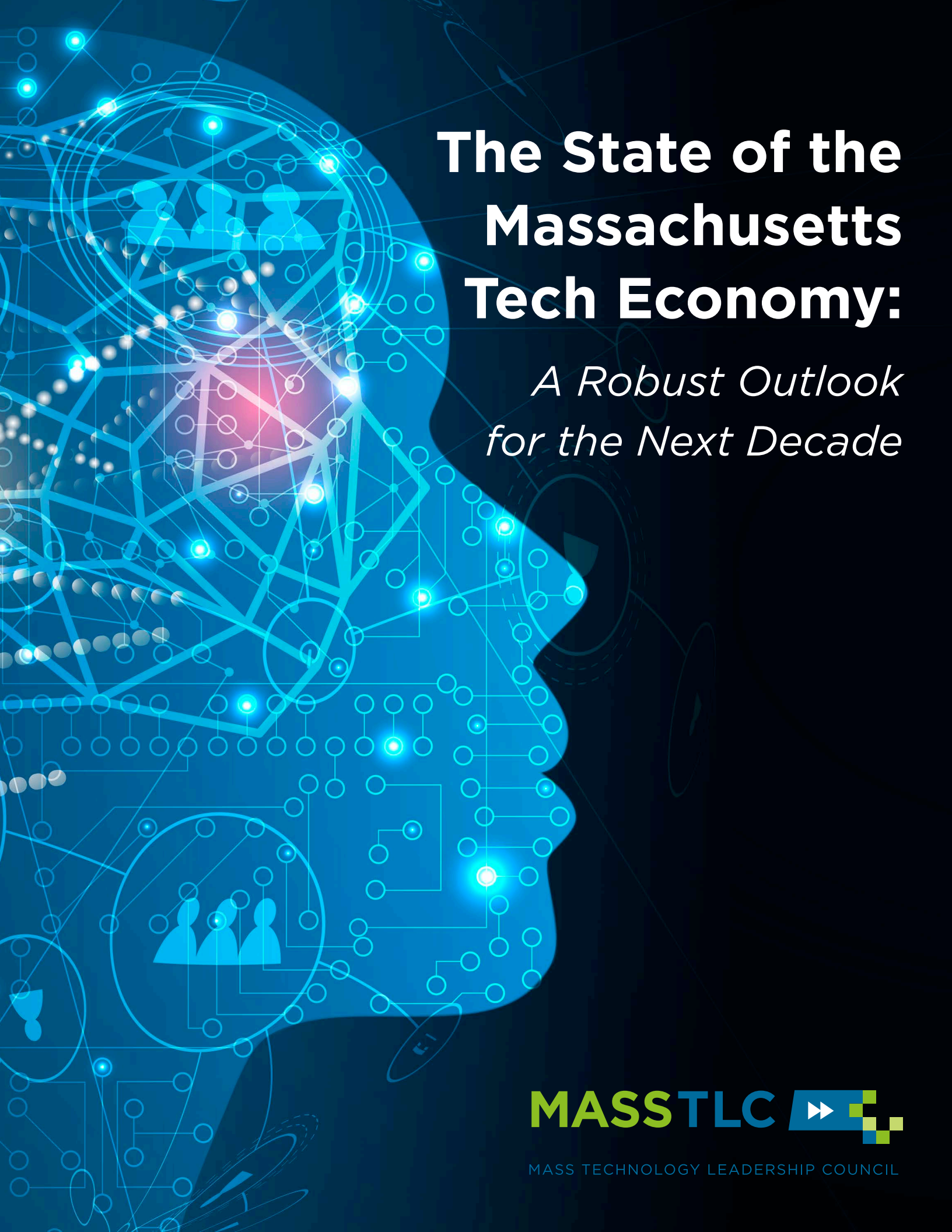




The State of the Massachusetts Tech Economy:

*A Robust Outlook
for the Next Decade*



MASS TECHNOLOGY LEADERSHIP COUNCIL

Acknowledgments

Thank you to the following for their contributions and support: Christopher Barr, Product Marketing Manager, Verizon; Deborah Boisvert, Executive Director, BATEC Center for Computing and Information Technologies, University of Massachusetts, Boston; Mario Delci, Ph.D., Assistant Commissioner for Evaluation and Policy Analysis, Massachusetts Department of Higher Education; Renee Foster, Former President, Curriculum Associates; Sara Fraim, Sr. Director, Community Impact, MassTLC; Tim Hebert, Sr. Vice President, Research & Market Intelligence, CompTIA; Leo Hermacinski, Owner, Luneside Consulting; Stephanie Lee, Director, State Government Affairs and Public Policy, Verizon; Will Markow, Manager of Client Strategy – Analytics, Burning Glass Technologies; Mark Melnik, Director, Economic and Public Policy Research, UMass Donahue Institute; Ruth Morris, Sr. Director, Marketing, MassTLC; Stephen O’Leary, Managing Director and Co-Founder, Aeris Partners; Deb Pine, Executive Director, Gloria Cordes Larson Center for Women and Business, Bentley University; Branner Stewart, Sr. Research Manager, Economic and Public Policy Research, UMass Donahue Institute.

About Massachusetts Technology Leadership Council, Inc.

With 450 member companies, the Mass Technology Leadership Council (MassTLC) is the region’s leading technology association and the premier network for tech executives, entrepreneurs, investors and policy leaders. MassTLC’s purpose is to accelerate innovation, growth and the development of an inclusive tech ecosystem in Massachusetts by connecting people from across the technology landscape, providing access to industry-leading content and ideas and offering a platform for visibility for member companies and their interests. More at www.masstlc.org.

MASS TECHNOLOGY LEADERSHIP COUNCIL

420 BEDFORD STREET, SUITE 250, LEXINGTON, MA 02420 | 781 993 9000 | MASSTLC.ORG

LETTER FROM TOM HOPCROFT

As CEO of the region's leading technology association, I count myself fortunate to be both witness to and participant in the vibrancy and growth in the Massachusetts technology and innovation ecosystem.

Ten years ago, MassTLC laid down a challenge to industry and policy leaders to grow tech employment by 100K jobs over the coming decade. It was a bold and ambitious challenge at a difficult and uncertain time in the local and global economy, with the preceding decade bracketed by the bursting of the tech bubble of 2000 and the financial bubble of 2008, and their resulting recessions.

In the decade that has followed, the Massachusetts technology ecosystem has seen a renaissance that can be seen in a vibrant start-up landscape, a large number of hyper-growth companies, reimagination of legacy businesses, a resurgence of investment capital, and the proliferation of corporate and academic research and development institutions and labs.

While we anticipated the potential for such transformation, we did not foresee back in 2010 the emergence of non-tech companies undergoing such radical digital transformations and becoming significant employers of technology workers in their respective sectors. Today, when evaluating the impact of tech in Massachusetts, we commonly look at the tech sector plus tech jobs in other sectors, a metric we call *net tech jobs*.

As you read this *State of the Tech Economy* snapshot, we invite you to join us in taking stock of the 2020 Challenge and how we stack up against our goal and against our peer states. We've made tremendous gains and still have much work to do.

We continue to provide metrics on the state's competitiveness, our workforce demographics, and progress on equity and inclusion. We review the profound and transformational impacts that emerging technologies such as 5G, edge computing, AI, and more will have on industry and society. And finally, we examine the current talent pipeline and outline a variety of pathways to help meet industry need for talent.

As we enter a new decade, we remain optimistic about the future and the transformational potential of technology and technology leaders to shape the future and address the challenges of our times.

