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[The Massachusetts Robotics Cluster]

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Executive Summary

The Massachusetts (MA) Robotics cluster is a rapidly growing cluster that includes both large global leaders in robotics as well as startups serving consumer, industrial, and government buyers in many markets. The cluster, just like any other in the nation, is exposed to overall national competitiveness issues including the administrative infrastructure. Political gridlock has prevented the US from creating a coordinated strategy for competitiveness and the US, as a result, is losing competitiveness relative to other nations. This report highlights these issues and elaborates on ones relevant to the MA Robotics cluster. Moving on to the state-level, our analysis reveals that MA is set apart by overall favorable macroeconomic and microeconomic competitiveness. Special attention in the state-level analysis is devoted to areas affecting the robotics cluster including the unique industry-academia-federal government collaboration. Subsequently, an overview of the global robotics industry provides the reader an understanding of the robotic market segments and the product offerings. The report then moves on to analyze the MA Robotics cluster in detail, where we found the cluster to be operating under a generally favorable business environment. Stronger coordination within the cluster and with other clusters is needed to stimulate growth. In addition, the problem of lack of venture capital attention to Robotics must be addressed. Recommendations to address these and other issues are made at the end of the report.

With its leading innovation infrastructure, MA as a state is well positioned to have a major contribution to the growth of national productivity. Robotics, inherently designed to increase the productivity of people and processes, fit naturally with this vision for MA. **Our vision for the MA Robotics Cluster** is to become an iconic US cluster greatly contributing to the growth of national productivity; the global leading hub for robotics research and development (R&D), product development and marketing; a home for large companies energized by startups.

Overview of the United States Economy

The United States (US) is the largest economy in the world, with a nominal GDP of $14.5 trillion in 2010—roughly a third of the world (US Bureau of Economic Analysis 2012). The country is well-endowed with natural resources and is recognized as one of the most innovative and productive economies in the world. In the World Economic Forum's Global Competitiveness Report, the country fell from top ranking in 2006–2007 to fifth place 2011–2012. Furthermore, the US's score in 2011–2012 was lower than the average of the top ten economies.

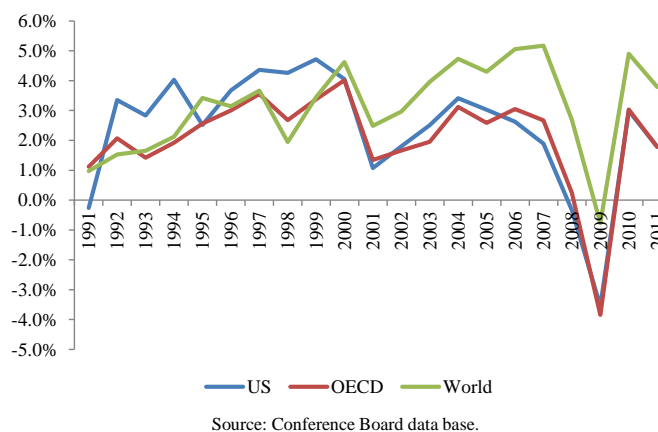The drop in competitiveness and ultimately productivity may be explained by a weak macroeconomic environment coupled with a perceived complex tax system and weakened public institutions. The pace of growth of the US economy has been slowing since even before the 2008–2009 recession. A lack of discipline in fiscal spending led to a significant public deficit, which peaked at 10.2% of GDP in

| | GCI 2011-2012 | | | GCI 2006-2007 | |
Country/Economy	Rank	Score	Country/Economy	Rank	Score
Switzerland	1	5.74	United States	1	5.80
Singapore	2	5.63	United Kingdom	2	5.56
Sweden	3	5.61	Denmark	3	5.55
Finland	4	5.47	Switzerland	4	5.54
United States	5	5.43	Japan	5	5.51
Germany	6	5.41	Finland	6	5.50
Netherlands	7	5.41	Germany	7	5.48
Denmark	8	5.40	Singapore	8	5.46
Japan	9	5.40	Sweden	9	5.44
United Kingdom	10	5.39	Hing Kong	10	5.37
Average Top 10		5.49	Average Top 10		5.52

Source: World Economic Forum, Global Competitive Report.

Figure 1. Global Competitiveness Ranking

US   OECD   World

Source: Conference Board data base.

Figure 2. Nominal GDP Growth Rates—US vs. Benchmarks

2009, and a net public debt of almost 70% of GDP in 2010 (Economist Intelligence Unit, 2012). Going forward, the country has to regain short-term public spending discipline and simultaneously foster innovation to fuel long-term competitiveness. Cuts in public spending may spur voices to protect the local economy and have it less exposed to foreign trade competition. This temptation

must be resisted and open trade guarded. Since 2009, the US economy has struggled to recover. Job creation has been low and the labor force 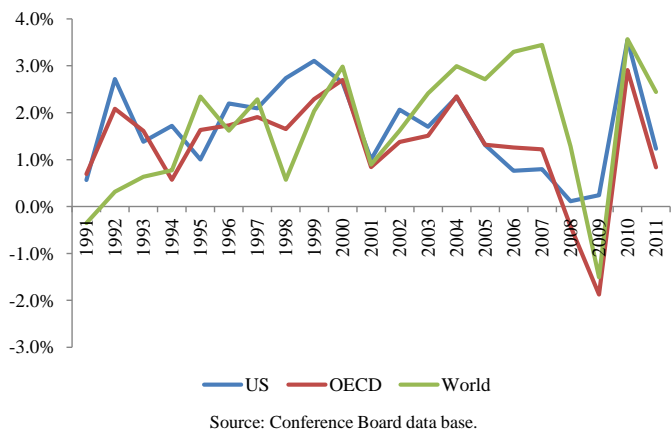has been declining since the mid-1990's, while households remain highly leveraged (US Bureau of Labor Statistics 2012). Nonetheless, some sectors—including healthcare, technology services, financial services, and higher education—have grown and become more productive, creating jobs that have cushioned the overall job destruction that occurred during 2008–2009. The need for productivity has resulted in the birth of new technology-driven industries. Among these is robotics; a large segment of robotics has grown to support productivity in industries such as auto manufacturing and helped to increase overall labor productivity by, for example, improving healthcare outcomes. In terms of social development measures, the US ranking has changed very little in the past 10 years - ranked nineteenth internationally in 2011. However, significant drops in ranking have registered in healthcare services (drop of 14 places in the last four years) and primary education enrollments (drop of 20 places in the past 11 years) (HBS ISC 2012).

Source: Conference Board data base.

Figure 3. Labor Productivity—US vs. Benchmarks

Composition of the US Economy by Cluster

The US economy is composed of a large number of clusters[1]. These clusters span many industries and levels of value. In the last decade, 23 of the top 25 traded clusters in the US economy lost share in the global market (Figure 4).

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[1] A cluster is a geographically proximate group of interconnected companies and institutions active in a particular field. Traded clusters include industries that sell products and services across economic areas (HBS ISC 2012).

