Massachusetts Department of Higher Education

# Advanced Manufacturing Workforce Plan

***A Foundation for Our Future***

Spring 2015

## Tables



## Charts

# Advanced Manufacturing Workforce Plan

*A Foundation for our Future*

## Executive Summary

*Plan Context*

Workforce planning is an initiative of the Department of Higher Education's (DHE) Vision Project to inform the Board of Higher Education (BHE) about current and future trends that impact the skills gap in key economic sectors of Massachusetts' economy.

Beginning in 2010, the DHE initiated workforce planning for the healthcare sector. A coalition of employers, educators, state government agency representatives and industry leaders were convened to address the then-looming competency gaps and pipeline constraints of the nursing workforce. This work continues today. The nursing workforce plan was followed by the Allied Health - Direct Care plan (2014) and IT/Tech plan (2014), each built upon the foundation provided by *Massachusetts' Plan for STEM Education V2.0, Expanding the Pipeline for All* (2014).

In 2011, the Executive Office of Housing and Economic Development established the Advanced Manufacturing Collaborative (AMC) to address an array of challenges faced by this sector, including workforce development. Given the importance of the manufacturing sector to the Commonwealth's economy and public higher education's role in preparing this workforce, the DHE has prioritized the development of this plan to inform the BHE and complement the ongoing work of the AMC.

It is important to note that a substantial body of national and state-level research is available that describes the challenges of the manufacturing sector, including a strong emphasis on workforce development. To inform the development of this plan the DHE conducted a careful although most certainly incomplete review of the available literature, as well as personal interviews with members of Massachusetts' advanced manufacturing community.

*Current Pathways and View to the Future*

The DHE has identified two primary topics for attention through this plan. The first is to assess the current manufacturing education pathways that span vocational education schools and community colleges and size the output of this pipeline to assess the supply/demand talent gap. These pathways serve (1) traditional-age and adult students in day and evening programs at vocational schools, (2) community college students pursuing certificate and degree programs, and (3) adult students enrolled in not-for-credit training programs (grant and employer funded) at the community colleges. Private sector and not-for-profit partners also make important contributions to these education pathways.

The second topic is to look beyond the requirements of today's advanced manufacturing workforce to new and possibly higher-level competencies that will be required of the *next generation* workforce. While the current focus of workforce demand is centered on today's definition of the production manufacturing worker, accelerating advances in materials, technologies and supply chain processes will require a workforce with substantially new and different knowledge, skills and abilities to build the products of the future. The public higher education system must consider and address these trends well in advance of employer demand as there is a lead-time to develop academic programs and in the $21^{st}$ century economy; market opportunities will not wait. A well prepared, readily available and agile next generation workforce will be an important competitive advantage for the Commonwealth.

### *Scale of Implementation*

Within these two topics one theme stands out. That is the need for a greater *SCALE* of implementation of workforce development.

The ability to identify and take effective programs to scale, statewide, may be the single most important and as yet unmet challenge in workforce development. Vocational high schools, community colleges and state universities have successfully demonstrated the ability to align curriculum with industry requirements and develop stackable credential pathway programs to address local workforce challenges. However, these programmatic responses are too often "boutique" in nature, not designed to comprehensively and sustainably upgrade the skills of the incumbent workforce, build a pipeline of new workers to support sector transformation and growth, and provide backfill for retiring workers and other routine turnover.

**The data suggest that we have a sizable gap between demand and supply. We estimate (conservatively) that Massachusetts is under-producing skilled production workers by a factor of at least two with some indications of a substantially larger gap.**

This plan provides a detailed examination of the workforce supply pipelines, regionally. By taking a supply-focused approach we hope to facilitate better-informed conversations among regional partners about specific actions and investments needed to quantify the near-term supply/demand gap and position the system to address future industry trends.

### *Action Recommendations*

## Gap Analysis

Through this plan we have conservatively estimated a statewide shortfall in graduates and program completers in the range of twice the current student pipeline. However, the nature of the advanced manufacturing sector is that workforce demand and supply is driven by regional dynamics (industry sub-sector requirements and education pipeline alignment). Therefore, to achieve a more accurate assessment of the statewide gap requires regional analysis and validation of the data, aggregated, statewide.

**Recommendation #1**

The public higher education system, working in collaboration with each of the regional manufacturing partnerships, will assess the validity of the data and models provided through this plan and refine the analysis of regional and sector workforce gaps. Regional data will be aggregated to articulate the statewide talent gap.

## Program Alignment and System Capacity

As the education pipelines for advanced manufacturing traverse high school vocational programs (day and evening) as well as community college certificate and degree programs and not-for-credit training programs, an assessment of overall program alignment and system capacity will require a comprehensive regional approach.

**Recommendation #2**

The public higher education system, working in collaboration with each of the regional manufacturing partnerships, will assess the alignment of high school and community college academic pathway programs for manufacturing, considering "stackable credential" certificate progressions as well as credit transfer. This assessment will characterize the alignment of program pathways to industry requirements and size the capacity of regional systems to identify constraints and opportunities for expansion.

## Student Recruiting

In the *Degrees of Urgency: Why Massachusetts Needs More College Graduates Now* (2014 Vision Project annual report), DHE called attention to a perfect storm of higher education challenges and proposed the "Big Three Completion Plan"—boost college completion rates, close achievement gaps, and attract and graduate more students from underserved populations to meet the growing demand for talent. The community colleges are currently implementing targeted strategies to improve student recruiting, retention and completion such as the Complete College America's Guided Pathways to Success in STEM programs, the STEM Starter Academy initiative, Early College High School programs and more. Manufacturing pathway programs can be emphasized through these initiatives to promote career opportunity awareness to a broader range of students.

**Recommendation #3**

The community college STEM Starter Academy (SSA) initiative is currently recruiting high school and adult students, including underrepresented populations, to pursue STEM programs and careers, statewide. Advanced manufacturing career awareness initiatives can be incorporated into high school and adult student outreach activities of the SSA and the academic support resources of the SSA can enhance student retention and success in relevant certificate and degree programs and job placements in this sector.

## Next Generation Workforce

Massachusetts' leading research institutions are exploring the future challenges and opportunities of the manufacturing sector. This includes university collaboration with industry partners to conduct research and also to facilitate the transfer of knowledge from the laboratory to practice. As an integral element of the research agenda, faculty prepares students with the knowledge, skills and abilities that will be required of the next generation manufacturing workforce. This unique and early insight into the future of manufacturing should be fully leveraged as a competitive differentiation for Commonwealth's economy.

**Recommendation #4**

The public higher education system will promote increased collaboration across all three segments (community colleges, state universities and the University of Massachusetts) to scale-up the transfer of information that will inform curriculum enhancements, industry collaboration and faculty development to accelerate the Commonwealth's future workforce readiness and competitive position.

# Introduction

## Workforce Development

Massachusetts, like the nation, is facing a shortage of new workers prepared for jobs in advanced manufacturing. We need to attract and grow talent just as we need to attract and grow jobs; both are necessary to sustain a vibrant economy for the 21st century. This simple but important notion often gets lost in the contemporary "skills gap" discussion. Yes, Massachusetts needs more talented professionals that possess higher level competencies (knowledge, skills and abilities) to meet the demands of industries that are transforming, expanding and innovating. We also need to attract, develop and sustain a profile of jobs and careers that fulfill the expectations of today's and tomorrow's workforce. The two are interlinked like never before.

In today's global economy, enabled by the Internet, jobs and talent are easily transportable and are positively correlated; they expand and contract in relation to each other. Talent attracts jobs and jobs attract talent. The converse is also true; talent shortages over time (although less time than in the past) will drive a flight of jobs. A healthy and vibrant economy and workforce system must balance the supply of talent and the availability of jobs, and both need to grow. There is truly no alternative. Massachusetts must support the acceleration of innovation, economic development and career opportunities in every region of the Commonwealth to assure the health and vitality of our society today and for future generations.

So what's different: Hasn't this always been the case?

Today's economy is different. Massachusetts leading industries – healthcare, technology, life sciences, advanced manufacturing and more are increasingly knowledge-based and driven by innovation. Enterprises within these industries address ever more specialized and regionalized market sub-sectors, globally. The emergence of data analytics as an information science is enabling new capabilities to mass-customize products, processes and services through shorter and therefore more responsive supply chains. And all of this drives demand for just the right talent, in the right amount, at the right place and time.

The Department of Higher Education's (DHE) Vision Project has identified the growing demand for college graduates to meet the workforce needs of employers in key sectors of the Commonwealth's knowledge economy. In the *Degrees of Urgency* (2014) report, DHE called attention to a perfect storm of higher education challenges, including the impact of a declining high school student demographic which, if unaddressed, will negatively impact future college enrollments. In response, DHE proposed the "Big Three Completion Plan" – boost college completion rates, close achievement gaps and attract and graduate more students from underserved populations to meet this growing demand for talent.

Workforce development is a key element of the VISION project and this focus has produced industry sector workforce plans for Healthcare (Nursing, and Allied Health – Direct Care) and Information Technology/Tech. These plans, developed in collaboration with employers, educators and industry leaders, promote the development of a systemic and sustainable response to close the gap between demand for talent and the current "pipeline" of students emerging from our public higher education institutions.

## Advanced Manufacturing

This plan, the fourth in this series from the DHE, focuses on one of the three largest economic and employment sectors of the Massachusetts economy – Advanced Manufacturing.

Despite a commonly held belief to the contrary, manufacturing is and will continue to be a significant and essential element of Massachusetts' and the nation's economy for the foreseeable future. Manufacturing generates 10% of Massachusetts' GDP (U.S. Bureau of Economic Analysis) and employs 6% of the state's entire employment base. This faith in the vital importance of manufacturing to the Commonwealth's economic future may seem contrary to the conventional wisdom of recent decades when manufacturing was aggressively "off-shored" to low labor cost countries and the "service economy" was promoted as our nation's competitive path forward. Clearly, key industries have undergone a significant economic disruption, many workers have been displaced and large numbers of jobs lost. However, a reawakening to the importance of manufacturing in the U.S. economy is occurring and "re-shoring" is underway as global cost advantages diminish, product safety and quality requirements increase and supply chains shorten to improve market responsiveness. There is also a growing appreciation of the synergistic relationship between innovation (the cornerstone of U.S. competitiveness around the world) and simply put, "making things".

In recent years, the process of innovation was considered by many to be independent of the act of production. Design and engineering were seen as domains separate from of the "shop floor". That is now changing as ever more rapid evolutions of technology and materials as well as methods of distribution and production require tighter integration across the full product life cycle of design, marketing, engineering and production.

While continued improvements in productivity and the expanded use of robotic and other technologies diminish the likelihood of employment growth in manufacturing (Massachusetts LMI, 2012-2022 Industry Projections), product innovations as a result of the application of new technologies, materials and processes will increase market opportunities globally and sustain manufacturing's strong economic contribution to Massachusetts' into the future.