Thank you,

Tom Hopcroft, President & CEO, MassTLC

CONTENTS

THE STATE OF THE MA TECH ECONOMY	1
2020 Challenge—A Changing Landscape	1
Where We Are Today	3
Competitiveness	5
Outlook and Challenges	5
REVOLUTIONIZING EXISTING INDUSTRIES	7
Emerging Technologies	7
Implementations of Emerging Technologies	9
TECH TALENT IN MASSACHUSETTS	12
The Situation Today	12
Expanding the Massachusetts Tech Talent Pool: Three Critical Areas	13
Innovating to Expand and Diversify the Talent Pipeline	14
Adapting the Education System	17
Alternative Pathways	18
Moving the Needle: Talent Programs and Initiatives	19
CONCLUSION AND NEXT STEPS	21
Endnotes	22

THE STATE OF THE MA TECH ECONOMY

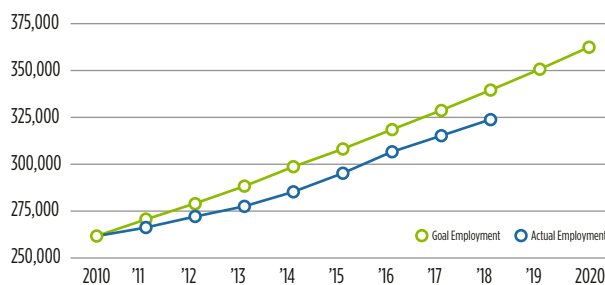
2020 Challenge—A Changing Landscape

Each year, MassTLC benchmarks progress toward the Council's 2020 Challenge, an aspirational call to the tech ecosystem in 2010 to create 100,000 new technology jobs in the state by the end of 2020.¹

When we created the Challenge back in 2010, we anticipated that technology companies would employ workers to build new technologies and implement them in technology and traditional companies alike. With hindsight, we can see that traditional companies are building sophisticated digital transformation teams that employ many of the technology workers we had intended to capture in the 2020 Challenge. As a result of this, coupled with the dramatic acceleration of automation, efficiency, and almost full employment in tech over the past few years, we concluded that a better metric of tech jobs should include all jobs in the tech sector as well as tech occupations within industries outside of traditional tech companies, a measure we call “net tech jobs.” We have, therefore, recast the Challenge to measure “net tech jobs” as a better reflection of how technology workers are being employed today.

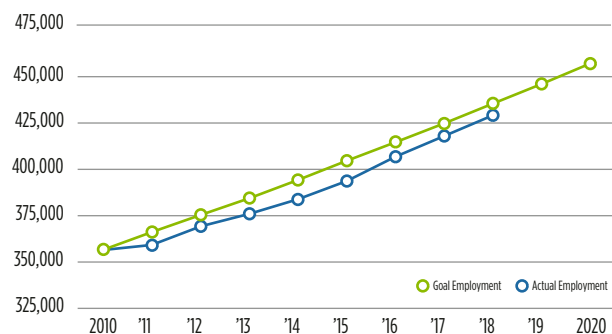
Figure 1 shows progress toward the original 2020 Challenge looking solely at tech sector job growth. **Figure 2** depicts the more complete picture of net tech job growth, the combination of all tech sector jobs as well as tech-oriented jobs within sectors outside of tech, which better reflects the state of tech in Massachusetts. This more accurate measurement puts Massachusetts on a trajectory that is likely to close the gap between net tech jobs and our 2020 Challenge by the end of the decade. Between 2010 and 2018, Massachusetts added nearly 72,000 net tech jobs. Due to the lag in data reporting, final Challenge results will not be reported until 2021.

Figure 1. Tech industry job growth lags 100k jobs target of 2020 Challenge



Source: Employment 2010–2018, CyberStates 2019. MassTLC “Goal Employment” is based on adding 100,000 tech jobs between 2010 and 2020 at a consistent rate of growth.

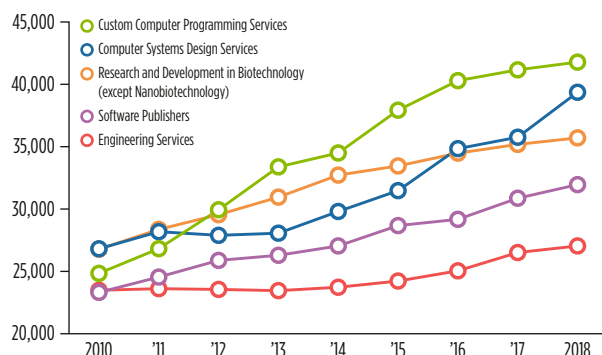
Figure 2. Revised net tech job growth on pace to meet 2020 Challenge



Source: Employment 2010–2018, CyberStates 2019. MassTLC revised “Goal Employment” is based on adding 100,000 net tech jobs between 2010 and 2020 at a consistent rate of growth.

Of the almost 72,000 net tech jobs created between 2010 and 2018, 38,000 were created in tech services, led by custom computing programming services, computer systems design services, research and development in biotechnology, software publishers, and engineering services (Figure 3). Conversely, we have seen a small decline in tech manufacturing jobs, although the output of tech manufacturing remains on the rise (Figure 4). This seeming contradiction suggests that the increase in automation of lower-skilled jobs combined with the state's focus on high value-added products have negatively impacted the number of jobs but positively impacted productivity and revenue. While we have seen small drops in the manufacturing of semiconductors and related devices, guided missiles and space vehicles, and computer storage devices, we have seen a slight uptick in analytical laboratory instrument manufacturing (Figure 5).

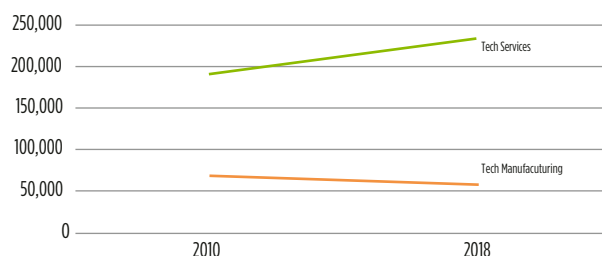
Figure 3. Since 2010, growth in tech services has been led by custom computer programming and computer systems design



Source: UMass Donahue Institute calculations based on CyberStates' 2019 Report, EMSI data

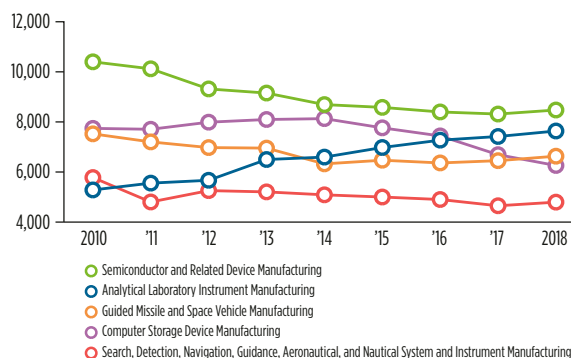
Overall, as we come to the close of the decade, with just one more year to meet the 100,000 new net tech jobs goal, we must keep in mind that the landscape of today is significantly different than in 2010. Today technology has become the core of many industries.

Figure 4. Tech services jobs have surged (+38,097) in Massachusetts while tech manufacturing has declined (-8,230) since 2010 (*Jobs in tech manufacturing and tech services, Massachusetts, 2010-2018*)



Source: UMass Donahue Institute calculations based on CyberStates' 2019 Report, EMSI data

Figure 5. Four of the top 5 manufacturing tech industries have seen a decline in jobs since 2010 (*Jobs in top 5 tech manufacturing industries, Massachusetts, 2010-2018*)

