

Strengthening the Innovation Ecosystem for Advanced Manufacturing

PATHWAYS & OPPORTUNITIES
for MASSACHUSETTS



MIT Industrial Performance Center
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Executive Summary

Recent years have brought a renewed focus on the importance of manufacturing to the health and future growth of the U.S. economy. Specifically, several studies have highlighted the need to maintain and build manufacturing capabilities to support economic growth, good jobs, and national security. Most critically perhaps, they have **linked America's strength in manufacturing to its ability to innovate**. Advanced manufacturing capabilities are essential to develop new products and processes across a range of industries, both established and emerging. As others have pointed out, the loss of this capability can shift an industry's center of gravity as higher value-added activities follow manufacturing abroad.

In few states is the link between manufacturing and innovation more evident than in Massachusetts. While manufacturing represents only 9 percent of employment (approximately 250,000 jobs) in the Commonwealth (compared to 11 percent in the country overall), manufacturing is integral to several of the **state's most important industry clusters**, including aerospace/defense, semiconductors and computers, biopharmaceuticals, and medical devices. Massachusetts-based manufacturers compete globally on their innovation capacity, high skills, product quality, and rapid response.

A 2013 MIT study titled *Production in the Innovation Economy* highlighted the fact that the large, vertically-integrated corporations of the 1980s have become less vertically integrated over time as they have focused on their core competencies, outsourced much of their production, and increasingly relied on suppliers to drive innovation. This process has left **"holes" in the industrial ecosystem**, reducing many of the important investments and spillovers—in areas such as training, technology adoption, and R&D—that used to flow from large corporations to smaller firms. As a result, the country's small and medium-sized manufacturers often find themselves **"home alone"** when it comes to competing globally and driving innovation in their companies.

This report focuses on how to fill these holes as they relate to innovation. Our analysis uses **a systems approach** that considers how knowledge and sources of innovation flow between key participants within the manufacturing innovation ecosystem. Strengthening these links and expanding the flow of knowledge between key actors will upgrade the system as a whole and enhance the region's competitiveness. As other regions and countries around the world increase investment in manufacturing and incentives for manufacturing firms, it is increasingly important for Massachusetts to invest in and leverage its own innovation assets to fully establish itself **as a world-class leader** in advanced manufacturing.

Study Objectives and Research Methodology

The objective of this research is to find pathways and opportunities for building and fostering innovation capacity among Massachusetts manufacturers, with a particular focus on small and medium-sized enterprises (SMEs). Strengthening the regional innovation ecosystem as a whole will improve the “**industrial commons**” and help all manufacturers in the state, not just a select few.

To that end, we have sought to develop a deep understanding of the current manufacturing landscape and of the intermediary systems that support manufacturing in Massachusetts. Our research included a quantitative analysis of the state’s industrial base as well as qualitative observations based on interviews with relevant actors in the innovation ecosystem. For benchmarking purposes we also included findings from interviews conducted in Germany.

Key Findings

1. Manufacturing in the Commonwealth Competes on Talent, Quality, and Innovation

Massachusetts has a long and illustrious history in manufacturing and in product and process innovation, and has built **advanced manufacturing capabilities** over the past 150 years that have allowed companies and workers to transition into new or emerging industries as market conditions change. In fact, one of the region’s strengths is a diverse manufacturing base that supports **cross-fertilization** between key industry clusters.

Several **attributes** characterize manufacturing in Massachusetts:

- Small-batch, niche production rather than large-volume mass production;
- Extremely high quality and performance requirements (zero percent failure);
- High knowledge and innovation content;
- New or early-stage products and prototyping;
- Products with high proprietary content;
- Products where proximity to market is desirable;
- Products where regulatory factors encourage siting in the U.S.; and
- Customized products with quick turnaround time if needed.