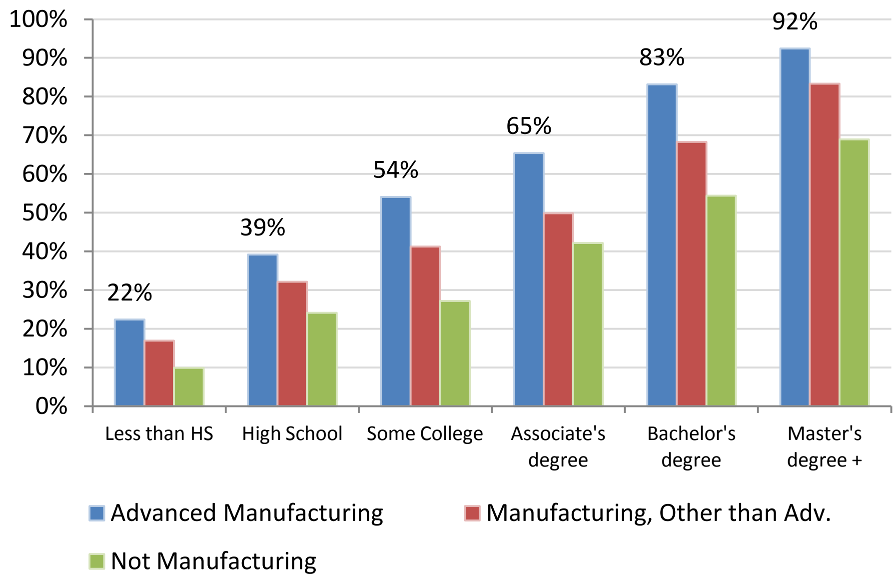
## Production Workforce

The production workforce is the cornerstone of this sector as "making things" is the purpose of every manufacturing enterprise. The ever-increasing utilization of computer-aided design and manufacturing systems has transformed the role of the "line production worker" into an advanced technology machine operator or manufacturing technologist. These jobs require higher-level workplace competencies (knowledge, skills and abilities), especially in science, technology, engineering and mathematics - the STEM subjects. Today's workforce is also expected to demonstrate stronger communication (reading and writing), critical thinking and problem solving skills, and the ability to collaborate in diverse, sometimes geographically distributed teams. Experienced, skilled and well educated production workers are in short supply and this gap is projected to worsen.

Industry restructuring and productivity gains that span over more than a decade have resulted in a significant downsizing of the workforce. Vertically integrated enterprises of the past have been disintermediated, resulting in today's framework of original equipment manufacturers (OEM's) focused on systems engineering and assembly, while contract manufacturers or small medium enterprises (SME's) are optimized for low cost and high quality production. This transformation plus several recent economic downturns have resulted in limited hiring and even less investment in workforce development and training programs. The effect has been to "hollow out" the middle tier of the workforce leaving both a highly skilled segment of older employees who are approaching retirement and a small pipeline of new workers emerging from limited capacity education and training programs.

While today's advanced manufacturing jobs offer lucrative pay and benefits packages in high quality work settings and provide many career advancement opportunities, this sector struggles to outdistance its legacy in the eyes of the next generation's workforce. As indicated in ***Chart 1***, advanced manufacturing workers earn more at every education level over workers in other sectors, demonstrating the economic value of manufacturing careers and labor-market demand for this workforce. However, despite these strong signals to the labor market, there are regular reports from employers of challenges they face in recruiting workers into manufacturing careers. This demand can be difficult to quantify as entry-level production manufacturing jobs are often marketed word-of-mouth, locally, and therefore underreported in job-postings, especially online. Also, employers with multiple job opportunities often only advertise a single job posting and some source talent through agencies, both strategies disguise total demand. Finally, employers report anecdotally that they sometimes forego contract opportunities due to their lack of confidence that they could source the necessary production talent; this opportunity cost isn't reflected in job posting.

**Chart 1 Percent of Massachusetts Workers Earning at least 45K Annually by Industry**




Source: US Census Bureau. American Community Survey, 2012, Accessed via IPUMS.

## Industry Segmentation and Workforce Characteristics

The term advanced manufacturing is used to broadly describe a major segment of Massachusetts' economy that encompasses an array of industry specific sub-sectors. These include: Computer and Electronic Products[1], Fabricated Metal Products and Machinery, Chemical and Plastics (incl. Pharmaceuticals), Medical Equipment and Supplies, Food Processing and Production, and Paper and Printing. According to the report *A Profile of Advanced Manufacturing in the Commonwealth: Key Industry and Occupational Trends July 2014* by Henry Renski, PhD and Ryan Wallace (2014), "as of 2012, there were just over 5,300 establishments and 200,000 workers in Advanced Manufacturing, representing roughly six percent of the total employment base of the Commonwealth and nearly 80% of its Manufacturing employment.

These industry sub-sectors[2] and the businesses that make them up are quite different in the products they produce, the competencies required of the production workforce they employ, and the demographics of that workforce and its impact on replacement worker demand. These sub-sectors are also regionally concentrated which has further implications for education and workforce planning. Of these six sub-sectors, four require moderate to high occupational skill levels typical of community college post-secondary certificate and associate degree programs and career training available through vocational education schools.

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[1] Includes many specialized product categories e.g. Photonics
[2] Reference Appendix A for a summary of sub-sector characteristics

These include:

- Computer and Electronic Products
- Fabricated Metal Products and Machinery
- Chemical and Plastics (incl. Pharmaceuticals)
- Medical Equipment and Supplies

It should be noted that technology and process improvements are impacting all sectors of manufacturing, some to a greater degree. The two remaining sub-sectors require generally lower average skill levels with moderate to higher skills in only a limited set of occupations.

- Food Processing and Production
- Paper and Printing

As this plan is focused on higher education's role in preparing the advanced manufacturing workforce, the primary focus of further analysis will be on the four sub-sectors that require moderate to high skill level workers.

## Production and Technical Workforce Projections

### Talent Demand - Statewide

One of the two primary topics identified for attention through this plan is the need to assess the current education pathways that span vocational education schools and community colleges, and size the current output of this "pipeline" to assess the supply/demand gap. We begin by assessing the demand for Production and Technical workers.

As there is no one resource commonly accepted as the gage of workforce demand, we reference three separate and distinct frameworks and data sources to triangulate a range for this calculation. These include (1) traditional labor market estimates produced by the state Labor Market Information (LMI) Office, (2) online job posting analytics, and (3) retirement projections. Through an Occupation Demand Estimation Model[3] we have identified a selected list of key manufacturing occupations to compare State LMI projections and online job posting data for Production and Technical Workers. The results of this analysis[4] shows the following projected demand:

- 3,815 projected annual job openings (LMI)
- 2,676 online job postings (prior 120 days)

[3] Appendix B
[4] Appendix C

To estimate total projected retirements over the ten year period of 2014-2024 we summarize data (Table 1) reported by Renski and Wallace (2014) in each of the four advanced manufacturing sub-sectors that are the focus of this plan. As indicated, a straight line ten year and a five year calculation (with the assumption that most retirements would occur in the 60-65 age range) were considered. We reference the five year calculation to complete our triangulation of demand with the projection of 2,742 retirements annually.

These three data sources and methods of analysis suggest a range of annual workforce demand of approximately 2,700 to 3,800. For our talent gap planning purposes we propose to use an annual projected demand in the four targeted sub-sectors of 3,000.

**Table 1 Production and Technical Workforce Demand from Retirements**

| | Computers & Electronics | Fabricated Metals & Machinery | Chemicals & Plastics | Medical Equipment & Supplies | Total |
|---|---|---|---|---|---|
| **Employment** | 66,662 | 50,019 | 27,708 | 11,825 | 156,214 |
| **Production as % of Employment** | 24% | 53% | 40% | 51% | |
| **Sub-total Production Workers** | 15,999 | 26,510 | 11,083 | 6,031 | 59,623 |
| **Workforce within retirement range** | 21.5% | 26% | 17% | 24.5% | |
| **Projected 10 Year retirements** | 3,440 | 6,866 | 1,928 | 1,478 | 13,712 |
| **Straight line 10 year annual replacement** | 344 | 687 | 193 | 148 | 1,371 |
| **Straight Line 5 year annual replacement** | 688 | 1,373 | 386 | 296 | 2,742 |

Source: Renski 2014. Analysis by DHE.

It is important at this point to call attention to how this analysis differs from that provided in the report, *Staying Power II A Report Card on Manufacturing in Massachusetts 2012* by Barry Bluestone et al. (2012) which projected approximately 100,000 manufacturing job openings in the period of 2012-2022.

For this plan we have referenced the data provided by Renski and Wallace (2014) which provided a baseline employment for manufacturing in Massachusetts at 200,000 vs. the 250,000 referenced in *Staying Power II (2012)*. Further, we narrowed our focus to four sub-sectors of advanced manufacturing that represent an employment base of approximately 156,000. These sub-sectors have a specific demographic profile which informed our retirement projection of approximately 14,000 over 10 years. To contrast the retirement percentage referenced in *Staying Power II* (approximately 50,000 on a base of 250,000 or 20%) to the calculation in this plan of approximately 14,000 on a base of 156,000 or 9%, the retirement projection in this plan is about half that reported in *Staying Power II*. In any case, we acknowledge that the projection of annual demand of 3,000 is likely a conservative figure and yet, as will be shown in the Talent Gap analysis, already exceeds the current supply by a factor of two.

In addition to job openings from retirements, Bluestone et al (2012) provided an analysis and projection of job vacancies based on voluntary separation and "quit rate" of the non-retirement workforce. This suggests approximately 50,000 additional vacancies (again, based on a workforce baseline of 50,000). We have not factored a "quit rate" into our analysis. This of course would only further widen the projected supply/demand gap.

## Talent Supply

The pipeline of new graduates from programs that prepare students for production manufacturing jobs comes from three primary sources:

- ☐ High School vocational education manufacturing programs
- ☐ Community college certificate/degree manufacturing programs
- ☐ Community college non-credit training programs

As shown in Table 2, 1,653 Massachusetts high school students graduated from programs related to advance manufacturing careers at comprehensive and CVTE high schools[5]. Of these graduates, 353 reported[6] directly entering related employment, 626 entered related programs in post-secondary education and 669 pursued unrelated activities. In the same timeframe 684 students completed programs related to manufacturing careers at community colleges[7].

At the current time, DHE does not have access to data on manufacturing program enrollments and completions in adult community education courses taught at public high schools. A small fraction of Bachelor degrees in engineering programs are oriented to manufacturing production; DHE estimates Massachusetts has 65 such graduates a year.

**High school vocational programs and community college programs together prepared approximately 1300 students for entry into manufacturing workforce per year.**

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[5] Reference Appendix D for program level detail, by school and regionally)
[6] DESE Career/Vocational Technical Education Graduate Follow-up Survey
[7] Reference Appendix E for program level detail

**Table 2 Graduates of Manufacturing Programs at Comprehensive and Career Vocational Technical High Schools (CVTE) and Community Colleges**

| | High School | | | | Higher Education |
|---|---|---|---|---|---|
| Region | Number of Graduates | Into Related Employment | Into Related Post-Sec Education | Unrelated Pursuits | Certificates and Degrees Conferred |
| Central | 324 | 71 | 127 | 126 | 104 |
| Metro Boston | 333 | 43 | 154 | 136 | 199 |
| Northeast | 245 | 59 | 110 | 76 | 146 |
| Pioneer and West | 235 | 77 | 56 | 102 | 153 |
| Southeast | 516 | 103 | 184 | 229 | 82 |
| Statewide | 1653 | 353 | 626 | 669 | 684 |

Sources: High School Career and Tech Reports, 2012 Graduates, IPEDS 2013 Completions, and Massachusetts 2013-2015 Annual Occupational Projections. Note: Excludes bio or health graduates.

*Note: Nearly 60% of high school students who completed programs related to manufacturing persisted in pursuit of their career interest either by entering the workforce or continuing on to higher education. As there is a concern about the need to attract more students to pursue careers in manufacturing this may represent an opportunity to learn from the choices the 40% of students who exhibited some interest in manufacturing yet did not continue in this field.*

In addition to high school and credit bearing community college programs, adult students (including incumbent workers, displaced workers seeking to refresh their skills and workers seeking entry into advanced manufacturing career pathways) enroll[8] in not-for-credit community college training programs. These customizable trainings represent a sizable share of the employer-sponsored or workforce development grant-funded training for manufacturing.