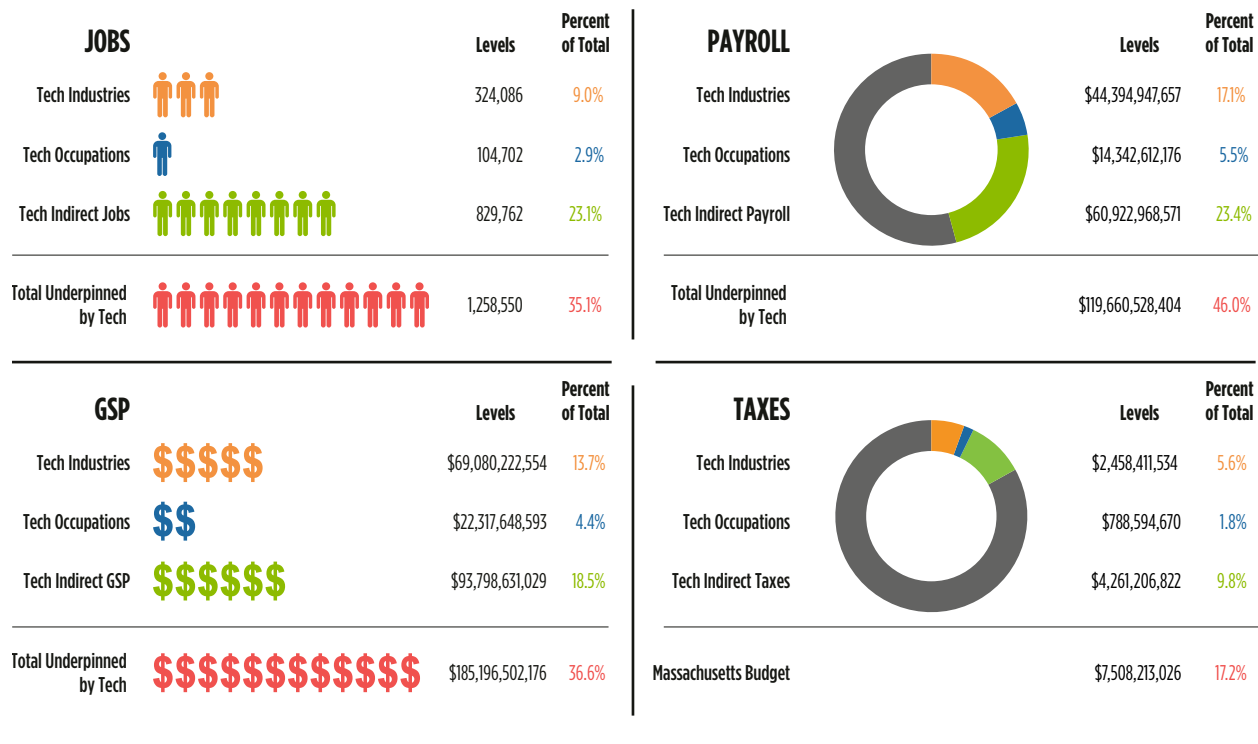


Source: UMass Donahue Institute calculations based on CyberStates' 2019 Report, EMSI data

Where We Are Today

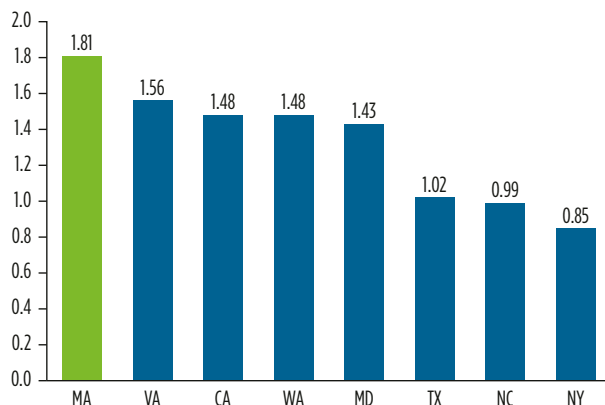
The tech sector continues to be a strong driver of the Massachusetts economy. When considering tech sector jobs, tech occupation jobs, and the indirect and induced jobs² that support them, tech in Massachusetts underpins 35% of all jobs in the Commonwealth, 37% of the gross state product (GSP), and 46% of payroll, contributing 17% of the revenue that makes up the state's overall budget (Figure 6). Among peer technology states nationwide,

Figure 6. Tech underpins over one-third of jobs and GSP in Massachusetts



Sources: CyberStates, UMass Donahue Institute economic impact calculations based on 2019 IMPLAN model for Massachusetts. State budget is for FY2020. GSP data are from the U.S. Bureau of Economic Analysis.

Figure 7. Massachusetts has the most concentrated tech sector among its peers (*Location quotient of tech sector jobs relative to the United States, 2018*)

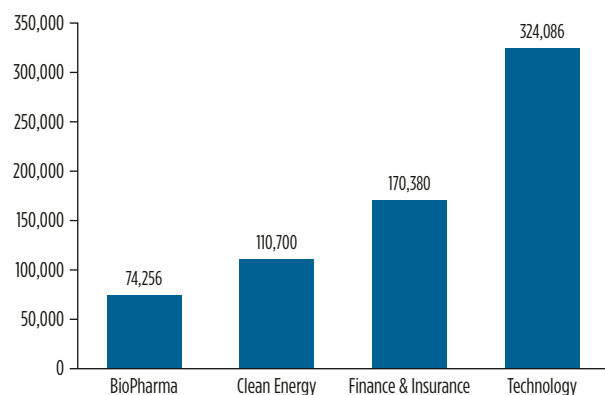


Source: UMass Donahue Institute calculations based on CyberStates 2019 Report, Bureau of Labor Statistics

Massachusetts boasts the most concentrated tech sector (**Figure 7**). Massachusetts also ranks 3rd across all peer states in terms of tech as a percent of total GSP.³ GSP includes only the value-added amount of the innovation that has been produced in Massachusetts and does not include any inputs purchased or developed outside of the state.

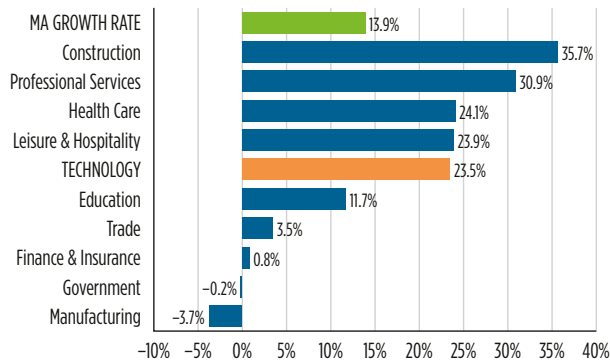
Consistent with national trends, Massachusetts unemployment is historically low, largely driven by tech and other leading sectors such as finance and insurance, clean energy, and biopharma (**Figure 8**). The tech sector continues to add jobs at a strong rate, and it is likely that the indirect impact of tech is also driving job growth in other industries such as construction, professional services, healthcare, and leisure and hospitality (**Figure 9**). MassTLC's most recent *Massachusetts Tech Pulse Index* report shows 54% of respondents felt positively about expanding in this region over the coming year due to access to talent. However, when asked about their greatest challenge to doing business in Massachusetts, respondents reported that availability of these skilled workers was their number one concern.⁴

Figure 8. Tech sector is a leader in Massachusetts employment (*Total jobs by industry cluster, Massachusetts, 2018*)



Sources: BioPharma: MassBio Industry Snapshot 2019 (jobs data are for 2018); Clean Energy: Massachusetts Clean Energy Center, Massachusetts Clean Energy Industry 2018 Report; Finance & Insurance: U.S. Bureau of Labor Statistics, 2018; Technology: CyberStates 2019 Report

Figure 9. Tech is adding jobs at a faster rate than the state, though other major sectors are outpacing tech (*Percent change in jobs by major sector, Massachusetts 2010–2018*)



Source: UMass Donahue Institute calculators based on CyberStates and U.S. Bureau of Labor Statistics

Competitiveness

Massachusetts is frequently recognized as a global innovation hub. The state has ranked number one for the best business environment for science and technology according to the Milken Institute, a designation it has received since 2002.⁵ It was ranked number one in innovation from Bloomberg's U.S. State Innovation Index in 2016, and in 2019 ranked second, only two tenths of a point behind California, but still leading in both the number of high-tech public companies headquartered here as well as the percentage of tech firms receiving venture-capital funding.⁶ And in the past year the region received top rankings in six science and technology indexes that cited talent as a critical driver.