These attributes are possible because large manufacturing companies can draw on **four primary assets:**

1. A well-educated and **highly skilled labor force**, particularly in engineering;
2. Suppliers with the ability to quickly deliver difficult-to-manufacture parts of very **high quality and reliability;**
3. **World-class universities;** and
4. Innovative startups and a dynamic **entrepreneurial ecosystem.**

For all of these reasons, Massachusetts continues to have a strong manufacturing base. Moreover, that base has stabilized since the 2008 financial crisis. As a result, manufacturers in the Commonwealth are well positioned to take advantage of recent national and global trends that suggest the U.S. may be more globally competitive in manufacturing in the future. Declining energy costs, rising labor costs in traditionally low-wage countries, and concerns about the protection of intellectual property are making the **U.S. a more competitive location** for certain types of manufacturing, including in particular those types of manufacturing in which Massachusetts excels. At the same time, the development of **new “game-changing” advanced manufacturing technologies**, such as additive manufacturing, cyber-physical systems, and integrated circuit photonics, is providing additional opportunities for U.S. firms to innovate and increase efficiency.

2. Advanced Manufacturing Capabilities Support a Diverse Set of Regionally Important Industry Clusters

Manufacturing employment in Massachusetts has steadily declined over the past several decades, dropping from 19% of total employment in 1990 to approximately 9% at present, in part due to the recessions of 2000 and 2008, as well as productivity gains. Today, employment has stabilized since the financial crisis to approximately 250,000 workers and 7,000 establishments in manufacturing. Approximately 97% of all manufacturing establishments in Massachusetts can be considered SMEs (with fewer than 500 employees) and about 92% have even fewer than 100 employees. Although SMEs vastly outnumber large firms, they generate a smaller fraction—only 30%—of all manufacturing jobs. Large firms—though they account for only about 3% of all manufacturing establishments in Massachusetts—employ approximately 70% of the state’s manufacturing workers.

Massachusetts has a diverse set of strong manufacturing sub-industries that support some of the state’s leading industry clusters. These sub-industries create foundational **cross-cutting capabilities** within the regional economy; ten of them are considered in this study because they are especially relevant for advanced manufacturing:

- Analytical Laboratory Instruments
- Search, Detection, and Navigation Instruments

- Industrial Process Variable Measuring Instruments
- Semiconductor Machinery
- Semiconductors and Related Devices
- Electronic Computers
- Aircraft Engines
- Surgical and Medical Instruments
- Pharmaceutical Preparation
- Machine Shops

3. The Massachusetts Manufacturing Innovation Ecosystem is Rich in Terms of Assets, but Relatively Poor in Terms of Interconnectedness

While firm innovation might have occurred in isolation in the past, particularly when many firms were vertically integrated, today's firms must have high degrees of interaction with a range of other companies and organizations, such as universities, suppliers, customers, and even competitors, in order to build a firm's innovation capacity.

Four key nodes and actors shape the advanced manufacturing innovation ecosystem in the Commonwealth:

- Large original equipment manufacturers (OEMs)— firms with more than 500 employees that manufacture marketable products based on 'original' designs,
- Supplier SMEs—firms with fewer than 500 employees that manufacture parts and components for OEMs,
- Startups, and
- Universities and research institutions.

While each node within the system is relatively robust, the strength of connection between them varies in terms of knowledge flows. In general, **OEMs** have the **strongest links** within the innovation ecosystem because they are driving much of the innovation. Knowledge flows between OEMs and research universities are strong in both directions, while knowledge flows with SMEs are relatively unidirectional flowing from OEMs to the SME. With respect to innovation, startups typically bring new ideas to the OEMs.

Over the past five to ten years, many OEMs have undergone a significant reorganization and rethinking of their supply chains. Pressures, primarily financial from customers, have forced them to rethink how best to drive greater efficiency and innovation from the supply chain. This has led to several major changes:

- **Integration of supply chain management with engineering** to bring design and technological innovation into the supply chain procurement process earlier.
- **Centralization of supply chain operations** across business units or particular products rather than within each business unit.
- **Consolidation** of the supply chain to reduce the overall number of suppliers and attendant complexity.
- Greater emphasis on **collaborative partnerships** with a select number of strategic suppliers, and a more solutions-oriented approach to suppliers in general.
- **Shorter lead times** overall and highly responsive supply chains to meet customer demands that can't be anticipated ahead of time.
- Increasing **globalization of the supply chain** such that supplies can be sourced from firms in any corner of the world as long as the firms are cost competitive and deliver quality products on time.
- Instances of firms **moving production back to the United States** where the manufacturing environment is becoming more competitive, particularly given the emphasis on shorter lead times.