This is evidence for loss of competitiveness of these clusters relative to competing ones globally, and can be explained at both microeconomic and macroeconomic levels, as discussed in the preceding section. Out of 42 clusters included in the International Cluster Competitive Project conducted by HBS Institute of Strategy and Competitiveness (ISC), financial services (with an 8.95% increase) and oil and gas products (with a 1.48% increase) are the only two clusters that have gained export share between 2000 and 2010 (HBS ISC 2012). Robotics connects directly to a group of related clusters that include automotive, medical devices, heavy machinery, biopharmaceuticals, motor-driven products, analytical instruments,
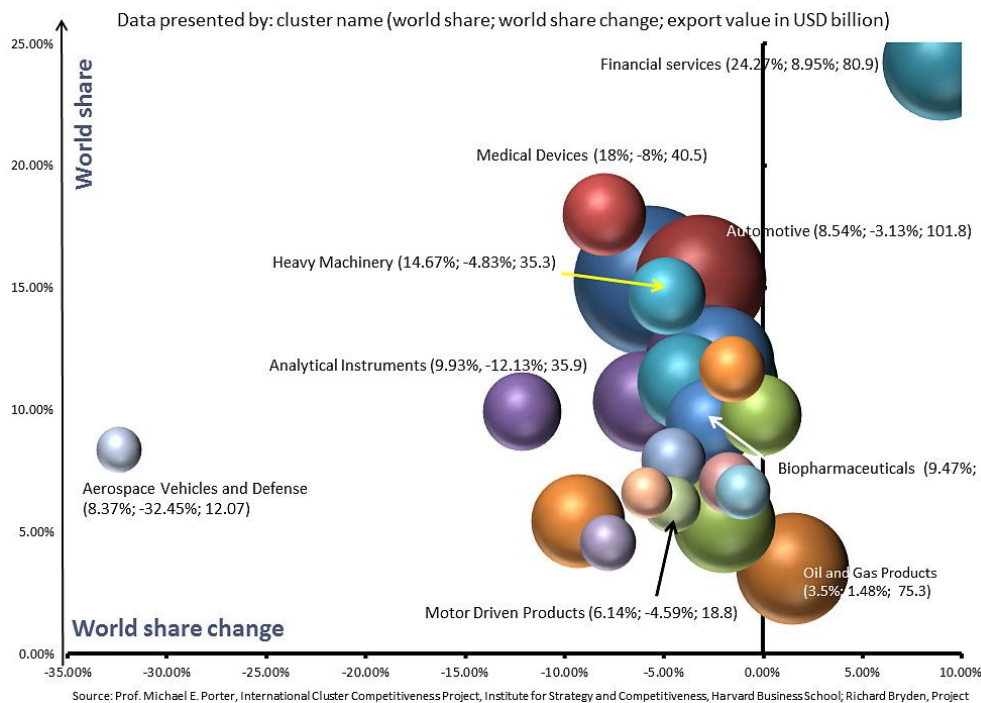
Figure 4. US Export Portfolio by Traded Clusters 2000-2010

aerospace vehicles, and defense. Due to the lack of national-level robotics-specific cluster data, the performance of these related clusters is indicated in Figure 4.

Quality of the National Business Environment

The quality of the US business environment is one of the determinants of the country's microeconomic competitiveness, and can be analyzed using the Porter's Diamond Model as follows:

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Factor Conditions (12, -10)

- Capital Markets Infrastructure (16,-15)
    + **Venture capital availability (7,-6)**
    - Soundness of banks (52,-39)
± Communications infrastructure (14,-8)
± Innovation Infrastructure (6,-4)
    + **University-Industry Research Collaboration (4,3); further enhanced with federal government collaboration**
    + **Availability of scientists and engineers (5,2)**
    ± **Quality of scientific research institutions (7,-6)**
- Administrative infrastructure (21,-12)
- Logistical infrastructure (20,-10)

Demand Conditions (13,-2)

+ **Government procurement of advanced technology products (4,13)**
+ **Market size / buyers' purchasing power**
± Buyer sophistication (10,-7)
- Presence of demanding regulatory standards (20,-13)
- Laws relating to information and communication technology (ICT) (17,-13)

Context for Firm Strategy and Rivalry (17,-13)

+ **FDI and Tech Transfer (32, 36)**
    + Unique tech transfer institutions that ensure utility of strong patent output
+ Strength of investor protection (5,0)
± **Intensity of local competition (16,-15)**
± Strength of auditing and reporting standards (27,-6)
- **Intellectual property protection (24,-21)**
- Impact of taxation on incentives to work and invest (31,-20)
- Prevalence of trade barriers (35,-20): temptation for protectionism as a result of recent economic conditions
- Distortive effect of taxes and subsidies on competition (59,-37)

Related and Supported Industries (11,-9)

+ **State of Cluster Development (8,-5)**
+ **Extent of Collaboration in Clusters (12,-10)**
- Local supplier quantity (12,-9)
- Local supplier quality (14,-12)
+ **Large amount of firms in hi-tech (electronics/semiconductors, auto and aircraft industries)**
+ High level of industrial specialization

Note 1: numbers indicate (GCI Rank, Change in GCI rank 2001–2011). Data from HBS ISC.
Note 2: Bolded issues are topics influencing the robotics cluster.

**Figure 5. United States Diamond**

Factor Conditions. As seen in the Global Competitiveness Index (GCI rankings), factor conditions in the US are worsening overall. Main areas of concern include the soundness of banks, the deteriorating administrative infrastructure, and the declining quality of air transport. Nevertheless, there are areas particularly influencing the robotics cluster that remain strong; these include innovation, science and technology education, and a healthy R&D environment where a unique collaboration exists between academia, industry, and the federal government.

Context for Firm Strategy and Rivalry (CSR). CSR is overall worsening with the key drivers for the negative trend being taxes, trade barriers and competition, and IP protection. One positive area that influences the robotics cluster and that is quickly improving is FDI and tech transfer. A better environment for FDI and tech transfer will ensure the marketplace adoption of the innovations produced by strong R&D.

Demand Conditions. Demand conditions have remained relatively strong. The key area of interest for robotics is government procurement of advanced technology, as a large portion of robotics industry is driven by defense procurement contracts (to be further discussed in the cluster analysis).

Related and Supporting Industries and Clusters (RSI). While the US consistently ranks in the top three for RSI, it has substantially worsened in the last two years, reaching a rank of eleventh. One area of concern related to robotics is the quality and quantity of local suppliers. As these measures worsen, the robotics industry is increasingly relying on offshore manufacturing.