Massachusetts has one of the most robust higher education systems in the world, with over 100 public and private colleges and universities, including fifteen public community colleges and nine state universities spread out over 29 campuses. In 2018, Massachusetts postsecondary schools awarded a total of 116,108 associate, bachelor, and graduate degrees. Of that, 7,554, or 6.5%, were awarded in Computer & Information Sciences & Support Services and Mathematics and Statistics.⁷

A number of these institutions also boast substantial innovation labs and entrepreneurship programs providing students an opportunity to incubate a technology or company with the resources of a university behind them. Helping to amplify the success of these programs are the more than 30 active technology transfer offices within these academic and research institutions that support the commercialization of the innovations for the public good. The federal R&D investments for these institutions totals over \$6 billion annually, further accelerating the research and development of technologies and new business here in Massachusetts.⁸

Outlook and Challenges

While Massachusetts educates the world and can lay claim to a number of top awards in tech innovation, companies still struggle to find the talent required to grow and succeed due to a number of factors. These include the finite number of skilled people, exorbitant housing costs, and a failing transportation system.

Education and investment in the tech talent pipeline are such important levers for economic growth that it is discussed in detail later in this report. Another important contributor to the local talent pool has been migration. According to *Massachusetts Benchmarks*, 55% of workers within the tech sector are not native to Massachusetts, with 35% coming from other U.S. regions and 20% coming from foreign countries.⁹ This puts a further burden on executives to attract talent not just to their companies, but to the region as well.

Federal immigration policies constrain the pipeline of international talent, much of which passes through the region while attending our many colleges and universities. As noted in MassTLC's 2017 report, *Impact of Immigration*, approximately 30% of master's degrees and 20% of doctorate degrees were earned by non-U.S. residents at the 10 largest four-year institutions in Massachusetts. In recent years, the number of immigrant students coming to the U.S. has declined, constraining an important pipeline for talent coming into the tech sector.

Two major challenges Massachusetts faces in the growing need for attracting and retaining talent are lack of affordable housing and an antiquated, unreliable transportation system. Tech companies need a skilled workforce that can afford to live within commuting distance of work. Improving transportation and increasing the commutable footprint will allow workers to live in more affordable areas outside of the metro Boston area.

Housing in the Boston metro region is scarce, and what is available is out of the price range of many entry- and mid-level workers, even in the tech sector, which pays roughly twice the state average. Many millennials and Gen-Zers looking to rent in the city are facing a 24% increase in rent over what was seen in 2000.¹⁰ As of 2016, these rental rates were higher than those for the nation by 20%. Worse still is home ownership, where Massachusetts is 80% higher than the national average.¹¹

While the state is working to infuse billions of dollars into transit improvements, commuters—regardless of whether they are using roads, rail, or subway—are facing crippling commutes. According to the Massachusetts Department of Transportation, the entire Central Artery/Tunnel project processes about 536,000 vehicles per weekday. And just under fifteen miles away is the single highest traffic volume in the state at the interchange of I-93 and I-95 in Woburn and Reading with 375,000 vehicles per weekday.¹² This inhibits not only drivers in cars but those that depend upon buses. As of September 2019, key bus routes on the MBTA have had a 77% on-time performance compared to an 80% target rate, and that drops to 60% for non-key routes versus their target rate of 75%.¹³

Massachusetts is a global force and model innovation economy. With this comes the need to tackle the struggle for skilled workers, the high price of living, and the—at times—paralyzed transportation system. Facing a critical need for skilled workers and encountering inducements—such as less expensive office space, tax incentives, and an overall lower cost of living—from domestic and international economic development organizations, many companies are choosing to hire talent and locate facilities outside Massachusetts. Many of these competing regions are marketing themselves as tech hubs and represent a growing threat to Massachusetts.

REVOLUTIONIZING EXISTING INDUSTRIES

Emerging Technologies

Massachusetts is favored with a diverse economy rooted in knowledge-based industries such as healthcare, education, high technology, life sciences, and financial services. While economic cycles and market forces have seen the periodic rise and fall of these various sectors, the present moment is one in which all of them are being fundamentally transformed, and in some cases reinvigorated, by technological advances in communications, AI, machine learning (ML), data analytics, sensors, virtual reality and augmented reality, edge computing, and next generation networking. Even traditional industries such as agricultural, fishing, and manufacturing are seeing dramatic changes due to these advances.

Recent years have seen the growing real-world uses of AI, machine learning, augmented and virtual reality, and IoT with its sensors, data analysis, and applications built on top. As profound as the advances driven by these technologies have been, there has been a roadblock to unlocking their full potential: the throughput limits and latency of the underlying communications. The emergence of 5G, coupled with compute resources at the cell site (edge computing), will enhance the capabilities of these technologies and further transform industries.

The core benefits of 5G are that it provides higher data rates and capacity, along with increased reliability, while maintaining lower power requirements and minimal latency. Small cell antennas that are closer to the customer will be connected to local edge computing, thus allowing end devices to offload much of their computing requirements and reduce their power needs or go longer between recharging.

While the promise of 5G holds great potential, there are some issues that need to be addressed for successful deployment and adoption. There are obstacles on the regulatory side, such as negotiating with municipalities to permit a dense deployment of 5G antennas and working with federal authorities to make spectrum available. Other issues are economic, as 5G deployment will require building and installing hundreds of thousands of antennas across the country. The cost of the fiber, hardware, skilled personnel, spectrum, and local fees is significant. The investment required over seven years to build out 5G in the U.S. is projected to be \$275B at a minimum.¹⁴

Technical challenges also have to be overcome in order to fully realize 5G. These challenges include the propagation characteristics of millimeter wave spectrum (which can carry lots of data but doesn't travel long distances), cybersecurity of this software-based network, and the resource demands on the network by the millions of sensors and devices that will be connected.

While 5G is just beginning to be rolled out in the U.S., major carriers have begun to deploy it in some locations. In Boston, Verizon has announced plans to roll out 5G Ultra-Wideband service for businesses and consumers in select areas this year. The economic impact of 5G on Massachusetts is likely to be substantial. CTIA, the wireless communications industry trade association, estimates¹⁵ that for the six largest cities in the state, 5G will:

- Create more than 12,000 jobs
- Save over \$750M from smart city implementations
- Contribute \$2B of additional, annual GDP

Once deployed, the possible use cases for 5G coupled with edge computing are endless. From improving food safety by using real-time environmental sensors in the food chain to track the temperature of perishables to creating mixed reality collaboration tools for remote workers in construction and engineering, 5G will help industries and technology providers rethink processes and solutions. The following are several possible use cases for industries of importance in Massachusetts.

Implementations of Emerging Technologies

Smart Cities

It is estimated that three million people are moving into U.S. cities each week,¹⁶ straining already aging infrastructure and services. Massachusetts cities are seeing the same trend, with Boston growing 12.5% and Cambridge growing 13% between 2010 and 2018, and this growth is expected to continue.

Municipalities seeking to improve city services while saving money will—and in some cases already do—benefit from intelligent infrastructure made possible by emerging technologies such as embedded sensors, edge computing, 5G communications networks, AI, and augmented reality.

Examples of the many possible uses for these technologies include:

- Better traffic management, which will reduce gridlock and commuting times while improving safety
- More efficient use of resources such as water and electricity
- Improved public safety from faster emergency services response, improved gunshot location detection, emergency response robots, smart street lights
- Reduced maintenance costs through advanced monitoring of infrastructure

In order to enable a fully smart city requires gigabits-per-second throughputs and single-millisecond latencies, along with nearly 100% reliability and availability. 5G networks promise to deliver on all three, and early implementations have been promising.



SMART LIGHTING

With the advent of the smart sensors, computational capabilities, and applications that underpin the Internet of Things (IoT), a wide range of companies—such as OSRAM and Philips Lighting—have already begun to deploy smart lighting in cities across the world.

By connecting smart lighting solutions to a 5G network and using 5G and edge computing to leverage capabilities such as augmented reality views of the lighting installations as well as real-time data on the energy grid, weather, traffic conditions, etc., cities can proactively manage maintenance needs and balance usage and energy consumption. This saves money and improves public safety.