These changes directly impact SMEs within supply chains. The standard requirement for top suppliers today is to perform well in quality (e.g., deliver products that meet certification requirements with zero defects), cost (e.g., able to offer yearly price reductions), and time (e.g., able to achieve 100% on-time delivery). This can be accomplished through the application of lean practices and high-performing managerial capabilities, including an enthusiasm for problem solving.

In contrast to OEMs, **SMEs** generally have the weakest links within the ecosystem. This is in part because they have historically been on the receiving end of knowledge flows from their large customers. As a result, their ability to drive knowledge and ideas toward the OEMs has been limited and highly dependent on the OEM. SMEs also generally have weak links to universities and to the startup community.

Universities have relatively strong links with large OEMs and with the startup community, but limited engagement with SMEs. They tend to be active in both basic and applied R&D but are often looking 10 to 15 years out in terms of new technological developments. Nevertheless, the Commonwealth has many applied R&D centers that are focused on today's manufacturing challenges.

Finally, the vibrant community of **startups** is an important source of innovation in advanced manufacturing, particularly for OEMs. At the same time, OEMs can also be useful to startups as they attempt to scale up. The strength of the link between startups and OEMs depends in part on the nature of the industry and on the extent to which OEMs are receptive to, and actively engaging with, the startup community. Links between startups and SMEs, by contrast, are generally not strong in the region and based on ad-hoc interactions.

Germany provides an interesting case study for Massachusetts and for the U.S. as a whole with respect to strengthening SMEs in the manufacturing ecosystem. Arguably the most important mechanism for fostering innovation among German manufacturers, particularly among SMEs, is through **industry–university applied research consortia** that require SME participation.

4. Manufacturing Intermediaries in the Commonwealth are Primarily Focused on “Point Solutions” and on the Supply Side

Massachusetts is rich in intermediaries that provide, among other things, services and advice to SME manufacturers throughout the state. This assistance takes six primary forms: (1) process improvements, (2) workforce training, (3) strategic technology and cluster development, (4) technical and engineering process support, (5) managerial and professional education, and (6) marketing. However, the current system tends to focus on “point solutions”—such as supporting SMEs on a one-on-one basis primarily in workforce training, lean practices, and certification. This is necessary but not sufficient in terms of building innovation capacity. State efforts to support SMEs also focus primarily on the supply side—i.e., on workers and suppliers—often without enough input from the OEMs that drive the demand side. In addition, despite investments in some emerging technologies, Massachusetts lacks an overall strategic vision for advanced manufacturing that looks out five to ten years in terms of supply chain developments, technology road maps, and talent and training needs.

Recommendations to Improve the Innovation Ecosystem

Based on these findings, we identify four distinct areas of opportunity for improving the Massachusetts manufacturing innovation ecosystem, particularly for SMEs. They involve a statewide manufacturing strategy and agenda, OEM collaboration, technological and managerial support, and connections with startups. Our recommendations in each of these four areas are summarized below.

Advanced Manufacturing Strategy and Agenda

1. Develop an Advanced Manufacturing Strategy for the State

In contrast to the state’s other cluster-focused strategies (e.g., for the biotech industry), advanced manufacturing requires the development of cross-cutting capabilities that work across industries. This makes it more challenging to develop strategies around particular capabilities.

A deep understanding of advanced manufacturing capabilities, their importance within key clusters, and trends in technology as well as in the global manufacturing marketplace is required.

A robust analysis of the state's advanced manufacturing capabilities combined with engaging key manufacturing leaders in the state is necessary to develop an advanced manufacturing strategy and agenda for the next five to ten years. This includes involving relevant stakeholders and establishing appropriate governance structures to oversee such an effort.

2. Introduce Consortium-based Applied Research Projects

Grant funds should be used to encourage regional consortium-based projects including Universities, OEMs, and SMEs that focus on pre-competitive product and process innovations, similar to the German model. Experience in consortium-building in the process of applying for the federal Institutes for Manufacturing Innovation (IMIs) could be instructive in developing regional, project-based consortia.

Collaboration with OEMs to Drive Innovation and Upgrade SME Capabilities

3. Support the Formation of a Commonwealth Manufacturing Innovation Advisory Group

OEMs are a driving force for innovation in Massachusetts, yet their collective voice on the subject is not being heard. With a window into global trends, R&D opportunities, supply chain demands, and training needs five to ten years out, OEMs need to be engaged in helping set the state's manufacturing innovation strategy going forward. Their participation should be coupled with the participation of several high-performing SMEs, universities and others. A Manufacturing Innovation Advisory Group will promote long-term strategic thinking, collective action (and impact), and can highlight best practices for SMEs.