Overview of the Massachusetts Economy
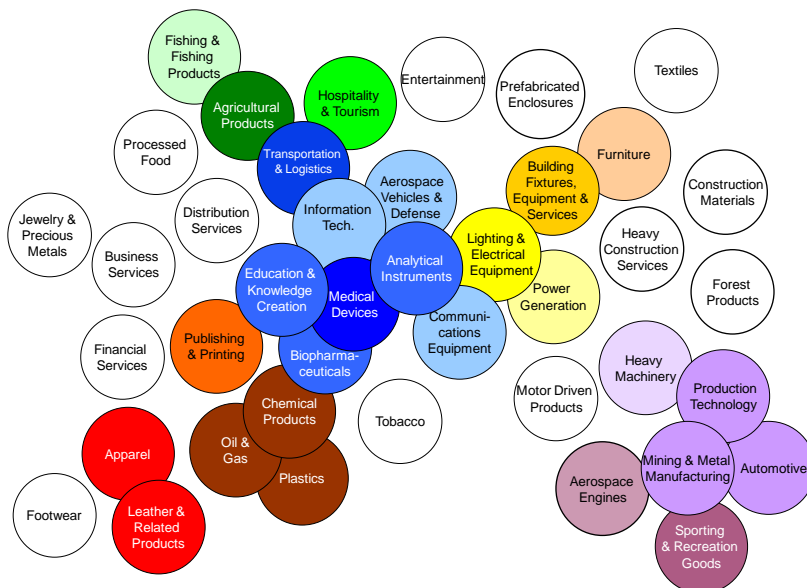
Note: clusters with overlapping borders or identical shading have at least 20% overlap (by number of industries) in both directions

Figure 6. Existing Clusters in MA.

Located on the northeastern coast of the United States, MA is one of the smallest states in terms of size, yet one of the richest in terms of GDP per capita. It has an area of 10,555 square miles (forty-fourth largest), a population of 6.6 million (fourteenth), and a nominal GDP per capita of $57,757, or $52,175 in real terms (fourth) (Bureau of Economic Analysis 2012). Throughout its history, MA has proven able to continuously upgrade its economy and allow its citizens to benefit from higher levels of income. Originally an endowment-based economy built around fishing and agriculture, MA has transformed itself into a knowledge-based economy. Currently, the state has a broad economy comprised of a wide array of industries, as seen in Figure 6.

Over the past 20 years, MA has outperformed the US in both GDP per capita (income) and GDP per employee (productivity), reaching $57,757 and $91,745, respectively, in 2010. GDP per capita growth for MA has been positive and outperforming that of the US overall, with higher momentum (Figure 8). Data suggest that part of
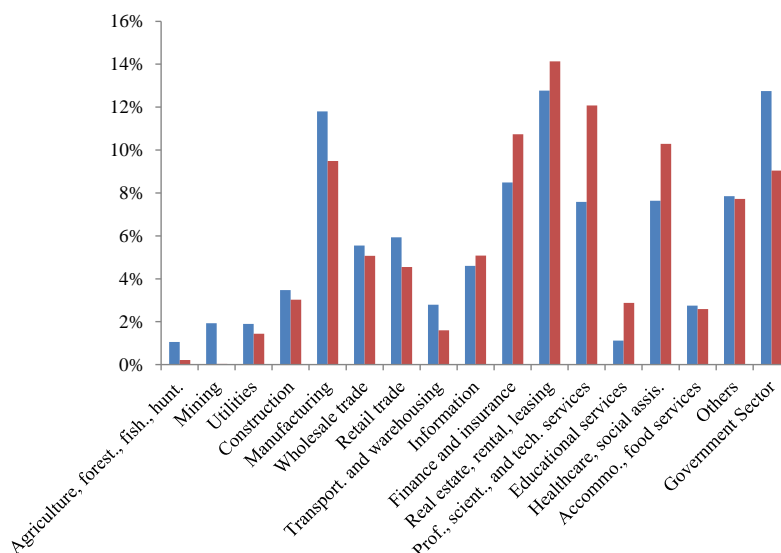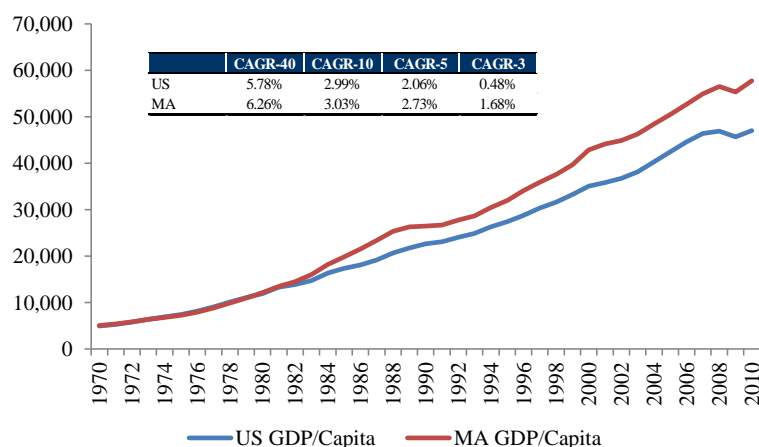

Figure 4. Industries GDP Contribution-—US vs. MA

Source: Bureau of Economic Analysis data base.

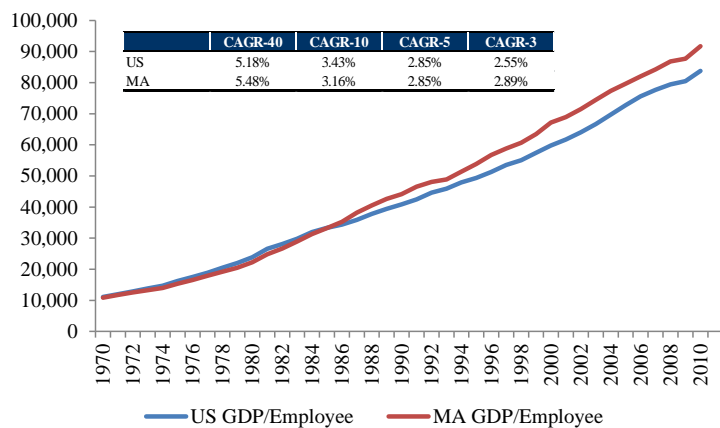this performance can be explained by efficiency gains, particularly since the 1990s. This coincides with the growth of industries spawned by new developments in technology, healthcare, financial services, real estate, and educational services. In MA, innovation input, measured as R&D spending, as well as innovation output, measured as patent registration, are among the highest in the US. MA R&D spending as a percentage of GDP grew from 5.0% in 2002 to 6.9% in 2007, while that of the US grew from 2.5% in 2002 to 2.7% in 2007[2]. Furthermore, MA R&D spending as a percentage of GDP surpasses the national level and that of such other nations as Finland, Sweden, Japan, South Korea,

	CAGR-40	CAGR-10	CAGR-5	CAGR-3
US	5.78%	2.99%	2.06%	0.48%
MA	6.26%	3.03%	2.73%	1.68%

Source: Conference Board data base.