It's not all about what 5G brings to smart lighting deployments—the benefits flow the other way too. As 5G begins to roll out in more cities, intelligent street lamps are often the perfect platform for 5G base stations. 5G transmission distance is short and requires density of transmission points. Intelligent street lamps already are densely deployed throughout cities that have smart lighting solutions and have power sources built-in to them. We already see, and will continue to see, the convergence of these two technologies in “smart poles” that serve as a platform for both.

Healthcare

AI, machine learning, deep learning, broadband communications, wearable technology, sensors, and other technologies are already transforming healthcare, both on the administrative and care delivery side. Better predictive and diagnostic abilities enabled by these technologies create greater efficacy in treatment, leading to better results as well as cost savings by preventing unnecessary testing and optimizing workflows.

On the care delivery side, many exciting developments are already underway. Sensors and wearable technology have enabled the Internet of Medical Things (IoMT), also known as the Internet of Medicine or the Internet of Things for Healthcare. Estimates of the IoMT market and growth rate vary greatly, but most estimates put the current market at over \$40B, with double-digit growth rates in the next few years. The development of a wide range of health applications and services—from insulin management to drug adherence solutions—are driving this growth, and the number of such services is growing daily.

Another area of tech-enabled healthcare is telemedicine, which is made possible by advances in communications technologies. This segment of the healthcare market is expected to have a 16.5% CAGR between 2017 and 2023.¹⁷ Currently, most telemedicine consists of consultations and remote diagnoses and is increasingly being used to provide care in rural settings that have seen a rise in hospital closings and where recruiting medical professionals is difficult.

In hospitals, radiology is an area that many see ripe for dramatic change as AI and machine learning lead to better image analysis and predictive abilities. While there is some debate about what this means for radiologists, most experts predict that it will free up radiologists to do higher value work on the treatment side.

All of these healthcare areas, as well as many others, will benefit from faster, more reliable, higher throughput communications technology, edge computing, augmented/virtual/mixed reality. For example, medical images that might be taken at a different location and that might be enriched by data gathered from sensors would make the already large image data even larger. For a doctor trying to consult from afar, the near real-time and accurate delivery of those images could be critical to the care she is delivering.



REMOTE SURGERY

Although there may be some trials already underway with remote surgery, the ability to conduct surgeries from afar has not been fully realized yet due to latency issues with existing communications networks. Surgical robots that surgeons can control to operate already exist, but they currently are controlled by doctors on site. To conduct surgery from a different location requires the low latency that 5G provides as any substantial lag time can endanger the patient.

Adding in augmented or mixed reality that allows the doctor to see the area on which she is operating in a complete 360-degree, 3D view with associated diagnostic information could further improve the surgeon's decision-making during surgery and in post-operative care.

Robotics

Robots, whether used in healthcare, manufacturing, warehouse management, emergency response, or an array of other applications, are poised to have their capabilities vastly expanded by 5G and edge computing. The high bandwidth and low latency of 5G, along with the data processing muscle of edge computing nodes, will allow for the use of visualization technologies and AI that permit new, real-time applications across industries. For example, the ability to test rapidly for manufacturing defects in real-time on the assembly line utilizing the combination of high-powered cameras and sensors with rapid data collection and processing, can save millions of dollars for manufacturers.

The ability to offload much of the processing of computationally intensive applications to 5G nodes and utilizing edge computing will lessen power requirements, reduce the size and weight of robots, and save money.



VERIZON 5G CHALLENGE

In 2019, MassTLC partnered with Verizon and Ericsson to run the Verizon 5G Robotics Challenge in which university and start-up teams were tasked with developing 5G-powered technologies in the areas of industrial automation, warehouse automation, and collaborative robotics. Teams from Northeastern University and the University of Massachusetts Lowell, along with five start-ups, had their proposals selected and received funding to create working prototypes.

The prototypes, demonstrated to a live audience at Verizon's 5G Cambridge Lab, included use cases such as:

- Autonomous, intelligent, mobile service robot whose navigation processes all take place on the network edge
- No-code robotic programming that uses AR and AI to enable deployment of manufacturing robots without writing any code
- Flying robotic system for monitoring industrial/warehouse environments and enabling coordinated operations
- Remote operation of a robotic arm via a smartphone
- Creation of accurate 3D images for use in robotic applications
- Remote management of bipedal robots in dangerous environments, such as natural disasters
- Collaborative, mobile robots using distributed computing to process and transfer large-scale data

TECH TALENT IN MASSACHUSETTS

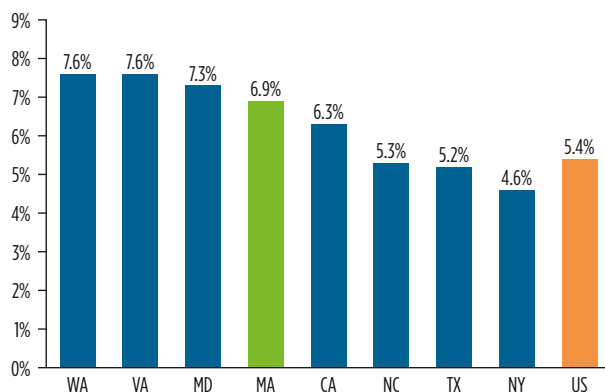
The Situation Today

Massachusetts has the nation's highest concentration of technology workers¹⁸ and is increasingly recognized as a global leader in technology innovation due in large part to an exceptional talent base. Technology occupations span industries, and in Massachusetts, one in every fourteen jobs—or almost 7% of all jobs—is a tech occupation (**Figure 10**). In the 2019 *Massachusetts Tech Pulse Index* report of technology organizations, 97% of respondents cited Massachusetts' talent as a source of strategic advantage. Almost 70% of the tech companies surveyed are looking to expand in Massachusetts over the next year, and of those over 54% say it is driven by access to talent.¹⁹

Massachusetts' leading K-12 and higher education systems deliver the highest number of STEM graduates per capita in the nation.²⁰ The vibrant technology ecosystem and city centers have made the region highly successful at attracting and retaining talent and the organizations that depend on that talent. While Massachusetts has a skilled workforce, the region is not immune to the national shortage of tech talent.

Despite the strength of our educational system, only about 7,500 students were awarded degrees in computer science and mathematics across associate, bachelor, and graduate levels in 2018.²¹ Demand for graduates in computing and mathematical occupations far outstrips supply with 26 job openings per bachelor level graduate, seven job openings per associate degree graduate, and three per master's level graduate (**Figure 11**).²²

Figure 10. One out of every 14 Massachusetts jobs (just under 7% of the total) is in a tech occupation



Source: UMass Donahue Institute calculations based on CyberStates 2019 Report and U.S. Bureau of Labor Statistics

Figure 11. Job openings in computer science and mathematics by degrees awarded in Massachusetts



The nature of hiring is rapidly evolving to include new areas of specialization as well as the incorporation of technology skills into an expanding array of occupations. Today there are almost 38,000 open job postings for tech occupations in Massachusetts.²³ Over 4.7 million tech workers nationally—including 143,000 in Massachusetts—are expected to retire over the next eight years, placing even greater pressure on the system.²⁴

These dynamics are the reason that while firms laud Massachusetts talent as a major advantage, they also cite in the most recent *Massachusetts Tech Pulse Index* report that “increasing the STEM talent pipeline” as the most important policy action needed in the state. The good news is that there are exciting innovations happening in the education, government, and corporate sectors to further expand the availability of technology talent and support high demand areas of specialization such as cybersecurity, AI, and data analytics.

