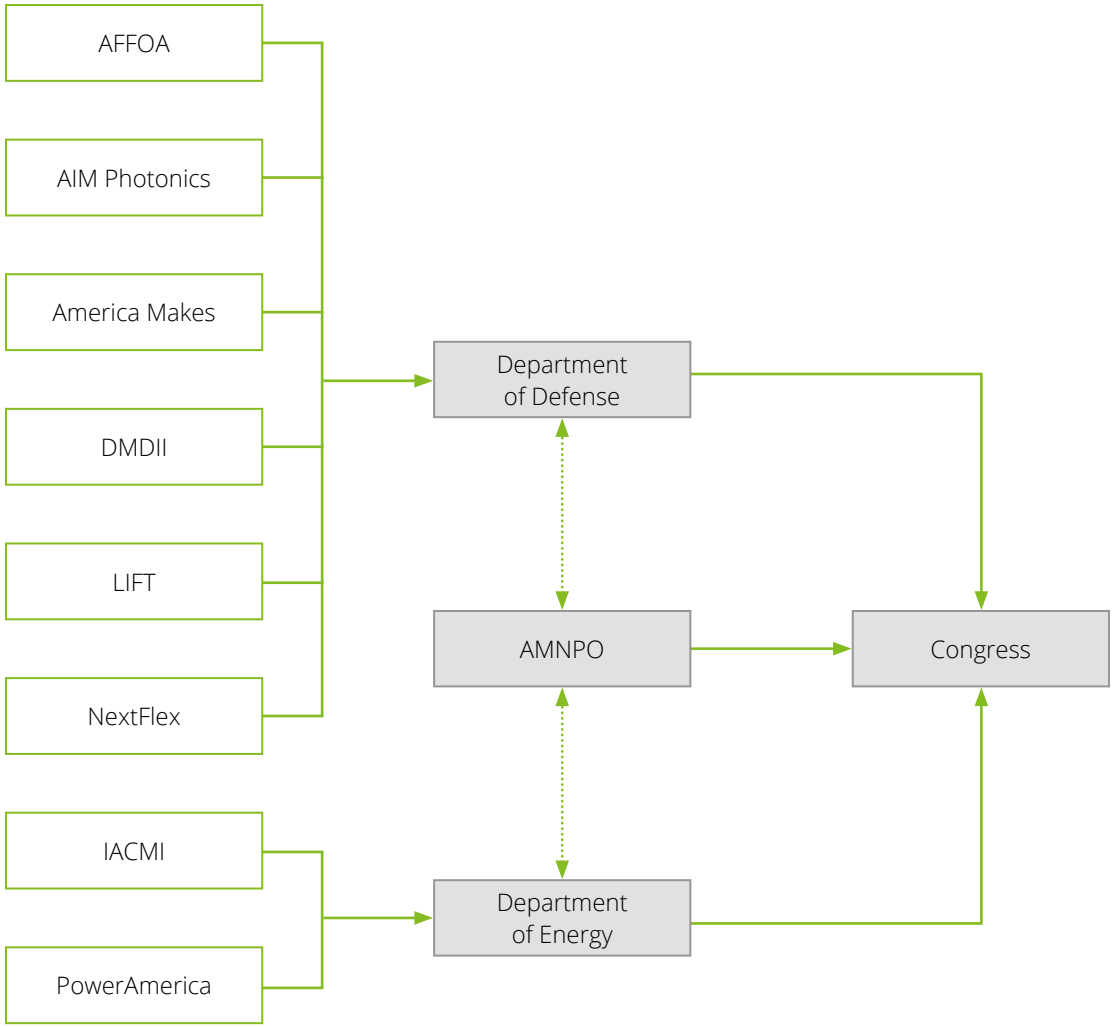
Categories	Metrics
Technology advancement (Development, Transfer, Commercialization, etc.)	• Number and value of active R&D projects • % of projects meeting key technical objectives
Financial leverage	• Total value of non-Manufacturing USA financial contribution (membership fees, etc.)
Development of advanced manufacturing workforce	• STEM activities – number of student interactions/participants • Educator/trainer engagement – total number of trainers trained
Impact to U.S. innovation ecosystem	• Total Institute members with signed agreements • Percentage of small and medium sized enterprises out of all corporate members

Path Forward

The rest of this section presents recommendations for frameworks to think about performance evaluation for Manufacturing USA, designed to supplement and shape – not replace – the Program and Institutes' preexisting work. These insights can enhance the efficacy of the Program's metrics and decision-making.