[8] DHE Non Credit student data in HEIRS is limited to individual course enrollments, not completions.

Currently, DHE does not report data on non-credit course outcomes. To estimate the supply of new manufacturing workers prepared to enter the field from non-credit enrollment[9] we use the figure of 250, roughly one per three enrollments using a five-year average.

Note: Significant investments by the Workforce Competitiveness Trust Fund in middle skill manufacturing training are represented through increased 2014 enrollments in manufacturing and GMP/LEAN/ Quality programs (Table 3).

**Table 3 Not-for-Credit Manufacturing Training at Massachusetts Community Colleges**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|
| Mfg | 504 | 159 | 1,732 | 479 | 369 | 359 | 94 | 129 | 146 | 594 |
| GMP / Lean / Quality | 180 | 298 | 62 | 74 | 290 | 315 | 312 | 234 | 138 | 474 |
| Bio-manufacturing | | 23 | 111 | | 88 | 405 | 32 | | | 11 |
| CNC | 11 | 29 | | | | | | | 15 | 13 |
| Drafting / CAD | 137 | 97 | 100 | 105 | 101 | 82 | 61 | 101 | 75 | 40 |
| Blueprint | 10 | 37 | 29 | 35 | 12 | 23 | 17 | 8 | | 51 |
| Welding | 51 | 83 | 47 | 33 | 13 | 25 | 22 | 1 | 6 | |
| Electrical | 212 | 147 | 241 | 6 | 1 | 11 | 14 | 6 | 153 | 5 |
| Total | 1,105 | 873 | 2,322 | 732 | 874 | 1,220 | 552 | 479 | 533 | 1,188 |

Source: Massachusetts Department of Higher Education. HEIRS Non-Credit Course Enrollments with course titles related to Manufacturing. This data is inclusive of courses contracted by employers for their own workers as well programs funded through the Workforce Competitiveness Trust Fund.

## Talent Gap

A primary objective of this plan is to assess the current education pathways that span vocational education schools and community colleges, and size the output of this pipeline in order to assess the supply/demand talent gap. We have quantified the gap on a statewide basis

[9] Reference Appendix F for program detail

and provided regional and sub-sector detail, as well as program detail by school and college to support further analysis in collaboration with each of the regional manufacturing partnerships.

By aggregating graduates and program completers from community colleges and high school vocational advanced manufacturing programs, we have provided a measure of the current student pipeline. This can be considered a proxy for the capacity of the system although at this time we have not attempted to determine actual system wide capacity and constraints. That is a recommended next step for the implementation of this plan. Incremental investments will likely be needed to significantly close the gap with known and anticipated demand.

Comparing our assessment of the student pipeline to our best estimate of state wide demand suggests the following talent gap.

### *Statewide Analysis*

Student Pipeline:

| | |
|---|---|
| High school graduates entering employment[10] | = 353 |
| Community College certificate/degree completers | = 684 |
| Community College not-for-credit program completers[11] | = 250 |
| Production-Oriented Bachelor's degrees | = 65 |
| Pipeline Total | = 1,352 |

Workforce Demand (Estimated based on the following data sources):

| | |
|---|---|
| LMI Projection | = 3,815 |
| Online Job Postings | = 2,676 |
| Retirements | = 2,700 |
| Demand estimate | = 3,000 |

**Based on this analysis we are under-producing talent, statewide, by approximately 1700 students per year or put another way, we need to more than double the number of students completing advanced manufacturing programs to meet current demand.**

### Rising Education Expectations

In addition to the shortfall in the number of students graduating from manufacturing programs at Massachusetts vocational schools and community colleges, employment and unemployment statistics show a shift to recruit workers with higher levels of education and a decline in the

[10] An addition 626 students entered postsecondary education. For this analysis we assume those are captured in the pipeline of community college certificate and degree completers although some likely pursue other postsecondary programs.

[11] Estimated based upon enrollments

number of jobs filled with individuals with no college education. According to the Census Bureau[12] less than a third of younger workers (age 25-34) employed in manufacturing have no college education, 21% have some college or an associate's degree, and 48% hold a bachelor's degree or above.

The top ten technical skills mentioned in entry and mid-level advanced manufacturing job ads[13] provide a view of the technical skills employers are seeking in their production, technician, and industrial engineering workforce.  A common set of skills are frequently mentioned across all four advanced manufacturing sectors[14], including, quality assurance, CAD, and process controls. Each sub-sector also has specific skill requirements.

The combination of an aging manufacturing workforce, upward shift in entry-level education requirements and the increasing technology-intensity of advanced manufacturing suggest there will be a growing demand for graduates of 2 and 4 year programs requiring an increase in the capacity of public institutions

In addition to the need to acquire and maintain state-of-the-art facilities and instructional equipment and technology, schools and colleges are further challenged to attract and retain faculty who are experienced with contemporary manufacturing systems, processes and industry practices and who can successfully engage students. Faculty recruiting and development may be one of the most significant barriers to scaling-up the advanced manufacturing workforce.

## Next Generation Advanced Manufacturing

### Innovation, Transformation, and the Future Workforce

Much of the current discussion about the workforce challenges in advanced manufacturing is grounded in the contemporary definition of production jobs.  While the competency expectations of today's workers are vastly different from those of the mass-assembly line worker of just a few years ago, those expectations will change even more in the years ahead. As the higher education system contemplates the preparation that students will need for the challenges and opportunities of the next generation of advanced manufacturing jobs, we can look for guidance from a broad range of initiatives underway at university research laboratories where technology, materials and process innovations are currently in development. These laboratories offer the opportunity to assess and define the needs for next generation

[12] American Community Survey, 2012 (five year average) accessed through IPUMS
[13] Many entry level job postings are not advertised on-line. Higher skill-level jobs are more likely to be advertised more broadly, online.
[14] Reference Appendix G for a detailed listing of skill requirements by sub-sector.

competencies (knowledge, skills and abilities) that will be required of the advanced manufacturing workforce. Just as advances in technology, materials and supply chain processes are accelerating in our laboratories, so must the development of curriculum, instructional platforms and teaching practices (faculty development) keep pace.

Today's advanced manufacturing ecosystem reflects the primary relationship of small/medium enterprises (SME's) that produce high quality/precision components at globally competitive prices for original equipment manufacturers (OEM's) who assemble completed systems for end-user customers. Quality, cost and a timely response to market opportunities are key drivers of business success. Admittedly, this is an oversimplification of what is a very complex marketplace. However, it is reasonable to acknowledge that today's manufacturers, while feeling the pressure to innovate or perish, have limited time, resources and organizational capability to engage in the application of emerging or early stage innovations that may well represent the future for their businesses. Innovation and transformation can be considered luxuries when job one is quality, schedule, cost and securing the next contract.

However, Massachusetts manufacturers are fortunate to operate in a virtual sea of innovation surrounded by leading research institutions that are advancing the state of the art of manufacturing in many domains. This focus on innovation and transformation requires a close collaboration between university faculty, OEM and SME manufacturers (including start-up companies) to accelerate the transfer of knowledge in all directions. As a result, university research centers have evolved an intermediary role to facilitate the process of innovation, innovation and mitigate the risk for manufacturers; particularly SME's to engage in early stage adoption of advanced technologies.

### University Research Centers

There are many outstanding examples of faculty/industry collaboration across the Commonwealth's public and private research institutions. These centers are not only developing new products and processes that will define the future of manufacturing but are also informing educators in each segment of higher education about the need for new curriculum, education platforms and opportunities for faculty development.

While it is not the intention of this plan to provide a comprehensive summary of the range, scope and scale of all the exciting research currently underway in the Commonwealth, the following example and others[15] offer a glimpse into the future for students and those who will prepare the next generation manufacturing workforce.

## Center for Hierarchical Manufacturing - University of Massachusetts Amherst

[15] Appendix H

Director: Dr. James J. Watkins
Dept. of Polymer Science & Engineering

http://chm.pse.umass.edu/

The Center for Hierarchical Manufacturing (CHM) is an NSF Nanoscale Science and Engineering Center (NSEC) that works extensively with industry collaborators on roll-to-roll nanomanufacturing technologies. Industrial partners work with research faculty in our nanomanufacturing facilities to develop and demonstrate new nano-based technologies.

The critical challenge for the nanotechnology R&D community is the transition from laboratory innovation and discovery to efficient, cost-effective manufacturing of nanostructured components, devices, and systems. While a strong foundation of outstanding fundamental science is a prerequisite, hierarchical manufacturing requires approaches to products and processes that are built from enabling technical advantages that are scalable to high-volume manufacturing and that have multiple paths to commercialization.

The bridge to high-volume process technology is accomplished through collaborations with leading industry partners and with academic centers of excellence in process technology and is demonstrated through system-level test beds. CHM partnerships with commercial fabrication tool and process suppliers provide a mechanism by which these techniques may be widely distributed for use by the broader nanomanufacturing community. Technology transfer is aided by proactive opportunity and application identification, facilitated engagement with potential partners and establishment of a unique facility for the R2R production of functional nanostructured hybrid materials and devices. This facility includes new process tools developed in cooperation with our industry partners.

The Center's educational programs reach K-12, community college, undergraduate, graduate students and the general public while the Center champion's diverse participation at all levels of education and NSEC operations.

## National Initiatives

During his fifth State of the Union address, President Barak Obama announced plans to create six high-tech manufacturing hubs to promote innovation and job growth in this resurgent industry sector. This signaled that manufacturing is a renewed national priority, reflecting its central role in advancing the innovation economy, the re-shoring of jobs based on overall competitiveness and the need to ensure the nation's defense. While Massachusetts has not yet been designated to host one of the regional innovation hubs, this possibility is on the horizon. Regardless, local manufacturers currently supply OEM's across the nation and therefore participate in the supply chains and industries that are emerging from this national initiative.

The following brief summary of one of these national initiatives suggests the scope and nature of workforce requirements in the not distant future. Summaries of the other national institutes extracted from the Manufacturing.gov website http://manufacturing.gov/Institutes.html can be referenced in Appendix I.

**The Institute of Advanced Composites Manufacturing Innovation (IACMI)**

http://www.iacmi.org/

Date Launched: Jan. 19, 2015
Headquarters Location: Knoxville, Tennessee

**Focus Area**: Advanced Fiber-Reinforced Polymer Composites
**Capsule Summary**: Advanced composites are currently used for expensive applications like satellites and luxury cars. Researchers at IACMI will work to develop lower-cost, higher-speed, and more efficient manufacturing and recycling processes for them. Bringing these materials down the cost curve 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. The Institute will focus on lowering the overall manufacturing costs of advanced composites by 50 percent, reducing the energy used to make composites by 75 percent and increasing the recyclability of composites to over 95 percent within the next decade.

## Statewide and Regional Workforce Coordination

### Massachusetts Advanced Manufacturing Collaborative

The Massachusetts Advanced Manufacturing Collaborative (AMC) http://www.mass.gov/hed/economic/initiatives/manufacturing/advanced-manufacturing-collaborative.html is a statewide, industry led public/private coalition of employers, state government agency representatives, statewide and regional workforce training organizations, vocational education schools and higher education colleges and universities working together to promote the importance of this sector to the Commonwealth's economy and address key challenges and overcome obstacles to growth. Workforce and education is one of five elements of the AMC's action agenda.