Expanding the Massachusetts Tech Talent Pool: Three Critical Areas

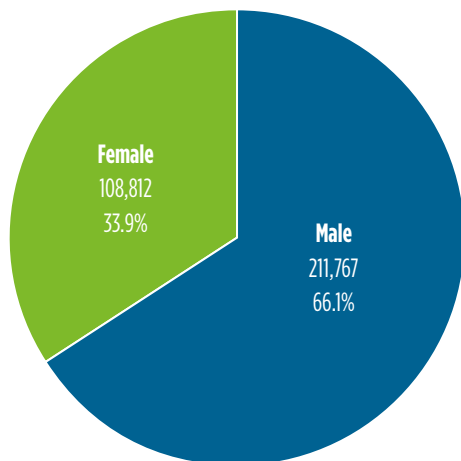
Massachusetts’ current leadership in the talent wars is the result of significant historical focus on developing leading educational systems and adopting policies to foster a vibrant technology ecosystem. To successfully meet new challenges resulting from the changing nature of work and technology, we will need to adjust our policies and educational systems. Three areas that will require careful attention are:

- **Radically Enhancing Diversity:** Participation rates for women and minorities in tech are low, and the slow rate of increase will be insufficient to reach parity with their white male tech counterparts for decades. The K-12 population is becoming increasingly diverse, yet achievement gaps for minorities are significant and must be addressed. At the post-secondary level, the Massachusetts Board of Higher Education is working to create parity by setting equity as its top priority among public higher ed institutions, which should increase our talent pool and help to close participation gaps in tech. Beyond the talent pipeline, work needs to be done within organizations to proactively attract and retain a greater number of women and minority leaders in tech.
- **Adapting the Education System to New Skill Needs:** Skill and specialization needs for technology roles are constantly evolving. Nontechnology roles are increasingly demanding technology skills. Our educational systems must more rapidly adapt to new needs and ensure the next generation is prepared for lifelong learning. Closer connections to the corporate sector are needed to link skill development to market needs.
- **Scaling Alternative Postsecondary Pathways:** We are unlikely to fill the technology workforce and retraining needs through traditional degree programs alone. Current innovative alternatives often serve small populations. Governmental incentives and policies to promote apprenticeships and other newer models are needed to enable those who demonstrate an aptitude for tech, but lack the formal credentials, to participate in the tech economy.

Innovating to Expand and Diversify the Talent Pipeline

Even as the state remains a top location for companies to find technology workers, it still faces a need to increase the talent pipeline. Massachusetts has a high concentration of expanding technology organizations looking for more talent, especially in software engineering and high-demand specialties such as AI and cybersecurity.

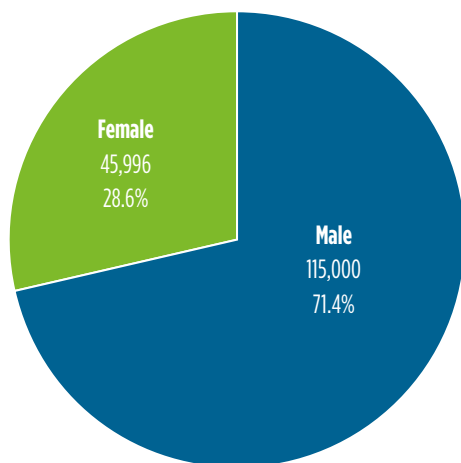
Figure 12. Massachusetts tech industry workers by gender (*Jobs in Massachusetts tech industry by gender, 2018*)



Source: UMass Donahue Institute calculations based on CyberStates 2019 Report data

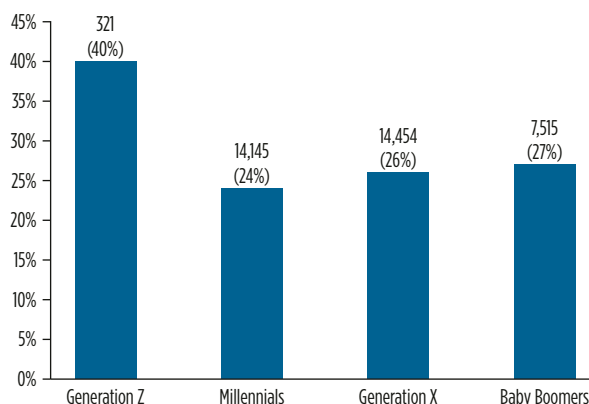
Females only account for one-third of workers within the Massachusetts tech sector (**Figure 12**). When considering females within tech occupations across all industries, the numbers are even lower at just 28.6% (**Figure 13**). There is evidence of small improvements in gender diversity among the younger generations as the most recent working generation, Generation Z, is more gender diverse, with 40% of tech occupations held by women (**Figure 14**.)

Figure 13. Tech occupations are predominately male



UMass Donahue Institute calculations based on U.S. Census Bureau

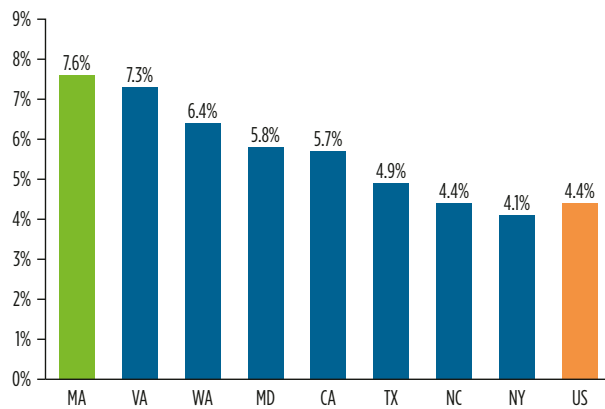
Figure 14. Share of women in mathematical and computer occupations by generation, Massachusetts, 2018



Source: UMass Donahue Institute calculations based on U.S. Census Bureau ACS PUMS, Generation Y and the Silent Generation have been excluded from Universe due to small sample sizes.

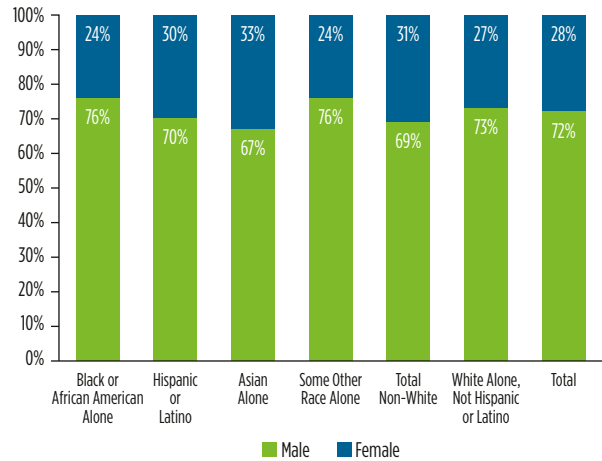
When looking at both race and gender within tech occupations, Massachusetts has the highest white male participation among peer states (**Figure 15**). There is slightly more female representation among non-white racial groups within tech occupations, although it is still from parity (**Figure 16**).

Figure 15. Massachusetts has highest white male participation compared to peer states (*Share of all workers by gender and race in computer & mathematical occupations by state, 2016–2018 average*)



Source: UMass Donahue Institute calculations based on U.S. Census Bureau, ACS Series B24010 (Sex by Occupation for the Civilian Employed Population 16 Years and Over)

Figure 16. Non-white computer and mathematical workers are slightly more gender diverse than white workers. (*Gender share of computer & mathematical occupations by race, Massachusetts, 2018*)



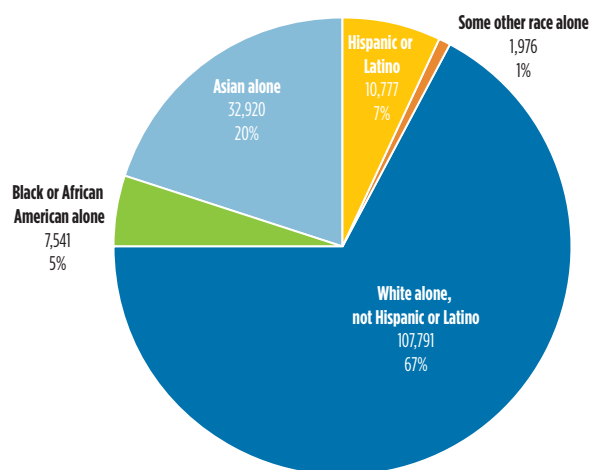
Source: UMass Donahue Institute calculations based on U.S. Census Bureau

In terms of race alone, workers in tech occupations are predominately white. In Massachusetts, only 5% of tech occupation workers are Black or African American, and 7% are Hispanic or Latino (Figure 17). In the past several years these ratios have improved, and while minorities are still a small percentage overall, some groups are showing strong gains. For instance, the number has more than doubled among Hispanics and Latinos and has almost doubled among Blacks and African Americans (Figure 18).