Manufacturing USA's sponsoring agencies and the AMNPO have developed a thorough set of processes to promote effective stewardship of federal funds

In addition to Institute self-monitoring, Program Managers, Agencies, and National the Program Office each collect detailed metrics on the operations of each of the Institutes and provide frequent reporting.



Institutes work closely with their sponsoring agency to report on progress toward agency goals

- Each Institute works directly with a dedicated program manager to regularly provide formal and informal updates and metrics (see slide 58 metrics table for details).
- Program managers and Institutes discuss status updates and metrics on a weekly basis and Institutes provide formal quarterly reports.

Sponsoring Agencies oversee their Institutes and act as a liaison between Institute and the AMNPO

- The goals and metrics of each individual Institute are aligned to the missions and goals of the sponsoring agency.
- Agencies and the AMNPO provide Institutes with guidance and feedback to promote effective and consistent metric collection and reporting activities.
- Sponsoring agencies own and validate the data from the Institutes and control the flow of reporting information to the AMNPO.
- Each agency provides an annual report to Congress summarizing the progress of their Institutes.

AMNPO provides Program-level metrics to Congress to convey the health of the Program

- AMNPO aggregates data from the agencies to build an annual report to Congress detailing the progress and successes of the Institutes.

Manufacturing USA should adopt phased metrics and track leading short-term outcomes to determine the likelihood of long-term success

Adopting phased metrics ensures that Program metrics are reflective of the maturity level of each Institute and avoids potentially misguided managerial responses (e.g., funding disruptions or over-management).

Key Recommendation

The most important conclusion about evaluating performance is that the Program would be best served by adopting phased metrics at the Institute and Program levels, and effectively tracking short-term outcomes which serve as leading indicators of long-term success.

The content in this Appendix is aligned to the framework depicted on the right side of this page and draws on extensive experience measuring performance for innovation organizations, as well as government agencies with missions to achieve broad economic and societal outcomes. Insights are derived from Deloitte's innovation consultancy, Doblin, as well as a review of Manufacturing USA's internal documents relating to evaluation.

Management Levers and Responses

What can Manufacturing USA do in response to different levels of performance among Institutes? In traditional business environments, managers have the "power of the purse" over business units, but can also contribute more managerial support as needed.

The Program should use metrics as a guide for determining the time necessary to provide additional support if desired by the Institute (e.g., helping an Institute recruit members, sharing best practices to improve the project call process, and anything else the Program can do to increase likelihood of Institute success).