Figure 8. GDP/Capita Growth—US vs. MA

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[2] Mass Tech Collaborative (2011). *Index of the MA Innovation Economy*. http://web27.streamhoster.com/mtc/index_2011.pdf accessed 3 May 2012

	CAGR-40	CAGR-10	CAGR-5	CAGR-3
US	5.18%	3.43%	2.85%	2.55%
MA	5.48%	3.16%	2.85%	2.89%

US GDP/Employee — MA GDP/Employee

Source: Bureau of Economic Analysis data base.

Figure 9. Productivity Level—US vs. MA

and Germany. In terms of innovation output, MA patents/million residents grew from 622 in 2006 to 931 in 2010, while that of the US grew only from 252 patents/million residents in 2006 to 267 in 2010[3].

Sectors in MA related to high technology, healthcare, and higher education cushioned, in part, the drop in overall economic activity during the 2008–2009 recessions. At the same time, sectors like real estate and financial services were less exposed and performed better than in other states. This resilience is particularly noteworthy given that the average fiscal spending for the past 10 years was lower in MA than in other states and lower than in the US economy as a whole. Job creation in MA, although sluggish after the dot-com bubble burst, has recovered and contributed to overall economic improvement. By the end of 2011, the state had regained half of the jobs lost during the 2008–2009 recession and layoffs had fallen below Q4 2007 levels[4].

Quality of the State Business Environment

Factor Conditions. Factor conditions in MA are generally positive. In terms of innovation infrastructure, MA is home to a sophisticated base for R&D and a unique culture of collaboration between academia, industry, and government (to be further discussed in the cluster analysis). The capital market infrastructure in MA is strong and includes an extensive risk capital network. Venture capital levels dropped from $1.063 billion in 2004 to $717 million in 2011 due to lack of capital as a result of the financial crisis of 2008–2009. Moreover, the financial services sector in general has

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3 Mass Tech Collaborative (2011). Index of the MA Innovation Economy. http://web27.streamhoster.com/mtc/index_2011.pdf accessed 3 May 2012
4 Chase (2011). The State of MA Economy. https://www.chase.com/online/commercial-bank/document/Massachusetts.pdf accessed 15 March 2012

proven more resilient in MA relative to the rest of the nation (Figure 7). The quality of the state's higher educational system is high. MA has the highest concentration of college students overall—and engineering and science students, specifically—compared to the rest of the country. The state is home to 3 of the top 15 research universities as measured by technology licensing revenues. That said, the interest in Science, Technology, Engineering, and Math (STEM) fields among high school students in MA has increased in the last 10 years but the state still lags by 8.7% below national average[5].
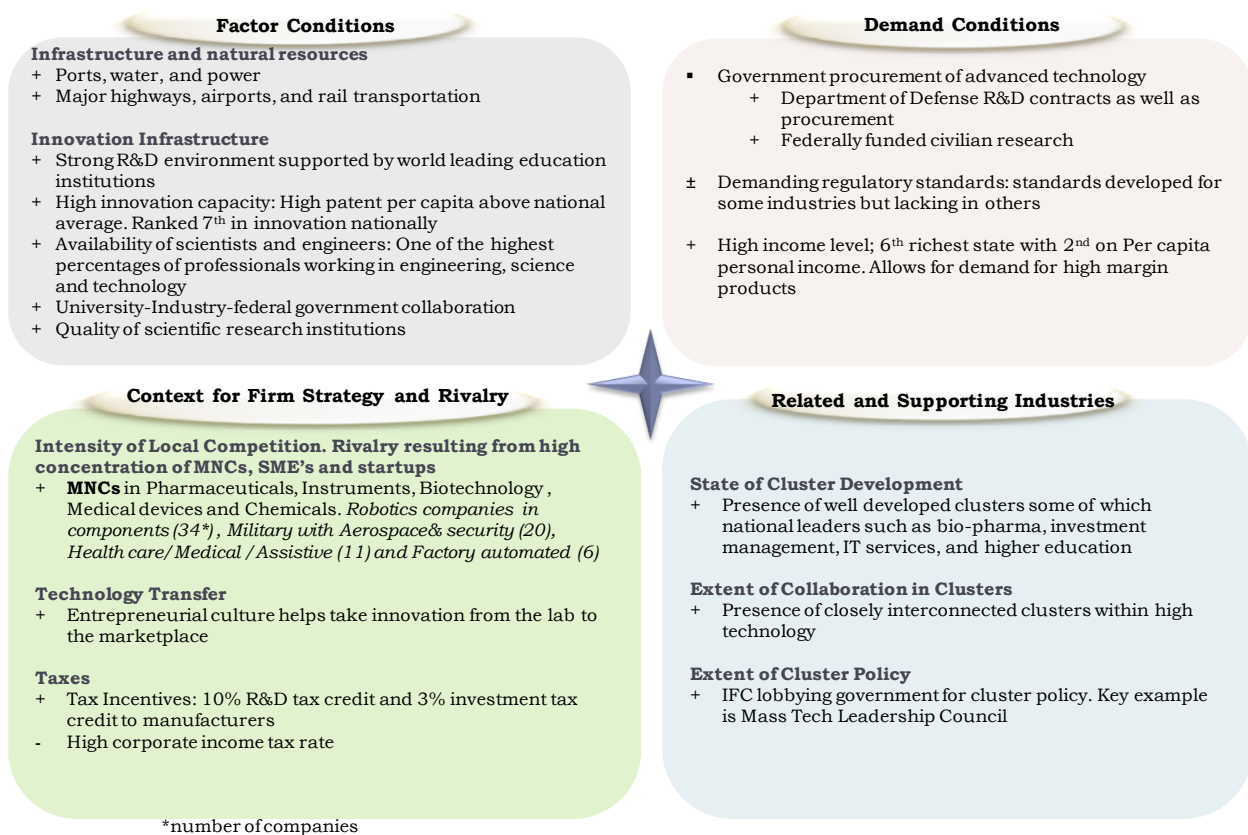
Factor Conditions

Infrastructure and natural resources
+ Ports, water, and power
+ Major highways, airports, and rail transportation

Innovation Infrastructure
+ Strong R&D environment supported by world leading education institutions
+ High innovation capacity: High patent per capita above national average. Ranked 7th in innovation nationally
+ Availability of scientists and engineers: One of the highest percentages of professionals working in engineering, science and technology
+ University-Industry-federal government collaboration
+ Quality of scientific research institutions

Demand Conditions

▪ Government procurement of advanced technology
  + Department of Defense R&D contracts as well as procurement
  + Federally funded civilian research

± Demanding regulatory standards: standards developed for some industries but lacking in others

+ High income level; 6th richest state with 2nd on Per capita personal income. Allows for demand for high margin products

Context for Firm Strategy and Rivalry

Intensity of Local Competition. Rivalry resulting from high concentration of MNCs, SME's and startups
+ **MNCs** in Pharmaceuticals, Instruments, Biotechnology, Medical devices and Chemicals. *Robotics companies in components (34*), Military with Aerospace& security (20), Health care/Medical /Assistive (11) and Factory automated (6)*