Expanding the tech talent pipeline to include more people from underrepresented groups is essential to meeting future talent demands. States that successfully grow the talent pool will have a significant strategic advantage. If Massachusetts could increase female participation rates to 33%, it would have an additional 28,000 people in the technology workforce.²⁵ While many of the current initiatives outlined in this report include strategies to boost representation of these groups, there remains significant need to radically expand participation.

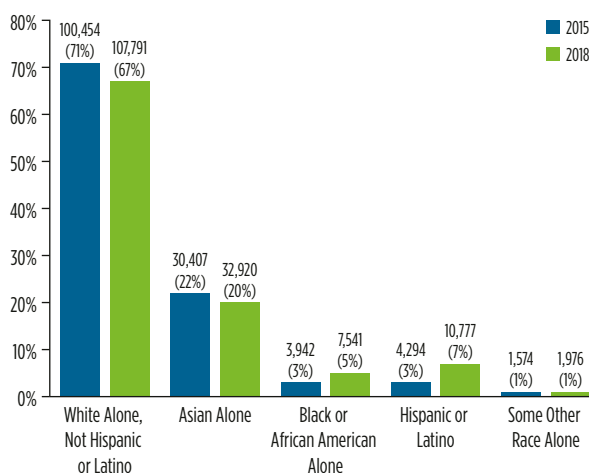
Fortunately, Massachusetts is home to many groups thinking about the future of work and driving research, policy, and investment toward developing the workforce of the future, and the state has been responding to talent pipeline challenges with legislative, educational, and corporate innovations to accelerate growth in the technology talent pool.

Figure 17. Massachusetts Workers in Computer & Mathematical Occupations by Race (*Share of computer & mathematical occupations by race, Massachusetts, 2018*)



Source: UMass Donahue Institute calculations based on U.S. Census Bureau

Figure 18. Blacks or African Americans and Hispanics or Latinos see increased participation for tech occupations in Massachusetts (*Share of computer & mathematical occupations by race, Massachusetts, 2015 and 2018*)



Source: UMass Donahue Institute calculations based on U.S. Census Bureau

Adapting the Education System

Work is being done, and needs to continue, at both the K-12 and postsecondary levels to expand students' interest in and preparation for technology careers of today and tomorrow. Students who take high school AP computer science courses are six times more likely to get an engineering degree, and for female students the likelihood increases by tenfold.²⁶ Research by Accenture and Girls Who Code found that 74% of women working in computer science had exposure to coding in middle school. We need to begin early marketing of STEM classes and careers to a more diverse population while simultaneously continuing to reduce entry barriers created through low math proficiency rates and degree retention rates.

K-12 Policy: Massachusetts already has some of the highest rates of computer science participation and math proficiency in the country, and the Commonwealth has been a leader in adopting policies to expand student interest and readiness for technology degrees.

The state has recently adopted policies to build an even larger and more diverse K-12 pipeline into STEM degrees and training. Several of these are in the early stages of implementation but hold promise for the future.

- **Standards:** Digital literacy and computer science standards have been adopted and schools across the Commonwealth have begun updating curriculum
- **Course Credit:** Computer science courses can now be used to fulfill a math or lab science credit
- **Teacher Preparation Programs:** New funding and certifications for teacher professional development have been added to expand the supply of computer science teachers
- **Math Pathways:** The Dana Center, an initiative of the University of Texas at Austin, works with a number of states to enhance student high school math preparation and enable effective remediation options in college

It will be important over the next couple of years to monitor the impact of these policies on improving the quality of computer science coursework, increasing the supply of computer science teachers, and expanding STEM career visibility and preparation to a diverse student base.

Higher Education Expansion and Innovation: Massachusetts successfully expanded its graduation rate from STEM programs by over 46% in five years and is now supporting new models in higher education to further scale degree access.²⁷ Partnerships between community colleges and local corporations as well as nonprofits, such as Year Up, is one model gaining traction. MIT is leveraging MOOCs as a way to identify remote talent pools and recruit the best of those to the Massachusetts education ecosystem. Bay Path University has been building a successful digital model that is helping to increase the participation of women in the New England talent base.

In addition to addressing how to reach a broader population and increase the number of STEM degrees, leaders in higher education need to rethink the curricula and skills that they provide in a rapidly changing work environment. Some of the issues that require rethinking include:

- **Technology skill needs in non-technology degrees:** Departments across the organizational spectrum—from human resources to marketing to operations—are struggling to access technology and data analytics skills. Baseline knowledge in these areas is anticipated to become a key differentiator for future job applicants
- **Soft skill needs in technology applicants:** Corporations increasingly cite the needs for more soft skills in technology applicants. Problem solving, collaboration, communication, and leadership are increasingly cited as gaps in technology workforce applicants.
- **Evolution of Technology Roles:** Forward-looking think tanks forecast declining needs in entry level technology areas that will become more automated. At the same time, specific coding and specialized engineering needs will continue to evolve rapidly. It will be important to not simply prepare students for the roles and skills of today but to focus instead on building the foundations and lifelong learning access that allow workers to adapt to changing employer needs.

Alternative Pathways

Massachusetts is home to a growing range of nontraditional alternatives—including governmental organizations, corporations, nonprofits, and new higher education partnerships—for building a technology ready workforce. Initiatives, including apprenticeship programs, in-house technical training academies, and bootcamps, have begun to evolve in the Commonwealth as organizations respond to the opportunities created by the robust job economy in the state. The most recent *Massachusetts Tech Pulse Index* report found that almost 50% of technology organizations reported having an apprenticeship program, and an additional 28% are interested in adding a program.²⁸ Across the respondents there was an emphasis on expanding diversity of the pipeline in order to expand the volume of talent.

In order to meet future technology talent demands we will need postsecondary skill development options that can evolve and scale more rapidly than traditional higher education programs. A 2014 analysis by the Massachusetts Department of Higher Education found that the state's public higher educational institutions would need to double annual computer science and IT graduates to meet industry demand. Many innovative alternative programs currently lack scale and sufficient proof of efficacy. Over the next few years it will be important to identify and promote workable models. We believe there are opportunities for government to create incentives for more collaboration among corporate entities and investment in scaling apprenticeships and other promising options.

Moving the Needle: Talent Programs and Initiatives

MASSTALENT

MassTalent: The region benefits from a number of public institutions and private organizations whose core mission is to create equity by bringing individuals who might not otherwise have the opportunity to work in tech. Whether through training, placement, or financial support, these programs are making a difference in people's lives.

As the association representing the tech industry, we know that having so many worthy programs to choose from is both a benefit and a challenge to navigate for tech companies. Tech companies are creating internal training and recruiting programs and making investments in diversifying their workforce—understanding a more diverse workforce yields better company performance—but with so many worthy options often don't know where to turn.

MassTalent helps make these programs more accessible for tech companies to identify the program that best serves their needs, whether that be training, placement, or funding for pipeline and workforce development. MassTalent is a resource that provides an overview of each program and the specific needs that they seek to address.



Bay Path: The American Women's College of Bay Path University was founded with a mission to expand access to higher education for the 76 million American women who do not have a college degree. The college offers close to 30 majors that can all be done online and utilizes a sophisticated data-driven platform that meets individual students at their own pace and academic needs, thus optimizing their success.