## Regional and Statewide Partnerships

Complementing the statewide focus of the AMC are regional and statewide partner organizations that assess local market needs informed through direct employer engagement and coordinate regional workforce development strategies and program investments with Workforce Investment Boards, community colleges and vocational schools, and other community based organizations. The regional partner organizations include (not limited to):

- ☐ Berkshire/Applied Technology Council
- ☐ Franklin-Hampden Advanced Manufacturing Group
- ☐ Northeast Advanced Manufacturing Consortium
- ☐ Precision Manufacturing Regional Alliance Project
- ☐ Southeast Advanced Manufacturing Collaborative
- ☐ Worcester County

Other statewide partners include (not limited to):

- ☐ MassMEP
- ☐ Mass Development

## Funding Sources

There are multiple sources of funding that support the AMC's agenda which includes a special focus on workforce development. The Commonwealth Corporation www.commcorp.org has been a primary source of funding in recent years through the Workforce Competitiveness Trust Fund. Grants from this program in 2007-2012 supported projects in the Berkshires, Hampden, Merrimack Valley and New Bedford. The most recent round of projects are in the Central, Northeast, Bristol, Franklin Hampden counties.

The U.S. Department of Labor's Trade Adjustment Assistance Community College and Career Training grant program has provided another important source of statewide funding to community colleges focused on displaced worker retraining. A portion of this funding has supported the development priorities to build and to sustain the necessary capacity of the of "stackable credential" curriculum for advanced manufacturing programs.

Other grant sources include federal programs (DOL, NSF…), the Department of Higher Education's Rapid Response program (state funded) and direct employer sponsored training initiatives have contributed to addressing employer and worker training needs in each region.

## Conclusion

Advanced manufacturing is an essential sector of Massachusetts knowledge and innovation economy and will continue to be a cornerstone into the foreseeable future.

The role and required competencies of the advanced manufacturing workforce have changed dramatically in recent years and this evolution will continue to accelerate as new technologies, materials and processes transform the nature of Massachusetts made products. Workforce shortages and skills gaps are estimated to be at least 2:1 with conservative estimates of annual demand for new and replacement workers at 3,000, statewide, and supply from vocational schools and community colleges at approximately 1,300. These gaps may vary by region as different industry sub-sectors have differing workforce supply/demand profiles.

In the near term, production worker shortages and capacity constraints can best be addressed through alignment of regional resources at vocational schools, community colleges and with not-for-profit partners and through statewide technical assistance and coordination of existing funding sources. Additional funding sources will likely be necessary to build system capacity and address emerging growth opportunities.

Longer term, the competency requirements of the next generation advanced manufacturing workforce, many of which are currently being defined at leading research laboratories across the Commonwealth and the nation, must be translated into curriculum, faculty development and education platform initiatives at community colleges, state universities and the University of Massachusetts.

The recommendations of this plan complement and build upon the long-standing work of the regional partnerships and the statewide Advanced Manufacturing Collaborative. The Department of Higher Education is eager to contribute to this record of success and support the development of a talent pipeline that will enhance workforce opportunities and contribute to the competitiveness of Massachusetts businesses, into the future.

Appendix A Sub-Sector Characteristics

## Moderate to High Skill Sub-Sectors

The four moderate to high-skill industry sub-sectors present quite different employment profiles in regional clusters (See Figure 1 below) across the Commonwealth. While each requires specialized knowledge, skills and abilities from their respective workforce, they do share some common competency requirements. And while the advanced manufacturing workforce is generally made up of an older demographic, the numbers and percentages of workers approaching the traditional age of retirement vary by sub-sector. As a result, while the curriculum expectations of vocational education schools, community colleges and not-for-profit training providers for production workers will have some common elements, there will be significant and unique content emphasis and demand, regionally.

### *Computer and Electronic Products*

This is the largest advanced manufacturing sub-sector, based upon employment, at more than 66,000 in 2012. However, this sub-sector has also seen the greatest employment decline (nearly 51,000 workers) since 2001. Nearly 80% of the employment is in two regions, Boston MetroWest and the Northeast, followed by the Southeast and Central regions. Renski and Wallace (2014) report the following data:

- ☐ At 24% this sub-sector has the smallest percentage although the second largest overall number of production jobs.
- ☐ The skill requirements are the highest and most diverse of the six sub-sectors. A much higher percentage of the jobs are in computer & mathematical and architectural & engineering occupations (areas generally requiring higher levels of formal education).
- ☐ Some 21.5% of its workforce was estimated to be 55 years of age or older in 2012 (3,440 workers).

### *Fabricated Metal Products and Machinery*

This is the second largest sub-sector, based upon employment, at more than 50,000 in 2012. It has seen the second largest employment decline (nearly 23,000 workers) from 2001. The Northeast Region has the largest workforce with heavy concentrations of these jobs in the Pioneer Valley and Central Regions, followed by Southeast and Boston MetroWest. Renski and Wallace (2014) report the following data:

- ☐ Some 53% of the workforce is in production jobs
- ☐ Approximately 9% of this workforce is in engineering-related occupations.
- ☐ Jobs in this sector are heavily oriented to machining and tool operator occupations:
    - o About 9% of all occupations in this sub-sector are machinists, representing about 51% of all machinists in the state;

- Another 12-14% covers varying types of machine setters and tooling specialists.
- Some 26% of this workforce, the highest percentage of all the advanced manufacturing sub-sectors, was estimated to be 55 years of age or older in 2012 (6,866).

### *Chemical and Plastics (incl. Pharmaceuticals)*

Employment in the Chemicals and Plastics sub-sector in 2012 neared 28,000, a decline of 8,000 from 2001. Half of this workforce is located in the Boston MetroWest and Northeast Regions followed by Central and Pioneer Valley with a concentration on a per worker basis in the Berkshires. Renski and Wallace (2014) report the following data:

- Approximately 40% of this workforce is in production jobs.
- Higher shares of the jobs in this sub-sector are in science occupations (9.2%) and engineering occupations (7.3%) reflecting a strong focus on innovation.
- At 17.4% this sub-sector has the lowest percentage although second lowest number of workers (1,928) estimated to be 55 years of age or older in 2012.

### *Medical Equipment and Supplies*

This is the smallest advanced manufacturing sub-sector, based upon employment, with 11,825 workers in 2012, declining by 3,000 from 2001. Nearly 85% of the employment in this sub-sector is located in the Southeast, Boston MetroWest and Northeast regions with a heavy concentration on a per worker basis in the Southeast.

- Approximately half of the workforce is in production jobs and an additional 10% in architecture and engineering occupations.
- According to Renski and Wallace (2014) "This sub-sector shares some core occupations with the fabricated metals and machinery sub-sector (e.g. machine tool setters, machinists and computer controlled machine tool operators)".
- More than 24% of this workforce was estimated to be 55 years of age or older in 2012 (1,478).

## Average Lower-Skill Sectors

While these sub-sectors are not the primary focus of the remainder of this plan, the following data is provided for overall context.

### *Food Processing and Production*

With employment of more than 24,000 in 2012 this is the fourth largest advanced manufacturing sub-sector and unlike other sub-sectors has seen employment growth of approximately 1000 jobs from 2001. Employment is greatest in the Northeast, Boston MetroWest and the Southeast. Renski and Wallace (2014) report the following data:

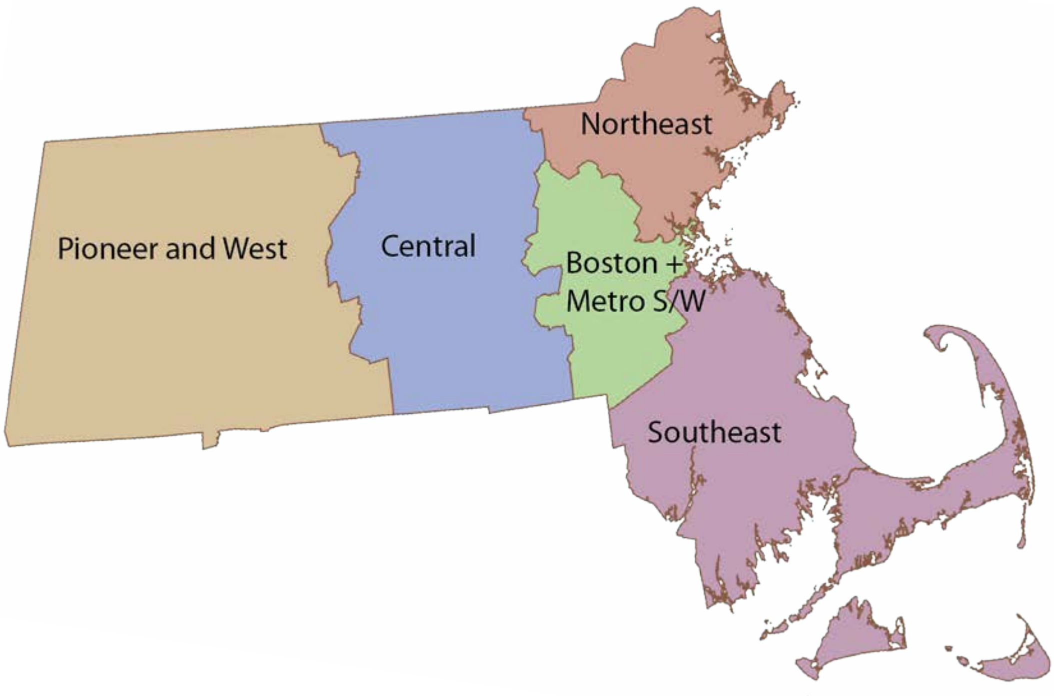
- ☐ Some 43% of the workforce is in production jobs.
- ☐ Many of the core occupations involve industrial food preparing and processing. ”On the whole, Food Processing and Production has few high-level skill requirements and is more characteristic of more traditional forms of low-skilled, routine forms of production”.
- ☐ An estimated 18.6% of this workforce, the second lowest of the sub-sectors, was estimated to be 55 years of age or older in 2012 (1,921 workers).

### *Paper and Printing*

The second smallest of the advanced manufacturing sub-sectors with employment of approximately 20,000 in 2012, Paper and Printing, has experienced substantial job losses of nearly 17,000 since 2001. Employment is somewhat equally distributed across all regions although the Berkshires have an unusually high concentration of its overall employment base in this sector, as do the Pioneer Valley and Central regions. Renski and Wallace (2014) report the following data:

- ☐ Roughly half of the employment is in production jobs.
- ☐ On average, the skill levels required for employment in this sector are relatively low with a few exceptions.
- ☐ An estimated 21.8% of this workforce was estimated to be 55 years of age or older in 2012 (2,236).

### Figure 1 Regions




Regions defined by Workforce Investment Areas

| **Pioneer and West** | **Central** | **Boston + Metro S/W** | **Northeast** | **Southeast** |
|---|---|---|---|---|
| Berkshire | North Central | Metro South/West | Greater Lowell | Brockton |
| Franklin Hampshire | Central | Boston | Metro North | South Coastal |
| Hampden | | | Merrimack Valley | Bristol |
| | | | North Shore | Greater New Bedford<br>Cape and Islands |

## Appendix B Occupational Demand Estimation Method

The demand estimates presented in this report are based on the key manufacturing occupations (listed below). The list includes the crossover and core occupations identified by Renski and Wallace. In addition, we looked at the current job postings by Massachusetts' manufacturers and added in other occupations that are showing a high concentration in manufacturing. The occupations identified by Renski and Wallace are identified in the right-hand column by category. Occupations identified through Wanted Analytics are noted as such. Occupations listed in purple are subcategories appearing in Wanted Analytics that are elsewhere part of the larger category listed above in black.