Technology Transfer
+ Entrepreneurial culture helps take innovation from the lab to the marketplace

Taxes
+ Tax Incentives: 10% R&D tax credit and 3% investment tax credit to manufacturers
- High corporate income tax rate

*number of companies

Related and Supporting Industries

State of Cluster Development
+ Presence of well developed clusters some of which national leaders such as bio-pharma, investment management, IT services, and higher education

Extent of Collaboration in Clusters
+ Presence of closely interconnected clusters within high technology

Extent of Cluster Policy
+ IFC lobbying government for cluster policy. Key example is Mass Tech Leadership Council

Figure 10. MA Diamond

Context for Firm Strategy and Rivalry (CSR). MA benefits from a high level of intensity of local competition. Multinational corporations (MNCs) are attracted to MA for its strong R&D

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[5] Mass Tech Collaborative (2011). *Index of the MA Innovation Economy*. http://web27.streamhoster.com/mtc/index_2011.pdf accessed 3 May 2012

infrastructure and its supply of engineering and science talents. These MNCs devote financial capital as well as other corporate resources to compete in the MA clusters, and therefore bring the latest technologies and best practices, which increases the overall level of competition. These MNCs are active in multiple clusters, including pharmaceuticals, instrumentations, biotechnology, medical devices, and IT services. MNCs are complemented by the presence of start-ups supported by a strong R&D infrastructure and venture capital availability. MA is among the top four states experiencing the largest increases in entrepreneurial activity over the past decade[6] and ranks as number three in the Entrepreneurial Index[7]. Taxes are another point of consideration for CSR. While MA in general has the highest corporate tax rate (8.0% currently; 8.75% in 2011)[8] of all states, specific tax incentive programs exist to encourage R&D and investments, such as the 10% R&D tax credit and 3% investment tax to manufacturers[9].

Demand Conditions. One of the important drivers for demand conditions in MA is federal government. This consists of government procurement of advanced technology products and R&D grants. A large portion of government R&D is contracted at Draper Labs (2010 budget of $493 million[10]) and Lincoln Labs (budget of $600 million[11]). Beyond R&D, the federal government procures advanced technology products for defense and civilian applications from MA-based companies. That said, this reliance on government spending for R&D and procurement contracts

[6] Fairlie, R. W. (2011). "Kauffman Index of Entrepreneurial Activity, 1996–1910." Ewing Marion Kauffman Foundation. Available at http://www.kauffman.org/uploadedfiles/kiea_2011_report.pdf.accessed 29 April 2012

[7] "New York, Washington and Massachusetts top list of best states for entrepreneurship" (2011). Accelerating Innovation: Focus on the Washington Innovation Ecosystem. innovate.typepad.com. 4 August. Available at http://innovate.typepad.com/innovation/2011/08/new-york-washington-and-massachusetts-top-list-of-best-states-for-entrepreneurship.html.

[8] Area Development Online Research Desk (2012). "Massachusetts Basic Business Taxes 2012." AreaDevelopment Online: Site and Facility Planning. www.areadevelopment.com. Available at http://www.areadevelopment.com/stateResources/massachusetts/massachusetts-basic-business-taxes-2012-45990.shtml. accessed 29 April 2012

[9] Massachusetts Alliance for Economic Development (2012). Webpage: Business Resources/Incentives. massecon.com. Available at http://massecon.com/business-resources/incentives#research_development_tax_-credit. Accessed 29 April 2012

[10] Draper Lab (2011). "Profile: Draper Laboratory—Who We Are." The Charles Stark Draper Laboratory. Available at http://www.draper.com/profile.html; accessed April 2012.

[11] Postol, T. A. (2012). "Opinion: MIT's Missile Defense Cover-Up." [MIT] Tech Online Edition. 5 February. Available at http://tech.mit.edu/V127/N66/postol.html; accessed April 2012.

exposes MA to a unique risk; as the federal government trims its budget to control fiscal spending, MA may be hit hard with declining federal contracts.

Related and Supporting Industries and Clusters (RSI). MA is home to a spectrum of well-developed and interconnected clusters (Figure 6) that vary widely in size and age. Institutes for Collaboration (IFC) support these clusters in various activities, including lobbying government for policies, organizing events and conferences, arranging for training, and facilitating financing. These activities help connect the professionals and organizations of their clusters. Some of the most notable of these IFCs are the Massachusetts Technology Development Corporation, the Massachusetts High Technology Council, the National Venture Capital Association, the MIT Office of Technology Transfer, and the Massachusetts Biotechnology Council.

Focus of Recent National and State Policies

National Level: short-term economic concerns currently dominate the attention of national politicians. Policies are directed at that dealing with the immediate needs (e.g., public budget balancing, short term unemployment rate changes) as opposed to long term competitiveness issues. Nevertheless, the Obama administration has taken some promising steps for improving long-term productivity namely the 2011 launching of the Advanced Manufacturing Partnership, with a budget of $500 million to invest in developing technologies[12]. This plan directly affects robotics at a national level as well as the MA robotics cluster. As part of this plan, the Obama administration has announced four main steps at a federal government level (i) building domestic manufacturing capabilities in critical national security industries, (ii) reducing the time to develop and deploy advanced materials, (iii) investing in next-generation robotics (National Robotics Initiative), and (iv)

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[12] White House (2012). Press Release: President Obama Launches Advanced Manufacturing Partnership. http://www.whitehouse.gov/the-press-office/2011/06/24/president-obama-launches-advanced-manufacturing-partnership accessed 4 May 2012

developing innovative energy-efficient manufacturing processes. The National Robotics Initiative mobilizes multiple entities (namely the National Science Foundation, National Aeronautics and Space Administration, National Institutes of Health and the Department of Agriculture) to make available today $70 million to support research in next generation robots.

State Level: To help improve MA competitiveness the MA legislature, in August 2010, approved and issued "An Act Relative to Economic Development Reorganization". As a direct product of this Act, the state economic development council of MA prepared a master plan entitled "Choosing to Compete in the 21st Century: An Economic Development Policy and Strategic Plan for the Commonwealth of Massachusetts"[13]. This plan sets focus on bolstering "innovation sectors"; among others, healthcare, higher education, technology, financial sectors, life science, and clean energy. The plan was released by a joint committee of the House of Representatives and the Senate, in January 2012.

Overview of the Robotics Industry

Robotics Products

Robots are systems that integrate electrical, mechanical, hardware, and software elements. Robots are designed to be able to take independent action and sometimes to sense the environment and act accordingly. Robotics products can be organized under two main categories: industrial robots and service robots.

Industrial Robots

Industrial robots are stationary robots used in manufacturing processes for purposes of automation. The main benefit of these robots is higher speed and more accuracy than can be obtained from

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[13] Documents available on http://www.mass.gov/hed/docs/eohed/economicdevpolicystrategy.pdf accessed 28 April 2012

human labor. Typical industries using robots are automotive, light manufacturing, heavy manufacturing, and food processing. The following are the most common applications for industrial robots (Frost and Sullivan, 2011):

- **Assembly:** robots are capable of automating assembly tasks in factories.