In 2018, Bay Path University, through the American Women's College, was awarded a grant from the Strada Education Network to help address the digital divide and close the equity gap by creating curriculum to prepare their students for core cybersecurity and information technology careers. As part of this grant, MassTLC is working with its members to help identify the broad array of skills that are needed for employment in a cyber field with a primary focus on entry-level career opportunities. The project will be completed in 2021.



Akamai Technical Academy: In 2016 Cambridge-based Akamai developed a model for attracting diverse talent from other industries and successfully preparing them for Akamai technology roles. The Academy is a paid 12-month classroom and on-the-job training program that has successfully expanded the talent pipeline of women, minorities, and veterans for the organization.

Since inception in 2016, it has conducted seven academies and placed participants in a variety of operations-based roles, including security operations technician, associate technical program manager, associate technical support engineer, associate technical consultant, associate business analyst, and technical writer. Participants attend classroom training during business hours in the Akamai office, and they complete a rigorous curriculum, including homework and assessments, attend regular presentations by Akamai business leaders, and participate in other required events.²⁹



Apprenti: The apprenticeship model has been adopted in a number of “blue collar” industries in the U.S. Yet, until recently, there have not been any significant apprenticeship models that existed in white collar jobs. With the high demand for skilled talent in tech and a renewed interest and push from federal and state government, employers have turned to this model as a proven method of pipeline and workforce development.

Apprenti, a non-profit created by MassTLC’s sister organization, the Washington Technology and Information Association’s (WTIA) Workforce Institute, engages directly with employers to deliver a registered tech apprenticeship program for non-traditional candidates, especially women, people of color, and veterans to pursue a career pathway in IT-related roles. The goal is to give candidates technical skills through related instruction over the course of two to five months, followed by one-year of on-the-job training, thus providing apprentices with practical, hands-on learning and work experience that will serve as a pathway for middle-skills tech jobs.

With the help of the One8Foundation and a partnership with the Massachusetts Executive Office of Labor and Workforce Development and Governor Baker’s Skills Cabinet, Apprenti launched its first cohort in the Commonwealth in 2019. MassTLC partnered with Apprenti Massachusetts to help ensure that tech apprenticeships become core to developing a pipeline of tech talent who may have chosen an alternative path to their education and training.

CHANCE IN TECH ACT

CHANCE in Tech Act: This federal bill would promote the expansion and development of technology apprenticeships across the country. This legislation, co-sponsored by Massachusetts Congressman Seth Moulton, has significant bipartisan and industry support. It would direct the Secretary of Labor to enter into competitive contracts with third parties to promote the development of, and access to, apprenticeship programs in the tech sector. This legislation would create public-private partnerships to serve as intermediaries between employers participating in registered apprenticeship programs, industry and training partners, and government entities. By streamlining and helping to fund the implementation of apprenticeship programs, the CHANCE in Tech Act would make these programs accessible to a much wider range of companies, greatly expanding student access to proven job on-ramps. MassTLC first introduced the CHANCE in Tech bill to Congressman Moulton and other members of the Massachusetts Congressional Delegation during the annual Washington, D.C., conference and advocacy event with our peer organizations around the country.

CONCLUSION AND NEXT STEPS

With world-class colleges and universities, strong research and development, healthy investments, and high-skilled talent, the state of the Massachusetts tech economy is robust. From automation to the geopolitical climate, external factors will play a role in our future. Furthermore, challenges remain with respect to size of the talent pipeline and current talent pool, affordable housing, and unreliable modes of transportation. These can be offset with a combination of public policy interventions, creativity from the private sector, and partnerships between the public and private sectors.

Pipeline and Training

Policy: The Commonwealth's revamping of the Foundation Budget is a significant step forward in funding public school systems. In addition, the recent adoption by the Massachusetts Department of Elementary and Secondary Education (DESE) of Digital Literacy and Computer Science (DLCS) Standards for students and Licensure for teachers is also noteworthy. Since digitization is more entwined with every industry, we must ensure that all students in Massachusetts have access to and are able to take DLCS coursework across all grade levels and school systems.

Private: With a limited pool of high-skilled individuals, companies must invest in lifelong learning for their workforces. While this shifts the burden of time and investment to the company, if all companies participate, the result will be a more robust workforce across the entire ecosystem.

Public/Private Partnership: Apprenticeships and other skill-based training programs are a successful staple for many other industries to build pipeline outside of a typical college or graduate program. As stated within the report, there is a finite number of graduates, and this number will not meet the needs of companies. There must be a concerted effort among all stakeholders to consider alternative pathways to training or obtaining talent, while simultaneously meeting the need to create a more inclusive workforce.

Affordable Housing

Policy: The legislature, along with municipalities, must increase the supply of affordable housing while also limiting the number of luxury and other cost prohibitive alternatives.

Private: While many companies are beginning to adopt more remote work options for their workers, this needs to continue as many workers are priced out of the city and are choosing to move further out where housing is more plentiful and affordable.

Transportation

Policy: Modernizing and maintaining our public transit system—including updating the antiquated MBTA, creating more bus lanes, and adding more alternatives to connect cities and towns to Boston and Cambridge—is an urgent priority. Creative policies that reduce the number of cars on the region's roads during peak hours should also be considered.

Private: In addition to allowing remote or flexible workers, companies must work together to develop creative programs for their employees to travel to their offices such as ride sharing or group shuttles.

Endnotes

1. Due to timing of data reporting from CompTIA, Department of Labor and other resources, the data analyzed for this report is current through 2018.
2. Tech occupations: Computer science, mathematics, and other tech focused jobs both inside and outside of the tech sector.
 - Tech jobs: All jobs within the technology sector
 - Indirect jobs: Jobs that have been created due to the technology sector
3. CompTIA, Cyberstates, 2019.
4. MassTLC's *Massachusetts Tech Pulse Index* report, November 2019.
5. Milken Institute—2018 State Technology and Science Index.
6. Bloomberg.com—Economics, 2019.
7. National Center for Education Statistics.
8. The federal R&D investments for these institutions have totaled over \$6 billion annually, emphasizing their confidence in the amazing research and technologies that happen here in Massachusetts.
9. *Massachusetts Benchmarks*, July 29, 2019, pages 7, 8.
10. *Massachusetts Benchmarks*, 2019, page 8.
11. *Massachusetts Benchmarks*, 2019. Page 8.
12. https://www.mass.gov/files/documents/2017/12/06/MassDOT_TransportationFacts2015.pdf.
13. <https://www.wgbh.org/news/local-news/2019/12/10/mbta-bus-system-performance-ripped-as-awful>.
14. Accenture, "Tackling the cost of a 5G build," August 3, 2018.
15. CTIA, The Race to 5G.
16. International Organization for Migration (IOM) World Immigration Report 2015.
17. "Global telemedicine market to experience 16.5% annual growth rate through 2023," Becker's Hospital Review, September 21, 2017.
18. CompTIA, Cyberstates 2019.
19. MassTLC's *Massachusetts Tech Pulse Index* report, 2019.
20. Mass Tech Collaborative, Massachusetts Innovation Economy, 2017.
21. National Center for Education Statistics.
22. National Center for Education Statistics and Burning Glass Technologies, December 2019.
23. Burning Glass Technologies, December 2019.
24. CompTIA, Cyberstates 2019.
25. Accenture, Cracking the Gender Code, 2016.
26. K-12 Computer Science Framework, 2016. Retrieved from <http://www.k12cs.org>.
27. Massachusetts Department of Higher Education, The Degree Gap 2016, page 59.
28. MassTLC's *Massachusetts Tech Pulse Index* report, 2019.
29. From interview with Anthony Williams, CHRO, Akamai Technologies.



MASS TECHNOLOGY LEADERSHIP COUNCIL

MASSTLC.ORG

420 Bedford Street, Suite 250
Lexington, MA 02420

TEL 781 993-9000

FAX 781 993-9009

CONNECT WITH US

Let's stay in touch. If you have any questions or would like to join MassTLC, visit masstlc.org, email membership@masstlc.org, or call (781) 993-9000.