4. Initiate a Collaborative OEM Supplier Upgrade Program

Most OEMs have their own individual supplier development programs to help suppliers produce efficiently and meet the OEMs' delivery, cost, and quality requirements. However, there is little collaboration across OEMs in the same or different industries when it comes to upgrading the supplier base in the state, even when OEMs share similar suppliers.

Initiatives to upgrade supplier capabilities based on collaboration across OEMs from different industries could provide a robust mechanism for leveraging state resources, sharing best practices, and expanding support to SMEs. Such initiatives could focus not only on process and quality improvements but also on technical problem solving and workforce training.

5. Introduce an Advanced Manufacturing SME Innovation Prize

While several awards for small businesses are already offered in Massachusetts, a state-wide prize for innovative “world-class” advanced manufacturers would not only help set a high bar for SMEs and bring visibility to best practices for SMEs, it would also help change perceptions around advanced manufacturing in the state. The award could be given by a jury comprised of representatives from OEMs, universities, and intermediary organizations who are in a position to identify and evaluate particularly motivated and innovative SMEs.

Technological and Managerial Support for Innovation in SMEs

6. Provide Technological and Engineering Support

Thus far, state efforts to support SMEs have largely revolved around workforce training and lean practices. Such practices can lead to greater efficiency and accuracy in terms of quality, cost, and time. However, lean practices are a necessary but not sufficient requirement for success in today’s global manufacturing environment. With the rise of new technologies, such as additive manufacturing, programs to support SMEs and build their innovation capacity need to go further. Specifically, support should be expanded to include centers, either existing or yet to be formed, that provide technological and engineering services to SMEs engaged in product and process innovation.

7. Better Promote and Increase Awareness of Support Services for SMEs

Although numerous support programs and intermediaries exist in Massachusetts, many SMEs we interviewed were not aware of the portfolio of manufacturing services available in the state. Multiple factors may account for this lack of awareness, but it speaks to the larger challenge of creating an ecosystem that is well connected and where knowledge flows freely. A coordinated communications effort among the various intermediaries that work in this area could help highlight and promote existing support programs and resources within the larger manufacturing ecosystem.

8. Support Executive Education Programs for SMEs

Advanced manufacturing SMEs are under constant pressure to improve efficiency and innovate. Being “world class” today requires not only a culture and practice of lean, but also sound managerial infrastructure and leadership, combined with a culture and practice of continual product and process innovation.

An executive education program offered by prestigious business and management schools in the state and focused on operations management would help SMEs rise to this challenge and meet a high bar for managerial excellence. Such a program could be offered on a competitive basis and could provide matching funds to support executive education for CEOs and managers at highly motivated SMEs.

Connections between Startups and the Innovation Ecosystem

9. Better Promote and Connect SME Capabilities in Early-Stage Scale-Up to the Startup Community

Many Massachusetts startups, let alone startups outside Massachusetts, are unaware of the deep capabilities that exist within the state to support early-stage prototyping and piloting. Startups currently find manufacturing support through an ad-hoc, word-of-mouth process. Efforts by SME trade associations and intermediaries to better communicate these capabilities, together with a more explicit, systematic effort to connect SMEs and startups, is required.

10. Connect Startups with OEMs for Beta Testing and Piloting

In general, we found it difficult to assess the relative strength or weakness of current links between the Massachusetts startup community and large OEMs in the state. What is clear is that startups are almost always interested in stronger partnerships with potential customers and that more could be done to facilitate such partnerships within the region. Several efforts already exist in particular industries within the state—such as energy and financial services—but more explicit efforts could be geared toward advanced manufacturing-related technologies (e.g., robotics, advanced materials), where development time horizons are longer and where capital requirements during scale-up are higher.

Together these ten system-level recommendations are intended to increase the innovation capacity of the Commonwealth's manufacturing ecosystem through strengthening the links between key nodes within the system. Such steps will build long-term capabilities and institutions for the future that focus on frontier technologies, managerial and operational excellence and connectivity within the ecosystem to ensure Massachusetts' place as a world-class leader in advanced manufacturing.



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