Institute-Level: Three Phases

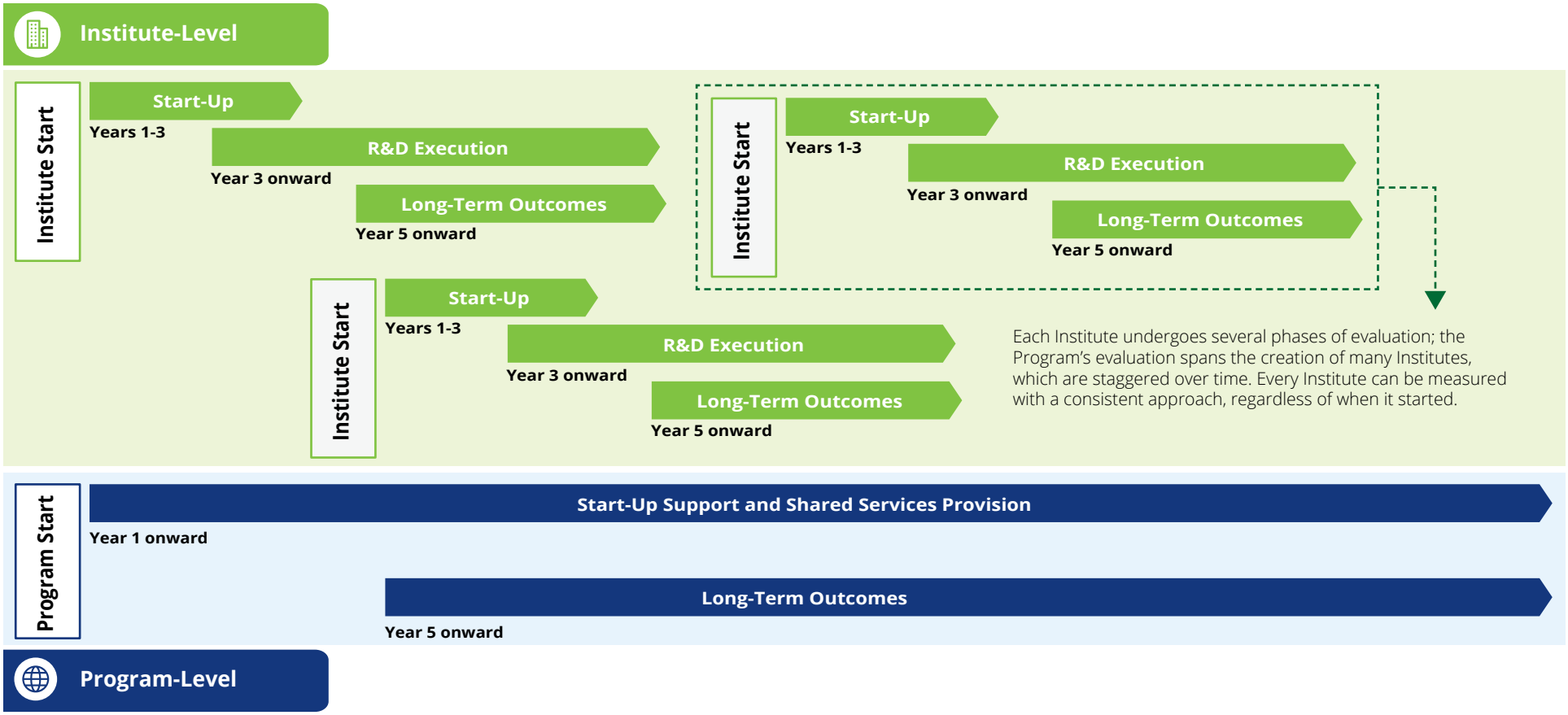
- **Start-Up** includes all necessary activities to operationally stand up an Institute, recruit membership, and lay the groundwork for R&D activity. If the Institute is asset-intensive, then physical equipment needs to be acquired and installed. If project-based, a project call process needs to be developed and executed.
- **R&D Execution** occurs once groups start using assets or have completed their first projects, where the first innovation results can truly be measured and ROI determined. Member engagement over time can also be tracked.
- **Long-Term Outcomes** concerns the achievement of Program goals on a technology-by-technology, industry-by-industry, and regional basis: industry competitiveness, regional macroeconomic results, and industry and regional workforce results.

Program-Level: Two Phases

- **Start-Up Support and Shared Services Provision** deals with two facets. The first is support rendered to individual Institutes in their establishment to accelerate and improve their setup (such as sharing templates and best practices from previous Institutes, or brokering connections with members to speed sign-up), and quality in the delivery of ongoing services applicable to all the Institutes (e.g., growth strategy, marketing, cybersecurity guidance, workforce activity coordination, etc.).
- **Long-Term Outcomes** concerns the achievement of Program goals on a manufacturing sector-wide and national basis: increased economic competitiveness, macroeconomic results, and workforce results alongside the fulfillment of the agency-specific missions of the Program. Not all long-term outcomes will be immediately identifiable at the beginning of this phase, but they will become progressively available over time.