**Key Advanced Manufacturing Occupations**

| SOC | Occupation | 2014 Median Pay | Annual Openings | Jobs Posted in 120 days | Source |
|---|---|---|---|---|---|
| **Engineers and Scientists** | | | | | |
| *Bio and Biomedical* | | | 368 | 752 | |
| 191042 | Medical Scientists, Except Epidemiologists | 87,000 | 165 | 726 | *Wanted Analytics* |
| 191021 | Biochemists and Biophysicists | 94,790 | 94 | 8 | *Chemical and Plastics Core* |
| 191022 | Microbiologists | 58,990 | 45 | 5 | *Chemical and Plastics Core* |
| 172031 | Biomedical Engineers | 87,410 | 64 | 13 | *Medical Core* |
| *Computer Science & IT* | | | 1,721 | 1,157 | |
| 151132 | Software Developers, Applications | 104,460 | 607 | 362 | *Computer and Electronic Core* |
| 151133 | Software Developers, Systems Software | 114,690 | 722 | 198 | *Computer and Electronic Core* |
| 151199 | Computer Occupations, All Other | 92,400 | 67 | | *Wanted Analytics* |
| 151199 | Software Quality Assurance Engineers and Testers | | | 136 | *Wanted Analytics* |
| 151199 | Computer Systems Engineers/Architects | | | 171 | *Wanted Analytics* |
| 151199 | Information Technology Project Managers | | | 197 | *Wanted Analytics* |
| 113021 | Computer and Information Systems Managers | 133,510 | 325 | 93 | *Wanted Analytics* |
| *All Other Scientists and Engineers* | | | 1,373 | 1822 | |
| 119041 | Architectural and Engineering Managers | 135,940 | 134 | 60 | *Crossover* |
| 119121 | Natural Sciences Managers | 163,810 | 69 | 53 | *Wanted Analytics* |
| 119121 | Clinical Research Coordinators | | | 94 | *Wanted Analytics* |
| 152041 | Statisticians | 81,870 | 64 | | *Wanted Analytics* |
| 152041 | Biostatisticians | | | 1 | *Wanted Analytics* |
| 152041 | Clinical Data Managers | | | 9 | *Wanted Analytics* |
| 152041 | Statisticians | | | 23 | *Wanted Analytics* |
| 172011 | Aerospace Engineers | 107,170 | 12 | 16 | *Wanted Analytics* |

| | | | | | |
|---|---|---|---|---|---|
| 172041 | Chemical Engineers | 100,860 | 27 | 35 | *Wanted Analytics* |
| 172061 | Computer Hardware Engineers | 114,070 | 80 | 32 | *Computer and Electronic Core* |
| 172071 | Electrical Engineers | 100,270 | 134 | 217 | *Computer and Electronic Core* |
| 172072 | Electronics Engineers, Except Computer | 107,150 | 122 | 107 | *Computer and Electronic Core* |
| 172081 | Environmental Engineers | 80,290 | 56 | 8 | *Wanted Analytics* |
| 172111 | Health and Safety Engineers, Except Mining Safety Engineers and Inspectors | 92,800 | 4 | 32 | *Wanted Analytics* |
| 172112 | Industrial Engineers | 90,160 | 174 | 824 | *Crossover* |
| 172141 | Mechanical Engineers | 88,640 | 288 | 152 | *Crossover* |
| 192031 | Chemists | 74,460 | 110 | 59 | *Chemical and Plastics Core* |
| 192041 | Environmental Scientists and Specialists, Including Health | 63,630 | 31 | 28 | *Wanted Analytics* |
| 419031 | Sales Engineers | 99,790 | 68 | 72 | *Wanted Analytics* |
| **Technicians** | | | **521** | **223** | |
| 173013 | Mechanical Drafters | 59,260 | 6 | 9 | *Stakeholders* |
| 173023 | Electrical and Electronics Engineering Technicians | 59,140 | 111 | 71 | *Crossover* |
| 173026 | Industrial Engineering Technicians | 57,820 | 48 | 51 | *Crossover* |
| 194021 | Biological Technicians | 44,620 | 227 | 21 | *Chemical and Plastics Core* |
| 194031 | Chemical Technicians | 49,880 | 60 | 4 | *Chemical and Plastics Core* |
| 194091 | Environmental Science and Protection Technicians, Including Health | 45,860 | 39 | 27 | *Wanted Analytics* |
| 194099 | Life, Physical, and Social Science Technicians, All Other | 50,440 | 30 | 40 | *Wanted Analytics* |
| **Operators, Fabricators** | | | **1,921** | **631** | |
| 113051 | Industrial Production Managers | 102,600 | 61 | 72 | *Crossover* |
| 113051 | Quality Control Systems Managers | | | 16 | *Crossover* |
| 499041 | Industrial Machinery Mechanics | 53,500 | 161 | 12 | *Crossover* |
| 511011 | First-Line Supervisors of Production and Operating Workers | 61,450 | 165 | 222 | *Crossover* |
| 512022 | Electrical and Electronic Equipment Assemblers | 36,620 | 86 | 18 | *Computer and Electronic Core* |
| 512023 | Electromechanical Equipment Assemblers | 37,190 | 35 | 15 | *Crossover* |
| 512041 | Structural Metal Fabricators and Fitters | 39,480 | 37 | 2 | *Fabricated Metals* |
| 512092 | Team Assemblers | 28,380 | 338 | 7 | *Crossover* |
| 514011 | Computer-Controlled Machine Tool Operators, Metal and Plastic | 43,190 | 52 | 29 | *Crossover* |
| 514021 | Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic | 38,500 | 35 | 4 | *Crossover* |
| 514031 | Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic | 35,140 | 13 | 9 | *Crossover* |
| 514033 | Grinding, Lapping, Polishing, and Buffing | 41,790 | 26 | 5 | *Fabricated Metals* |

| | | | | | |
|---|---|---|---|---|---|
| | Machine Tool Setters, Operators, and Tenders, Metal and Plastic | | | | |
| 514034 | Lathe and Turning Machine Tool Setters, Operators, and Tenders, Metal and Plastic | 47,970 | 9 | 2 | *Fabricated Metals* |
| 514041 | Machinists | 47,170 | 170 | 57 | *Crossover* |
| 514072 | Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic | 34,850 | 27 | 2 | *Crossover* |
| 514081 | Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic | 35,600 | 20 | 1 | *Crossover* |
| 514111 | Tool and Die Makers | 52,250 | 4 | 3 | *Crossover* |
| 514121 | Welders, Cutters, Solderers, and Brazers | 44,120 | 57 | 12 | *Fabricated Metals* |
| 514122 | Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders | 38,410 | - | 1 | *Medical Core* |
| 514193 | Plating and Coating Machine Setters, Operators, and Tenders, Metal and Plastic | 34,120 | 10 | | *Fabricated Metals* |
| 519011 | Chemical Equipment Operators and Tenders | 42,330 | 4 | | *Chemical and Plastics Core* |
| 519023 | Mixing and Blending Machine Setters, Operators, and Tenders | 37,660 | 26 | 5 | *Chemical and Plastics Core* |
| 519061 | Inspectors, Testers, Sorters, Samplers, and Weighers | 43,020 | 156 | 57 | *Crossover* |
| 519111 | Packaging and Filling Machine Operators and Tenders | 27,290 | 211 | 16 | *Crossover* |
| 519121 | Coating, Painting, and Spraying Machine Setters, Operators, and Tenders | 36,970 | 12 | | *Crossover* |
| 519141 | Semiconductor Processors | 35,610 | 8 | | *Computer and Electronic Core* |
| 519198 | Helpers--Production Workers | 23,950 | 143 | 41 | *Crossover* |
| 519199 | Production Workers, All Other | 31,390 | 55 | 23 | *Medical Core* |
| **Total Mfg (**ex Bio,CS/IT**)** | | | **3,815** | **2,676** | |

Wage data and projected annual openings from Massachusetts EOLWD LMI, Jobs Posted online from Wanted Analytics, New Unique Ads 120 days ending May 11, 2015.

### *LMI Regional Demand Projections*

Based on projections of the Massachusetts EOLWD (Table 4), 3,815 technical and production workers will be needed annually in key manufacturing occupations, excluding biological and computer scientists[16]. Biological, bio manufacturing, and chemical technicians are included in our counts of "technician" jobs and graduates (see Appendix B for occupation level detail).

**Table 4 Annual Job Openings by Region in Manufacturing Production and Technical Occupations**

| | Pioneer and West | Central | Boston + Metro S/W | Northeast | Southeast | Statewide |
|---|---|---|---|---|---|---|
| Engineers and Scientists | | | | | | |
| Biological | 0 | 22 | 143 | 193 | 10 | 368 |
| Computer Science & IT | 38 | 104 | 994 | 539 | 46 | 1,721 |
| All Other | 41 | 80 | 557 | 600 | 95 | 1373 |
| Technicians | 17 | 46 | 273 | 174 | 11 | 521 |
| Operators, Fabricators | 284 | 342 | 232 | 600 | 463 | 1921 |
| Total Mfg (ex Bio,CS/IT) | 342 | 468 | 1062 | 1374 | 569 | 3,815 |

Source: Massachusetts EOLWD, LMI. Short Term Occupational Projections by WIA 2013-2015. Regions may not sum to State wide total due to suppression.

### *Online Job Posting Regional Reporting*

Referencing online job postings in the last 120 days, Massachusetts manufacturers have posted 2,676 jobs (Table 5) in those same fields. It is important to consider that online job postings don't necessarily reflect actual job openings but are an indicator of the relative intensity of demand for those occupations.

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[16] It is important to acknowledge the demand for biological and computer science in the advanced manufacturing sub-sectors; however, as the majority of these graduates do not work in manufacturing and they follow a substantially different educational pathway, we have highlighted this data but not included it in our calculation of the advanced manufacturing workforce.

**Table 5 Job Postings in Advanced Manufacturing Production and Technical Occupations by Region 120 Days ending May 11, 2015**

| | Pioneer and West | Central | Boston + Metro S/W | Northeast | Southeast | Not assignable by region | Statewide |
|---|---|---|---|---|---|---|---|
| Engineers and Scientists | | | | | | | |
| Biological | | 8 | 210 | 404 | 27 | 103 | 752 |
| Computer Science & IT | 70 | 20 | 644 | 317 | 48 | 49 | 1148 |
| All Other | 92 | 107 | 476 | 757 | 194 | 197 | 1823 |
| Technicians | 4 | 15 | 36 | 85 | 25 | 57 | 222 |
| Operators, Fabricators | 79 | 78 | 81 | 212 | 127 | 54 | 631 |
| Total Mfg (ex Bio,CS/IT) | 175 | 200 | 593 | 1054 | 346 | 308 | 2676 |

Source: Wanted Analytics. New Unique Ads 120 days ending May 11. 2015. Limited to Advanced Manufacturing Employers.

**Table 6 Job Postings in Advanced Manufacturing Production and Technical Occupations by Sub-Sector**

| | Chem & Plastics | Computer & Electronic | Fabricated Metals | Medical Equip. | Sum of 4 Adv Mfg Sectors |
|---|---|---|---|---|---|
| Engineers and Scientists | | | | | |
| Biological | 657 | 29 | 5 | 61 | 752 |
| Computer Science & IT | 123 | 948 | 61 | 16 | 1148 |
| All Other | 614 | 916 | 143 | 150 | 1823 |
| Technicians | 100 | 81 | 28 | 13 | 222 |
| Operators, Fabricators | 197 | 147 | 191 | 96 | 631 |
| Total Mfg (ex Bio,CS/IT) | 911 | 1144 | 362 | 259 | 2676 |

Source: Wanted Analytics. New Unique Ads 120 days ending May 11. 2015. Massachusetts.