- **Material removal:** includes grinding, polishing, cutting, and sanding, which are processes well suited for robots due to the need for high precision.

- **Material joining and welding,** with most current robots focused on arc welding.

- **Loading and unloading, palletizing, and dispensing** material and components in a process.

- **Packaging:** this is most popular in the food processing industry. Protects humans from high ergonomic risks in performing repetitive tasks.

Service Robots

These are mobile robots that are designed to assist, or service, humans in a wide variety of tasks. Service robots operate with a control system that allows them to respond to their environments. Service robot markets are relatively immature and promise strong future growth (Frost and Sullivan, 2010). The service robot category is further segmented by use: personal and professional.

Personal Service Robots. These are domestic robots performing one or several tasks to service humans at home. Such tasks may include vacuum cleaning, lawn mowing, physical assistance in standing up, sitting down, and moving around the house. Recent developments are targeting much more sophisticated robots to act as personal butlers.

Professional Service Robots. These mobile robots are designed for professional use, as opposed to domestic, and are often deployed in dangerous, dirty, distant, or unique environments. Each robot is designed for a specific application. The variety of applications includes surveillance, inspection, and

maintenance on the battlefield, underwater, and in space. Professional service robots are much more sophisticated than their domestic counterparts and therefore sold at higher prices.

Global Market for Robotics and Growth Rates[14]

The global market for robots is a growing one and reached a size of $9.44 billion in 2010. The market is roughly split 60% for industrial robots and 40% for service robots.

Industrial Robots Market

Industrial robotics was hit hard during the 2008–2009 global recession but made a strong recovery in 2010, where sales recovered by 50% to US$5.7 billion; however, this is still below 2008 levels. The automotive industry is leading the global growth in industrial robotics as automakers compete to become more
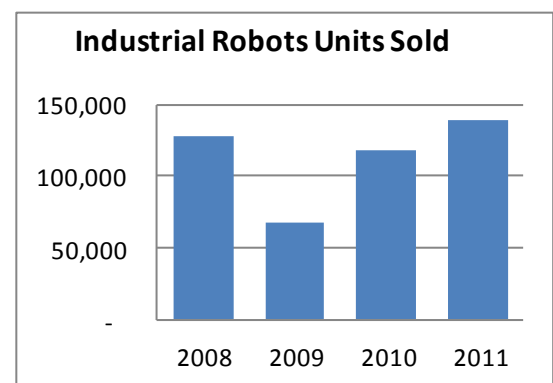
Figure 11. Industrial Robots Market (IFR 2012)

competitive in manufacturing (IFR, 2011). This market is growing at an average rate of 4.2% per year (Massachusetts Technology Leadership Council, 2009).

Service Robots Market

While the service robot is currently the smaller segment ($3.8 billion), its value is growing at a rate of 17.5%—faster than that of the industrial robots segment. The growth rates within service robots vary widely according to the different subsegments; personal robots are growing at 11.5% (below average) and

	Professional Service Robots	Personal Service Robots
2010 Units	1,377	2.2 million
2010 Sales	$3.2 billion	$540 million
Average $/Unit	$2.3 million	$245
% of Segment	85%	15%

Table 1. Service Robots Market Data (IFR 2012)

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[14] Data in this section, unless otherwise specified, is taken from the International Federation of Robotics (IFR, 2012

health assistance robots are growing at 19% (above average).

Also interesting within the service robots market is the variation in unit price. Personal service robots generate far lower prices and higher volumes than professional service robots. This can be explained by the fact that consumer robots are produced for a mass market with different pricing and marketing approaches than professional robots. Professional robots tend to be more sophisticated, more reliable, and custom designed for specific business uses. Currently, the professional service sub-segment represents 85% of the $3.8 billion service robots segment, and the remaining 15% is filled by the personal service sub-segment. Each sub-segment includes robotics companies that sell to various industries, as described in the pie chart below.
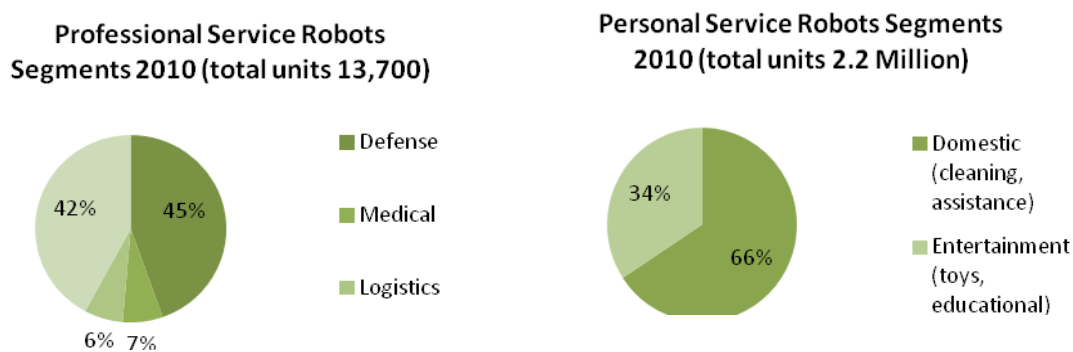
Figure 12: Service Robots Market Data

Profile of Key Robotics Players Globally

	FANUC	KUKA	iRobot	adept
Headquarters	Yamanashi, Japan	Augsburg, Germany	Bedford, MA	Pleasanton, CA
Founded	1965	1898	1990	1983
# of Employees	5,060	6,471	619	183
Revenue	JPY 522B ($6.3 B)	E 1.357B ($1.8B)	$466 M	$61 M
Market Cap	JPY 3035B ($36.7B)	E 535M ($712M)	$763 M	$47 M

Table 2. Key Robotics Pure-Play Companies (CapitalIQ, 2012)

FANUC Corporation: FANUC, the Japan-based industrial robot company, had its beginnings as part of Fujitsu developing numerical control (NC) and servo systems. It is now a leading robotics company with clients including the US and Japanese automobile and electronics manufacturers. Automotive customers include GM, Ford,

Peugeot Citroën, and Volkswagen. The company is the leading supplier of industrial robotics in North and South America, with over 200,000 robots installed (Hoovers, 2012).

KUKA AG: **KUKA AG** is an old Germany-based company focused on industrial robotics, with clients in various industries including automotive, electronics, plastics, and solar power. Its robotics and systems divisions provide planning and project management services for factories as part of the installation of industrial robots. KUKA has operations in Asia, Europe, and the Americas and makes about 60% of its sales in Europe (Hoovers, 2012).

iRobot Corporation: Originating from the Massachusetts Institute of Technology (MIT) in 1990, iRobot is a service robot company. The company designs and manufactures service robots for the consumer, government, and industrial markets worldwide. iRobot's home-consumer robots (roughly half of sales) are focused on performing time-consuming domestic activities. On the other hand, the defense and industrial robots (roughly the other half of sales) perform sophisticated tasks, such as battlefield reconnaissance and bomb disposal, and special tasks in the marine environment. Its consumer products are sold through a chain of retailers, while its professional products are made to contract directly with the end customer (One Source, 2012).