The Program Office's existing evaluation work, combined with this phased approach, can help promote an enduring performance management capability

Phased Metrics Approach for Institutes and the Program



Manufacturing USA should continue to use effective performance measurement principles when further developing its evaluation strategy and plans

Four core principles drive insights around recommended metric categories and are applied to each phase, while keeping in mind the specific business operating designs and purposes of the Institutes.

(1) Begin with the end in mind, and make data actionable.

Strategic. Evaluation must begin with and be aligned to the organizational strategy. Without knowing the outcome the organization is trying to achieve or the hypothesis they are investigating, managers can't know what data to collect or what to look for in the data to reach their conclusions.

Actionable. Metric results should be tied to managerial responses. The creators of a metric must know what action they will take to correct course if performance expectations are not met.

(2) Consider unintended behavioral results.

Appropriate. Depending on their structure, metrics can result in unintended negative behaviors – the Institutes may try to "game" whatever measures are implemented if not carefully developed.

For instance, if the Program wants to measure Institute continuation viability, it could measure cash flow ratio (revenue to non-project expenditures) or incoming revenue from membership fees. Potential unintended negative behaviors to this measure, as expressed by Institute Directors, could be:

- Reducing operating costs and services to just "survive"
- Raising membership dues and driving non-strategic recruitment efforts
- Recruiting new members that are headquartered and/or primarily manufacturing outside the U.S. just to increase member count

To meet the Program's intent of maintaining a highly-impactful, U.S.-centric mission, the Program might prefer to measure continuation of the U.S. government role in each Institute as opposed to the scenario described above.

(3) Conform expectations to age, scale, and nature of the Institute. Make targets reasonable.

Time-bound. Performance expectations shouldn't be static over time, either in the items measured or the degree of progress expected. Institutes are early-stage start-up organizations and should be evaluated in a phased approach. Rushing to judgment could result in onerous and unnecessary re-engineering of management processes, or needless funding withdrawal.

Size-bound. Expectations should be tailored to Program size; the Program is only a total expenditure of ~$600 million in a ~$18 trillion economy. Moreover, that funding is distributed over at least 5 years, and across numerous industries. To counteract multi-billion dollar investments by the governments of competitor nations in advanced manufacturing (e.g., China), more U.S. investment may be needed to produce noticeable results on the macroeconomic level.

(4) Keep it simple; less is more, and easier to collect.

Focused. Trying to achieve and measure too much at once dilutes impact. Organizations must focus on what truly matters instead of sprinkling resources across many efforts. This is especially important where metrics conflict (e.g., Institute member quality vs. quantity), as managers often try to meet both goals and fall short across the board.

Simple. Starting with a few measures makes metrics more feasible to implement with reasonable effort. To be effective, metrics should be non-burdensome to gather and analyze data to calculate, with automated processes where possible.

APPENDIX C

Acknowledgments, Glossary, and References

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Glossary of Key Terms

Term	Definition
Manufacturing USA	The program established by the RAMI legislation that includes of all the individual Institutes. This program was previously referred to as the National Network for Manufacturing Innovation (NNMI).
Manufacturing USA Network	The connections and super-structure between and across Institutes and their consortia. Examples of network activities include IACMI's collaboration with LIFT, informal and formal communications between Institute directors (e.g., directors' council), and a cross-agency workforce development committee.
Institute	The staff and facilities of an Institute itself (e.g., America Makes, AFFOA, IACMI, etc.).
Innovation Ecosystem	Non-geographically bounded communities of actors involved either as members of the consortium or non-members with a vested interest in the topic of the "innovation ecosystem." This can include academic institutions, nonprofits, and industry groups who either generate value to or receive value from the activities of the innovation ecosystem.
Regional Economic Cluster	Bounded geographic area that reflects the impacts (e.g., on industry knowledge spillover effects, jobs, movement of companies into the region, etc.) of the Institutes.
Industrial Commons	The Commons is a shared source of competitive advantage where R&D know-how, advanced process development and engineering skills, and competencies related to specific technologies converge across a geographic area encompassing multiple companies.

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