Appendix D Manufacturing Programs at Massachusetts High Schools

2012 Completions, Comprehensive and Career, Vocational, Technical (CVTE) High Schools

| | Joining Technologies | Engineering Technology | Drafting | Electronics | Technology | Automation | Biotechnology | Stationary Engineering | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Total All Regions | 331 | 438 | 413 | 138 | 283 | 40 | 30 | 10 | 1683 |
| Pioneer and West | | | | | | | | | |
| North Adams | | 56 | | | | | | | 56 |
| Northern Berkshire Regional Vocational Technical | 12 | | 10 | | 11 | | | | 33 |
| Chicopee | 7 | 7 | 7 | | 7 | | | | 28 |
| Pathfinder Regional Vocational Technical | | | 3 | 9 | 13 | | | | 25 |
| Springfield | 6 | | | | 11 | 2 | | | 19 |
| Franklin County Regional Vocational Technical | 10 | | | | 8 | | | | 18 |
| Pittsfield | 10 | | | | 4 | | | | 14 |
| Gateway | 8 | | | | | | | | 8 |
| Northampton-Smith Vocational Agricultural | | | | | 8 | | | | 8 |
| Westfield | | | | | 8 | | | | 8 |
| Holyoke | 1 | | | | 6 | | | | 7 |
| Easthampton | 5 | | | | | | | | 5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Amherst-Pelham | | 3 | | | | | | | 3 |
| South Hadley | | 3 | | | | | | | 3 |
| Central | | | | | | | | | |
| Worcester | 15 | 64 | 17 | | 8 | 11 | | | 115 |
| Blackstone Valley Regional Vocational Technical | | | 19 | 6 | 22 | | | | 47 |
| Montachusett Regional Vocational Technical | 12 | 8 | 10 | | 12 | | | | 42 |
| Leominster | | 18 | 6 | 10 | 7 | | | | 41 |
| Southern Worcester County Regional Vocational Tech | 10 | | 8 | 8 | 5 | | | | 31 |
| Fitchburg | | 26 | | | | | | | 26 |
| Tantasqua | | | 7 | | 15 | | | | 22 |
| Metro Boston | | | | | | | | | |
| Assabet Valley Regional Vocational Technical | 12 | | 18 | | 12 | | 6 | | 48 |
| Blue Hills Regional Vocational Technical | 6 | 12 | 12 | 9 | | | | | 39 |
| Newton | | 23 | 8 | | | 6 | | | 37 |
| Brookline | | 33 | | | | | | | 33 |
| Minuteman Regional Vocational Technical | 6 | 7 | 7 | | | 6 | 6 | | 32 |
| Framingham | | 14 | 12 | | | | | | 26 |
| Waltham | 4 | | 2 | 3 | | | | | 9 |
| Tri County Regional Vocational Technical | | 7 | | | | | | | 7 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| South Middlesex Regional Vocational Technical | 3 | | | | | | | | 3 |
| Northeast | | | | | | | | | |
| Greater Lowell Regional Vocational Technical | 19 | | 17 | 11 | 17 | | | | 64 |
| Somerville | 9 | | 38 | | 6 | | | | 53 |
| Shawsheen Valley Regional Vocational Technical | 13 | | 16 | 13 | 9 | | | | 51 |
| Whittier Regional Vocational Technical | 10 | | 24 | 5 | 7 | | | | 46 |
| Northeast Metropolitan Regional Vocational Tech | 14 | | 24 | | | | | | 38 |
| Greater Lawrence Regional Vocational Technical | | | | 10 | | | 17 | | 27 |
| Lowell | | 10 | 11 | | | | | | 21 |
| Lynn | 15 | | | 4 | | | | | 19 |
| Watertown | | 8 | 4 | | | | | | 12 |
| Nashoba Valley Regional Vocational Technical | | 3 | | 5 | 2 | | | | 10 |
| Cambridge | | 8 | | | | | 1 | | 9 |
| North Shore Regional Vocational Technical | | | | | 8 | | | | 8 |
| Peabody | | | | 8 | | | | | 8 |
| Salem | | 3 | 2 | | | | | | 5 |
| Gloucester | | | | | 3 | | | | 3 |
| Southeast | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Greater New Bedford Regional Vocational Technical | 21 | 16 | 17 | | 8 | | | 10 | 72 |
| Greater Fall River Regional Vocational Technical | 18 | | 18 | 18 | 15 | | | | 69 |
| Taunton | | | 46 | | | | | | 46 |
| Southeastern Regional Vocational Technical | 5 | 25 | | | 10 | | | | 40 |
| Plymouth | 13 | | 13 | 6 | | | | | 32 |
| Brockton | | 24 | | | | 7 | | | 31 |
| South Shore Regional Vocational Technical | 11 | | 4 | 9 | 7 | | | | 31 |
| Old Colony Regional Vocational Technical | 11 | | 6 | 3 | 9 | | | | 29 |
| Bristol-Plymouth Regional Vocational Technical | 13 | | | | 11 | | | | 24 |
| Fall River | | 22 | | 1 | | | | | 23 |
| Dighton-Rehoboth | | | 7 | | 14 | | | | 21 |
| Quincy | 5 | 14 | | | | | | | 19 |
| Stoughton | | 17 | | | | | | | 17 |
| New Bedford | | 1 | 6 | | | 8 | | | 15 |
| Weymouth | | | 14 | | | | | | 14 |
| Attleboro | 12 | | | | | | | | 12 |
| Silver Lake | 9 | | | | | | | | 9 |
| | | | | | | | | | |
| Cape Cod Regional Vocational Technical | 6 | | | | | | | | 6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Upper Cape Cod Regional Vocational Technical | | 6 | | | | | | | 6 |

Source: Massachusetts Dept. of Elementary and Secondary Education, Perkins Graduate Follow-Up Data. Class of 2012. www.doe.mass.edu/cte/data

## Appendix E Manufacturing Certificates and Associates Degrees by Institutions

| Pioneer and West | Completions | |
|---|---|---|
| Berkshire CC | 14 | Engineering, General |
| | 7 | Electrical, Electronic, Communications Engineering Technology |
| Greenfield CC | 9 | Engineering Science |
| Holyoke CC | 14 | Engineering, General |
| | 6 | Environmental Control Technologies, Other |
| Springfield Technical CC | 25 | Engineering, General |
| | 2 | Engineering, Other |
| | 4 | Electrical, Electronic, Communications Engineering Technology |
| | 6 | Laser and Optical Technology |
| | 15 | Electromechanical/Electromechanical Engineering Technology |
| | 3 | Robotics Technology |
| | 15 | Mechanical Engineering/Mechanical Technology |
| | 18 | Computer Engineering Technology |
| | 1 | Mechanical Drafting CAD/CADD |
| | 14 | Computer Numerically Controlled (CNC) Machinist |
| **Southeast** | | |
| Bristol CC | 14 | Engineering, General |
| | 3 | Hazardous Materials Management and Waste Tech |
| | 1 | Industrial Technology |
| | 21 | Drafting and Design Technology, General |

| | | | |
|---|---|---|---|
| | 27 | Engineering-Related Fields, Other | |
| Cape Cod CC | 2 | Environmental Control Technologies, Other | |
| | 3 | Computer Technology/Computer Systems Technology | |
| Massasoit CC | 11 | Electrical, Electronic, Communications Engineering Technology | |
| Central | | | |
| Fitchburg State University | 1 | Plastics and Polymer Engineering Technology | |
| Mount Wachusett CC | 8 | Energy Management and Systems Technology | |
| | 2 | Plastics and Polymer Engineering Technology | |
| Quinsigamond CC | 5 | Engineering -Biomedical Engineering Opt (AS) | <Bio |
| | 28 | Engineering (AS) | |
| | 5 | Electronics Engineering Technology - Biomedical Instrumentation Option (AS) | <Bio |
| | 11 | Electronics Eng. Technology – Mechatronics (AS) | |
| | 5 | Electronics Technology Certificate | |
| | 3 | Manufacturing Technology (AS and Cert) | |
| | 18 | Computer Systems Engineering Technology (AS) | |
| | 4 | Computer Aided Design Certificate | |
| | 5 | Biotech Certificate | <Bio |
| Metro Boston | | | |
| Bunker Hill CC | 6 | Engineering, General | |
| | 1 | Bioengineering and Biomedical Engineering | <Bio |
| | 17 | Electrical/Electronics Maintenance Technology, | |

| | | | |
|---|---|---|---|
| | | Other | |
| ITT Technical Institute | 29 | Electrical, Electronic, Communications Engineering Technology | |
| | 30 | CAD/CADD Drafting and/or Design Technology | |
| Massachusetts Bay CC | 3 | Environmental Engineering Technology | |
| | 6 | Mechanical Engineering/Mechanical Technology | |
| | 4 | Drafting and Design Technology, General | |
| | 7 | Engineering Design | |
| | 4 | Engineering-Related Fields, Other | |
| | 2 | Biotechnology Laboratory Technician | <Bio |
| Middlesex CC | 8 | Electrical, Electronic, Communications Engineering Technology | |
| | 9 | Electrical and Electronic Engineering Technologies, Other | |
| | 17 | Energy Management and Systems Technology | |
| | 14 | Electrical/Electronics Drafting, CAD/CADD | |
| | 22 | Engineering-Related Fields, Other | |
| | 60 | Biotechnology Laboratory Technician | <Bio |
| Northeastern University | 1 | Electrical, Electronic, Communications Engineering Technology | |
| | 1 | Mechanical Engineering/Mechanical Technology | |
| Quincy College | 6 | Biotechnology Laboratory Technician | <Bio |
| Roxbury CC | 5 | Engineering, General | |
| Wentworth Inst of Tech | 16 | Engineering-Related Fields, Other | |
| Northeast | | | |

| | | | |
|---|---|---|---|
| Merrimack College | 2 | Electrical and Electronics Engineering | |
| North Shore CC | 11 | Engineering, General | |
| | 22 | Manufacturing Engineering Technology | |
| | 6 | Mechanical Drafting CAD/CADD | |
| | 7 | Biotechnology Laboratory Technician | <Bio |
| Northern Essex CC | 4 | Electrical, Electronic, Communications Engineering Technology | |
| | 5 | Electrical and Electronic Engineering Technologies, Other | |
| | 24 | Electromechanical, Instrumentation, Maintenance Tech | |
| | 4 | Computer Engineering Technology | |
| | 6 | Computer Systems Technology | |
| | 17 | Drafting/Design Engineering Technologies, Other | |
| | 18 | Engineering-Related Fields, Other | |
| | 6 | Physical Science Technologies, Other | |
| U Mass Lowell | 1 | Engineering, General | |
| | 4 | Electrical, Electronic, Communications Engineering Technology | |
| | 1 | Manufacturing Engineering Technology | |
| | 1 | Industrial Production Technologies, Other | |
| | 7 | Mechanical Engineering Related Technologies, Other | |

Source: IPEDS, 2013 Completions. QCC program titles from Kathy Rensch.