Adept: A 29-year-old company based in California, Adept has evolved into a high-quality automation products supplier. The robots it sells can handle, assemble, test, inspect, and package goods in the electronics, food processing, automotive component, and pharmaceutical industries. To differentiate itself from competitors, Adept uniquely integrates its robots' motions-controls technology with vision-guidance technology (Hoovers, 2012).

Trends in the Robotics Industry

Industrial Robots' Purpose: Robots as Co-workers. Robots were originally conceived to substitute for humans, but the recent trend has been for robots to work alongside humans to enhance

labor productivity. Advanced interfaces are enabling enhanced coordination between humans and robots (Frost and Sullivan, 2011). As technology advances, it is becoming increasingly possible to design robots to interact with humans, as opposed to traditional automation-oriented robots that, due to lack of ability to interact with humans, were designed to perform specific tasks—effectively replacing humans.

Integration. For industrial automation, multiple technologies are now being integrated to yield better outcomes. One key element allowing this integration is affordability; as technology advances and the cost of components drops, it becomes more affordable to integrate components to build more sophisticated robots. An example can be found in packaging operations, where a vision system that verifies box size is integrated with a mechanical system for placing labels on cases. While such system 10 years ago would cost around $100,000 and include the complexity of multiple cameras, the same outcome can be achieved today by integrating advanced vision systems into a robot for approximately $30,000[15].

Massachusetts Robotics Cluster

Robotics Value Chain

Aside from the sales process, industrial and service robots share similar steps in the value chain. For industrial robots, the sales effort occurs at the beginning of the chain when companies bid for R&D contracts from the government or submit bids for procurement from both government and private companies. Service robot companies typically manufacture the products first and then push them to customers through retail channels. Some service robot companies, like iRobot, sell through multiple retail channels, including superstores, and directly to consumers via their own websites. MA

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[15] Thryft, A. R. (2011). "Blog: Top 5 Robotics Trends of 2011." DesignNews. 7 February. Available at http://www.designnews.com/author.asp?section_id=1386&doc_id=236475&page_number=2 and accessed April 2012.

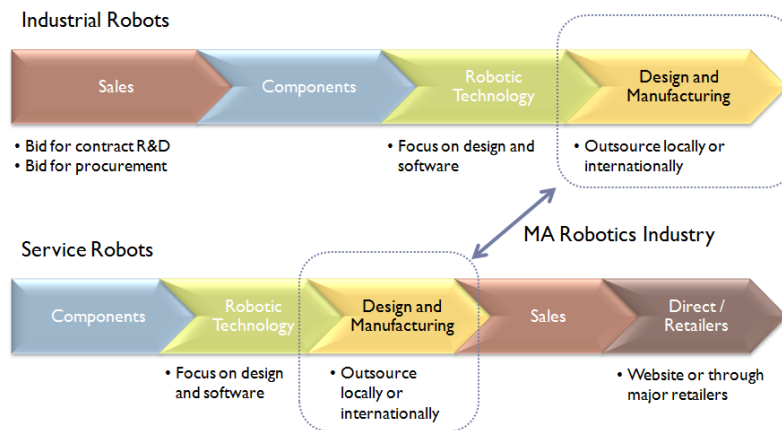Robotics companies are active in the Design and Manufacturing stage of the value chain. While R&D and product development is done in-state, manufacturing is done in other states or abroad. Department of Defense often mandates that its procured products be made in the US for security reason. Due to this fact, MA-based robotic companies will outsource

Figure 13: Robotics Value Chain.

manufacturing to other states (e.g. iRobot outsourcing manufacturing to North Carolina) even if less cost competitive compared to off shoring to China.

History of the Robotics Cluster in MA

The seeds of the cluster were sown in 1960s, when the MIT Artificial Intelligence (AI) research group was founded. Much groundbreaking research was unde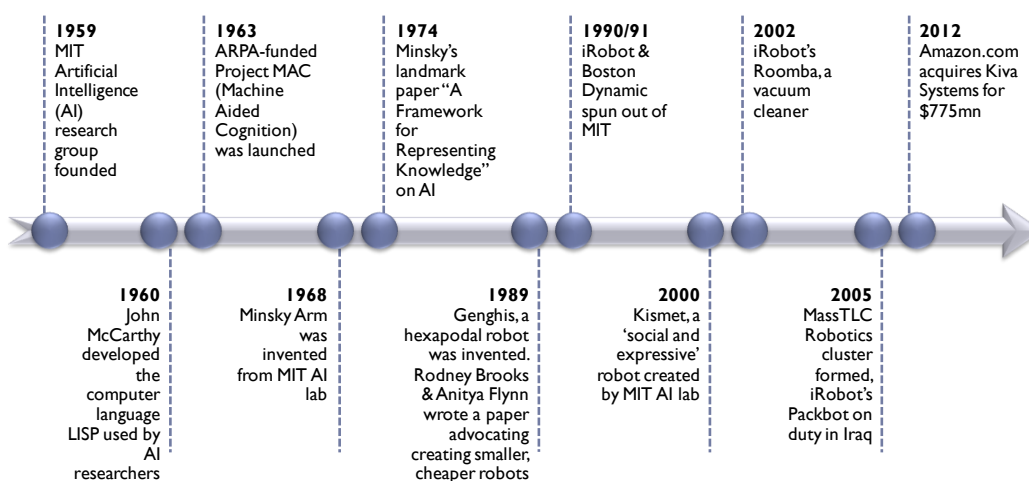rtaken during this initial period, often funded by the US Department of Defense (DOD) through the Advanced Research Program Arm (ARPA). John McCarthy

Figure 14: Timeline of the Robotics Cluster in MA

developed the computer language LISP, widely used by AI researchers, while the Minsky Arm was