Appendix F Manufacturing Related Non-Credit Course Enrollment by Community College and Course Title

| | 2012 | 2013 | 2014 | Three-Year Total |
|---|---|---|---|---|
| Berkshire Community College | | | 51 | 51 |
| Advanced Manufacturing McCann | | | 21 | 21 |
| Lvl 1 Entry Manufacturing | | | 30 | 30 |
| Bristol Community College | 190 | 22 | 194 | 406 |
| Indust.Maint & Electrical | 1 | | | 1 |
| Industrial Instrument/Electric | 4 | | | 4 |
| Industrial Tech./Power Plant | 7 | | | 7 |
| Industrial Technology | 2 | | | 2 |
| Lean - Green Belt Training | | | 9 | 9 |
| Lean 101 | | | 4 | 4 |
| Lean 101 NBIC | | | 70 | 70 |
| Lean Champ Cohort 1 NBIC | | | 10 | 10 |
| Lean Champ Training Titleist | | | 11 | 11 |
| Lean Manufacturing - 3 | 14 | | | 14 |
| Lean Manufacturing - 6 | 14 | | | 14 |
| Lean Manufacturing 01 | 14 | | | 14 |
| Lean Manufacturing -5 | 14 | | | 14 |
| Lean Manufacturing Trng - 2 | 14 | | | 14 |
| Lean Mfg Training Needletech | 14 | | | 14 |
| Lean Mfg Trng - NeedleTech | 14 | | | 14 |

| | | | | |
|---|---|---|---|---|
| Lean Mfg Trng: 07 NeedleTech | 15 | | | 15 |
| Lean Process Improvement | | | 6 | 6 |
| Lean Process Improvement Diman | | | 10 | 10 |
| Lean Six Sigma Champ. Training | | | 8 | 8 |
| Lean Six Sigma Green Belt | | | 5 | 5 |
| Lean Six Sigma Green Belt Con1 | | | 21 | 21 |
| Lean Trans Champ Lvl Precix | | | 14 | 14 |
| Lean Transformation | | | 12 | 12 |
| Lean Transformation - 5Star | | | 9 | 9 |
| Quality Improvement | 63 | 22 | | 85 |
| Quality of Teaching | | | 5 | 5 |
| Greenfield Community College | 9 | 13 | 50 | 72 |
| Adv Manufacturing MSMI | | | 29 | 29 |
| AutoCAD | 1 | | | 1 |
| FMI Found Manufacturing Int | | | 14 | 14 |
| Intro Comp Draft/Design | 8 | 9 | | 17 |
| Intro to AutoCAD | | | 7 | 7 |
| Machine Science II | | 4 | | 4 |
| Holyoke Community College | 5 | | | 5 |
| Lean Productivity | 5 | | | 5 |
| Mass Bay Community College | 28 | | | 28 |
| ENGINEERING MECHANICS: DYNAMIC | 14 | | | 14 |
| STRENGTH OF MATERIALS I | 14 | | | 14 |

| | | | | |
|---|---|---|---|---|
| Massasoit Community College | 7 | | 45 | 52 |
| Indust Measure | 7 | | | 7 |
| Lean Green Belt | | | 45 | 45 |
| Middlesex Community College | 1 | 21 | 108 | 130 |
| Advanced Mechanical Assembly | | | 8 | 8 |
| Advanced Mfg orientation | | | 2 | 2 |
| Advanced Robotics | | | 16 | 16 |
| Johnson Compounding - Job Fair | | | 3 | 3 |
| LMAC Robotics A | | | 26 | 26 |
| LMAC Robotics B | | | 15 | 15 |
| Machine Shop Training | | 21 | | 21 |
| Statistical Process Control | | | 38 | 38 |
| Welding I | 1 | | | 1 |
| Mt. Wachusett Community College | 122 | 382 | 613 | 1117 |
| AMIRT Basic Machines | | | 16 | 16 |
| AMIRT Blue Reading | | | 15 | 15 |
| AMIRT Career Ready | | | 16 | 16 |
| AMIRT Computers | | | 16 | 16 |
| AMIRT Cover letter and Resume | | | 9 | 9 |
| AMIRT Electronics | | | 10 | 10 |
| AMIRT Integrated Project | | | 5 | 5 |
| AMIRT Lean Manufacturing | | | 15 | 15 |
| AMIRT Measurement Tools | | | 11 | 11 |

| | | | | |
|---|---|---|---|---|
| AMIRT Orientation | | | 16 | 16 |
| AMIRT OSHA | | | 15 | 15 |
| AMIRT Quality | | | 16 | 16 |
| AMIRT Stem Power | | | 16 | 16 |
| Blueprint Reading | | | 12 | 12 |
| BluePrint Reading Intermediate | | | 17 | 17 |
| BluePrint Reading Intro | | | 4 | 4 |
| Electrical Pre Assessment | | 46 | | 46 |
| Electrical Training | | 94 | | 94 |
| Electromechanical Certificate | 3 | 2 | | 5 |
| Intermediate BluePrint Reading | | | 9 | 9 |
| Intro BluePrint Reading | | | 9 | 9 |
| ISO 13485:2003 | | | 12 | 12 |
| ISO 9001:2008 | | | 12 | 12 |
| ISO Good Manufacturing Practic | | | 23 | 23 |
| Isometric Drawing | | 23 | | 23 |
| jobs high tech manufacturing | | | 5 | 5 |
| Lean and Six Sigma Bridge | | 20 | | 20 |
| Lean DTS Turbine Base | | | 10 | 10 |
| Lean DTS Turbine Project | | | 8 | 8 |
| Lean Overview | | 20 | 69 | 89 |
| Lean Overview for Champions | 13 | | | 13 |
| Lean Overview group 1 | | 17 | | 17 |

| | | | | |
|---|---|---|---|---|
| Lean Overview group 2 | | 17 | | 17 |
| Lean Overview group 3 | | 19 | | 19 |
| Lean Process Improvement | | | 26 | 26 |
| Lean Project Management and Team | | | 14 | 14 |
| Lean Project Mgmt Team Impleme | 15 | | | 15 |
| Lean Six Sigma | 14 | | | 14 |
| Lean Supply Chain | | | 26 | 26 |
| Lean Thinking | | 17 | | 17 |
| Lean Thinking with Six Sigma | | | 11 | 11 |
| Lean Transformation Executive | | | 11 | 11 |
| Manufacturing Career prep prog | | | 45 | 45 |
| Math and Engineering | 77 | 75 | | 152 |
| Math and Engineering- MEP | | 10 | 20 | 30 |
| Med Device Manufacturing readi | | | 17 | 17 |
| Med Device Mnfg Info Session | | | 14 | 14 |
| Med Device Mnfg Orientation | | | 27 | 27 |
| Med Device Mnfg Pre Assessment | | | 10 | 10 |
| Med Divice Mnfg Info Sesssion | | | 2 | 2 |
| MEP | | | 7 | 7 |
| Robotics | | | 17 | 17 |
| Statistical Process Control | | 16 | | 16 |
| Welding | | 6 | | 6 |
| North Shore Community College | 81 | 32 | 27 | 140 |

| | | | | |
|---|---|---|---|---|
| AUTOCAD 2010-INTERMDIATE | 10 | | | 10 |
| AUTOCAD 2012: AN INTRODUCTION | 19 | | | 19 |
| AUTOCAD 2012: INT - PART 2 | 4 | | | 4 |
| AUTOCAD 2012: LEVEL 1 | 5 | 15 | | 20 |
| AUTOCAD 2012-INTERMDIATE | 5 | | | 5 |
| DRAFTING BEST PRACTICES | 22 | 7 | | 29 |
| SOLID WORKS:AN INTRODUCTION | 7 | | | 7 |
| SOLID WORKS: DRAWINGS | | | 5 | 5 |
| SOLID WORKS: LEVEL 1 | | 10 | 22 | 32 |
| Solidworks | 9 | | | 9 |
| Northern Essex Community College | 21 | 37 | 22 | 80 |
| AutoCAD | 10 | 9 | 4 | 23 |
| ELECTRICAL SYSTEMS | 6 | 13 | 5 | 24 |
| Mach. Tool/Mach. Operator CNC | | 15 | 13 | 28 |
| Quality | 5 | | | 5 |
| Quinsigamond Community College | 8 | 2 | 16 | 26 |
| AutoCAD | | 1 | | 1 |
| Autocad Introductory 2D | | 1 | | 1 |
| AutoCAD I Introductory 2D | | | 2 | 2 |
| Blueprint Reading | 8 | | | 8 |
| Introduction to Robotics | | | 14 | 14 |
| Roxbury Community College | | | 11 | 11 |
| BIOTECHNOLOGY TECHNIQUES | | | 11 | 11 |

| | | | | |
|---|---|---|---|---|
| Springfield Technical Community College | 7 | 24 | 51 | 82 |
| Autocad 2011-AUTOCAD 3D | 1 | | | 1 |
| Basic Manufacturing Program | | | 15 | 15 |
| Basic Manufacturing Program | | 14 | | 14 |
| Intro. Lean Manufacturing | 6 | | 7 | 13 |
| Intro. Lean Productivity | | 6 | 6 | 12 |
| Manufacturing Fundamentals | | | 1 | 1 |
| Manufacturing Production Tech. | | | 18 | 18 |
| Stat Proc Cont | | | 4 | 4 |
| Stat Process Cont | | 4 | | 4 |
| Grand Total | 479 | 533 | 1188 | 2200 |

Source: Massachusetts Department of Higher Education. HEIRS Non-Credit Course Enrollments with course titles related to Manufacturing.

Appendix G Top Technical Skills from Current Online Job Postings

| | Technician and Engineering Jobs | | Production Jobs |
|---|---|---|---|
| **Crosscutting to All Industries** | | | |
| 1 | Quality Assurance | | Quality Assurance, Quality Control |
| 2 | Computer Aided Design | | Computer Aided Design |
| 3 | Technical support | | Good Manufacturing Practice |
| 4 | Process controls | | CNC programming |
| 5 | Instrumentation | | ISO 9001 |
| 6 | Product design | | Lean Manufacturing |
| 7 | Lean Manufacturing | | Shop Math |
| 8 | ISO 9001 | | Precision machining |
| 9 | Quality engineering | | Preventative maintenance inspections |
| 10 | Design verification | | Process controls |
| **Chemicals and Plastics** | | | |
| 1 | Good Manufacturing Practice | | Extrusion process |
| 2 | Technical writing | | Animal health |
| 3 | Technology Transfer | | Autoimmune diseases |
| 4 | Corrective And Preventative Actions | | Preventive maintenance |
| 5 | Process validation | | Technical writing |
| 6 | Autoimmune diseases | | Injection molding |
| 7 | Animal health | | Sterilization |
| 8 | Statistical process control | | Prima Systems OPTIX |
| 9 | Risk assessment | | Process validation |

| | | | |
|---|---|---|---|
| 10 | Failure modes and effects analysis | | Corrective And Preventative Actions |
| **Computer and Electronic Products** | | | |
| 1 | MATLAB | | Ultra performance liquid chromatography |
| 2 | Mechanical design | | Geometric Dimensioning & Tolerancing |
| 3 | Field Programmable Gate Array | | Enterprise Resource Planning Software |
| 4 | Power system modeling | | Statistical process control |
| 5 | Systems Integration | | Instrumentation |
| 6 | Simulation and modeling | | Value stream mapping |
| 7 | Software design | | MIL-STD-883 |
| 8 | Photonics | | Multilingual |
| 9 | Embedded software | | Capability Maturity Model Integration |
| 10 | Real-time signal processing | | Blueprints |
| **Fabricated Metal Products and Machinery** | | | |
| 1 | Mechanical design | | Blueprints |
| 2 | Product engineering | | Geometric Dimensioning & Tolerancing |
| 3 | Water treatment | | Enterprise Resource Planning Software |
| 4 | Microsoft Office Visio | | Water treatment |
| 5 | Capital equipment | | Injection molding |
| 6 | Oasys | | Equipment Maintenance |
| 7 | Statistical process control | | Work order |

| | | | |
|---|---|---|---|
| 8 | Embedded systems development | | Computer-aided manufacturing |
| 9 | Python | | Machine maintenance |
| 10 | Finite Element Analysis | | Capability Maturity Model Integration |
| **Medical Equipment** | | | |
| 1 | Good Manufacturing Practice | | 20/20 software |
| 2 | Process validation | | Extrusion process |
| 3 | Technical writing | | Injection molding |
| 4 | MiniTab | | Instrumentation |
| 5 | Geometric Dimensioning & Tolerancing | | Trovix |
| 6 | Failure modes and effects analysis | | Blueprints |
| 7 | Corrective And Preventative Actions | | Equipment Maintenance |
| 8 | Design of experiments | | Microsoft Office Visio |
| 9 | Statistical software | | Preventive maintenance |
| 10 | Risk assessment | | Sterilization |

Source: Wanted Analytics. Top Technical Skills mentioned in entry and mid level job ads by Industry. Excludes R&D functions. April 29, 2015.

## Center for eDesign - University of Massachusetts Amherst

Site Director: Sundar Krishnamurty, PhD

http://edesign.ecs.umass.edu/

The Center for e-Design is a joint research coalition comprised of seven universities working closely with numerous businesses and government organizations. The coalition was established to create new design paradigms and electronic design tools that will assist in generating high quality products and systems at a reduced cost while also reducing the time associated with designing complex engineered products and systems.

Research at the Center for e-Design is oriented to application areas where large scale, complex projects are being developed, often involving multiple collaborators at various locations. Application areas include transportation, manufacturing, information technology, and health and safety. Research is categorized into five thrust areas – New Design Paradigms and Processes, Visualization and Virtual Prototyping, Enabling Information Infrastructure, Design Optimization, and Design Education. Research projects address a diverse range of engineering challenges faced by high-tech companies and agencies competing in a global economy.

The mission of the Center for e-Design is two-fold.

1. Enable the design and realization of high quality products and systems at reduced cost and reduced time to market through research and development of methods and tools for:

- ☐ Improved design process and methods
- ☐ Knowledge/information capture and reuse
- ☐ Integration environments that support collaboration and decision making

2. To nurture and cultivate a new breed of engineers, scientists, and business leaders through a synergistic university/industry collaborative model.

## Institute for Applied Life Sciences (IALS) - University of Massachusetts Amherst

Director: Peter H. Reinhart, Industrial Research Programs
James Capistran, Executive Director, UMass Innovation Institute

http://www.umass.edu/ials/

The Institute for Applied Life Sciences (IALS) transforms life science discoveries into products and services in collaboration with industry that improve human health and well being. Three unique research centers comprise the Institute:

**Bioactive Delivery** - develops and applies design principles necessary for creating innovative delivery vehicles with optimal performance characteristics for drugs and nutritional bioactives

**Models to Medicine** – identifies and validates new therapeutic paradigms, initially in the area of protein homeostasis

**Personalized Health Monitoring** – creates wearable sensor systems for personalized health and biometric monitoring

In addition, the Institute for Computational Biology, Biostatistics and Bioinformatics (ICB3) supports the development and application of novel computational and statistical tools and techniques for the analysis of "Big Data" in IALS research.

The IALS Centers and the ICB3 represent a new emphasis on advancing research and innovation from bench to bedside and beyond, including product development. IALS research builds upon the campus's national reputation in the fields of nanotechnology, polymers, chemistry, animal biotechnology, food science, kinesiology, computational sciences, and engineering. In addition to its research, IALS fosters a culture of innovation and entrepreneurship through interdisciplinary education and mentoring programs. The Centers also build a workforce pipeline through hands-on training, professional certificate programs, and skill-based workshops. Collectively, these research, education and training programs support economic development.

## Advanced Composites Materials & Textile Research Lab - University of Massachusetts Lowell

Director: James A. Sherwood, Associate Dean of Engineering for Graduate Students, Professor, Director, Co-Director

http://www.uml.edu/Research/ACMTRL/default.aspx/

The Advanced Composite Materials and Textile Research Laboratory (ACMTRL) has as its charter the task of developing a better understanding of the design, analysis, and manufacture of high performance composite materials and textile structures. The laboratory is interested in collaborative projects and in providing support and technology transfer to industry and government agencies.

The Advanced Composite Materials and Textile Research Laboratory is involved in active integration of analytical modeling, experimentation, and numerical simulation to understand the behavior of fiber-reinforced, polymer matrix composites. Currently the laboratory has the capacity for in-house design, analysis, fabrication, and testing of advanced composite structures. A full complement of testing machines, fixtures and data acquisition systems are available for composite materials and textile characterization as per ASTM standards and for special configurations. The laboratory has the ability to fabricate specimens using standard techniques such as hand lay -up, braiding, filament winding, vacuum diaphragm forming, and press forming. The laboratory has full instrumentation capabilities to collect real time data and a photo microscopy system is available for all associated experiments.

## Nanomanufacturing Center - University of Massachusetts Lowell

Co-Director, **Joey Mead** Nanomanufacturing Center of Excellence
Co-Director**, Carol Barry,** Coordinator of Education & Outreach

http://www.uml.edu/Research/Centers/Nano/CHN/default.aspx

This centers focus is on basic nanomanufacturing research, collaborative research with industry, and education of the future workforce that enables advanced manufacturing and commercialization of nanotechnology products.

The excitement and promise of nanotechnology provides a unique opportunity to increase public awareness of the critical importance of science and technology to society. Nanotechnology and nanomanufacturing will require a more diverse technical education of the current and projected workforce. Moreover, nanotechnology should motivate more youth to become interested and better prepared for careers in science, math, engineering and technology

Nanoproducts are likely to fuel the next economic boom. Existing products can be made more useful, cost-effective and durable through incorporation of nanoelements. Entirely new nanoproducts, as yet undreamed of, will revolutionize many aspects of our lives. As innovation moves toward biocompatible, flexible materials that are low-cost and environmentally benign, the strengths of UMass Lowell become evident -- UMass Lowell is a world leader in the technologies that make a difference

## Printed and Flexible Electronics - University of Massachusetts Lowell

Craig Armiento, Electrical & Computer Engineering, HEROES, PERC, RURI, CPEN
Professor, ECE Department; Director, PERC, Co-Director, RURI; Director, CPEN

http://www.uml.edu/Research/PERC/default.aspx

The mission of the Printed Electronics Research Collaborative (PERC) is to establish strategic partnerships between industry (large, medium, and small companies), universities and government that contribute to development of a printed electronics ecosystem. PERC research will develop technologies relevant to the entire supply chain - from enabling materials up through system applications. PERC will establish working research relationship between its members that pre-positions a team for pursuit of large federal funding opportunities.

Appendix I Approved Manufacturing Institutes

**America Makes**

https://americamakes.us/about/overview

**Date Launched:** Aug. 16, 2012

Headquarters location: Youngstown, Ohio

**Focus Area:** Additive manufacturing
**Capsule Summary:** America Makes focuses on helping the United States grow capabilities and strength in 3D printing, also known as additive manufacturing. 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.

**Digital Manufacturing and Design Innovation Institute (DMDII)**

http://www.dmdii.uilabs.org/

**Date Launched:** Feb. 25, 2014

**Headquarters Location:** Chicago, Illinois
**Focus Area:** Integrated digital design and manufacturing
**Capsule Summary:** The DMDII is the nation's flagship research institute for applying cutting-edge digital technologies to reduce the time and cost of manufacturing, strengthen the capabilities of the U.S. supply chain and reduce acquisition costs for the U.S. Department of Defense (DoD). The DMDII develops and demonstrates digital manufacturing technologies, and

deploys and commercializes these technologies across key manufacturing industries. The goal is to create product and manufacturing process definitions simultaneously. Design innovation is the ability to apply these technologies, tools and products to re-imagine the manufacturing process from end to end.

**LIFT: Lightweight Innovations For Tomorrow**

http://lift.technology/

**Date Launched:** Feb. 25, 2014

Headquarters Location: Detroit, Michigan

**Focus Area:** Lightweight Technology
**Capsule Summary:** LIFT is part of a national network of research institutions and industrial companies geared toward advancing America's leadership in manufacturing technology. The center will speed development of new lightweight metal manufacturing processes from laboratories to factories for products using lightweight metal, including aluminum, magnesium, titanium and advanced high-strength steel alloys. An equally important mission is to facilitate the training of the workers who will use these new processes in factories and maintenance facilitates around the country.

**PowerAmerica**

http://www.ncsu.edu/power/

Date Launched: Jan. 15, 2015

**Headquarters Location:** Raleigh, North Carolina
**Focus Area:** Wide Bandgap Semiconductors
**Capsule Summary:** The mission of PowerAmerica is to develop advanced manufacturing processes that will enable large-scale production of wide bandgap (WBG) semiconductors, which allow electronic components to be smaller, faster and more efficient than semiconductors made from silicon. WBG semiconductor technology has the potential to reshape the American energy economy by increasing efficiency in everything that uses a semiconductor, from industrial motors and household appliances to military satellites.

## Institutes in Development

The following institutes are currently in competition and anticipated to be awarded in the near future.

**Flexible Hybrid Electronics Manufacturing Innovation Institute (FHE-MII)**

http://manufacturing.gov/fhe-mii.html

A Flexible Hybrid Electronics Manufacturing Innovation Institute (FHE-MII) will advance the state-of-the-art in the design, manufacturing, integration of electronics and sensors, and assembly and test automation through technology platform demonstrations of complex flexible hybrid electronics on non-traditional conformal, bendable, stretchable, and foldable substrates.

**Integrated Photonics Institute for Manufacturing Innovation (IP-IMI)**

**http://manufacturing.gov/ip-imi.html**

The Integrated Photonics Institute for Manufacturing Innovation (IP-IMI) will create an end-to-end integrated photonics manufacturing ‘ecosystem’ in the U.S., and will include integrated design tools for efficient simulation and design of integrated photonic circuits, domestic photonic device fabrication foundry access, automated packaging, assembly and test of integrated photonic circuits, and workforce development. Activities under the IP-IMI will enable universities and small-to-medium enterprises to participate in the integrated photonics revolution. This IMI will bring government, industry and academia together with the goal of organizing the current fragmented domestic capabilities in integrated photonic technology and better position the U.S. relative to global competition.

**Revolutionary Fibers and Textiles Institute for Manufacturing Innovation (RFT-IMI)**

http://manufacturing.gov/rft-imi.html

The Revolutionary Fibers and Textiles Institute for Manufacturing Innovation (RFT-IMI) will ensure that America leads in the manufacturing of new products from leading edge innovations in fiber science, commercializing fibers and textiles with extraordinary properties. Known as technical textiles, these modern day fabrics and fibers boast novel properties ranging from being incredibly lightweight and flame resistant, to having exceptional strength. Technical textiles have wide-ranging applications, from advancing capabilities of protective gear allowing fire fighters to battle the hottest flames, to ensuring that a wounded soldier is effectively treated with an antimicrobial compression bandage and returned safely. The RFT-IMI will serve as a public-private partnership between government, academia and industry to address the spectrum of manufacturing challenges associated with this technology, from design to end products. It is envisioned to support an end-to-end innovation 'ecosystem' in the U.S. for advanced fibers and textiles manufacturing and leverage domestic manufacturing facilities to develop and scale-up manufacturing processes.

**Clean Energy Manufacturing Innovation Institute on Smart Manufacturing: Advanced Sensors, Controls, Platforms and Modeling for Manufacturing**

**http://energy.gov/eere/amo/articles/notice-intent-noi-clean-energy-manufacturing-innovation-institute-smart**

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