invented in the AI lab. It took another 30 years after the AI lab was founded before the first startup spin-offs were launched—iRobot and Boston Dynamics[16]- and an additional 10 years for these companies to introduce significant products to the market. iRobot produced the Roomba self-operated vacuum cleaner, followed by the Packbot, a robot deployed in Iraq to defuse bombs.[17] Another significant milestone was the recent acquisition of Kiva Systems by Amazon.com for $775 million in March 2012.[18] This acquisition marks an inflection point in the cluster as it indicates to investors that sizable exit returns are achievable in this industry.
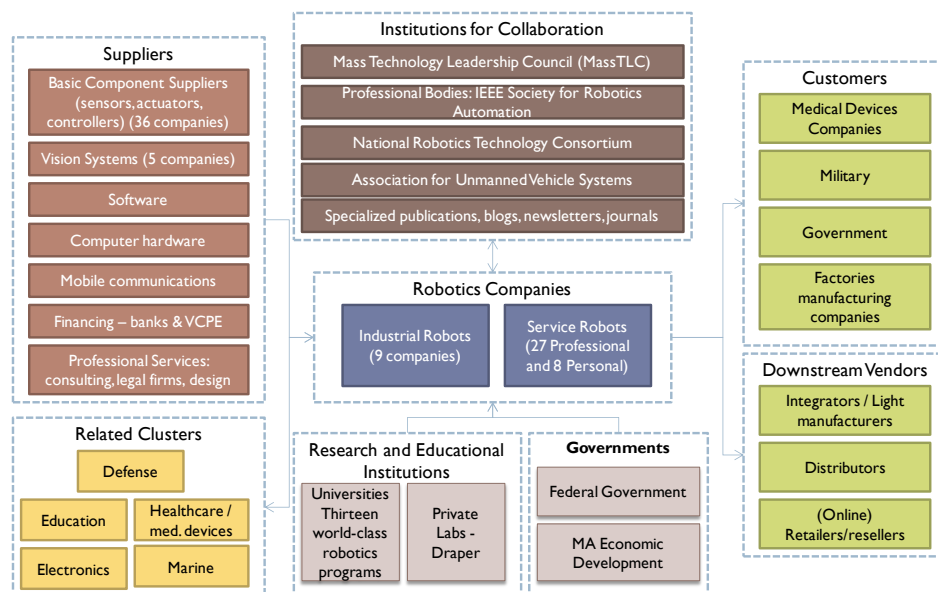
Robotics Cluster Map

Figure15. MA Robotics Cluster Map

Despite the fact that the MA robotics cluster is an emerging one, various actors are already involved in the ecosystem under well-defined categories (Figure 15). At the core of the ecosystem are the robotic companies, divided into industrial and service robots. One of the most important linkages in the cluster is the unique industry-academia-federal government interdependence (elaborated in Figure 16). The key academic institutions and research labs will be discussed in detail in the factor conditions analysis to follow. Furthermore, the robotics companies are supported by suppliers of services and products.

[16] BostonDynamics (2012). Changing Your Idea of What Robots Can Do. Available at http://www.bostondynamics.com. Accessed 30 April 2012
[17] iRobot Corporation (2012). Webpage: Robots That Make a Difference. Available at http://www.irobot.com. Accessed 27 April 2012
[18] Rusli, E. M. (2012). "Amazon.com to Acquire Manufacturer of Robotics". 19 March. Available at http://dealbook.nytimes.com/2012/03/19/amazon-com-buys-kiva-systems-for-775-million/ accessed 3 May 2012

Currently, there are nineteen companies operating in the software and vision systems within the cluster and supply the vital components to robotic companies that focus on building robots for industrial and service applications. BBN Technologies, founded by MIT professors and students and
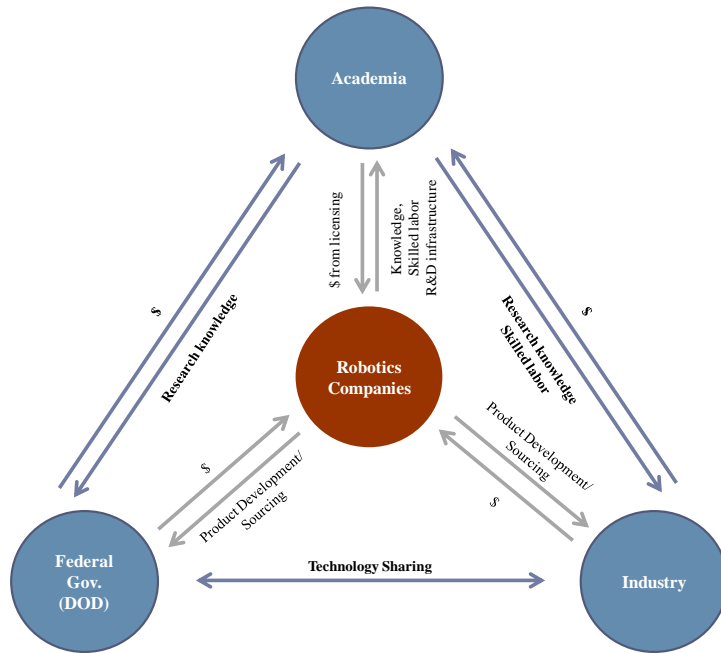

Figure16. Linkages between Robotics and Key Actors

acquired by Raytheon in 2009 is one such company; it pioneered several technologies in acoustics and computer-networking essential to developing autonomous robotic systems.

Cognex, an MIT spin-off with a presence in over 50 countries, provides another example of a company that supplies important components in the robotics value chain—machine vision systems. It was founded in 1981 to address the burgeoning market in artificial intelligence, developing integrated solutions—hardware and software solutions—to other companies in the value chain. There are more than 80 companies that operate within the cluster boundaries ranging from a small, early-stage start-ups to large companies. The table below includes a list of important companies organized by category:

Consumer	iRobot, QRobotics, Gears Educational Systems
Automation	Barrett Technology Inc, BlueShift Technologies, Brooks Automation
Defense	iRobot, Scientific Systems, Textron Systems
Marine	Bluefin Robotics, Teledyne Benthos, Ocean Server Technology, Inc.
Components - Software	Microsoft, The Math Works (Matlab), Ratheon BBN Technologies
Components - Sensors	Valde Systems, Inc., Cognex, Harmonic Drive Technologies
Components - Engineering	Electromechanica, Boston Engineering, Protonex
Medical Devices	Myomo, SensAble Technologies, VECNA

Table 3. Examples of Robotics Companies in Boston

The cluster is linked to other related clusters, namely defense, education, electronics, healthcare/medical devices, and marine that both buy robotics products and share technologies with robotic companies (these are referred to as 'industry' in Figure 16). IFCs exist to support the cluster growth and are discussed in detail in a separate section of this report to follow.

Performance of the Robotics Cluster

Data on economic performance for the cluster is scarce given its emerging-cluster status, yet MassTLC collected data through a survey it conducted in 2008. The survey results yielded encouraging signs that the cluster was sizeable and growing. In 2008, it registered sales of $1 billion among all of ~80 companies with an average annual growth of 47%; and these companies hired around 2,500 employees, 90% of which were local residents of MA. However, the robotics cluster is highly dependent on government as a source of funding for both R&D grant and procurement contracts. Close to half of sales in 2008 were derived from government, with little to no federal funding for home robotics research. Since government spending on robotics is mostly out of the control of the cluster, this significant dependence on government is a large risk for the cluster market, particularly in the context of cuts in federal spending due to accumulating fiscal deficits. In addition, one player had a significant market share in cluster: a third of the 2008 sales were generated by iRobot. That said, former iRobot employees are spinning off new start-ups in the field. The MassTLC report also noted an encouraging fact: About 40% of companies in the cluster were start-ups younger than six years. These startups promise to bring new innovation and create jobs within the cluster in the coming years.

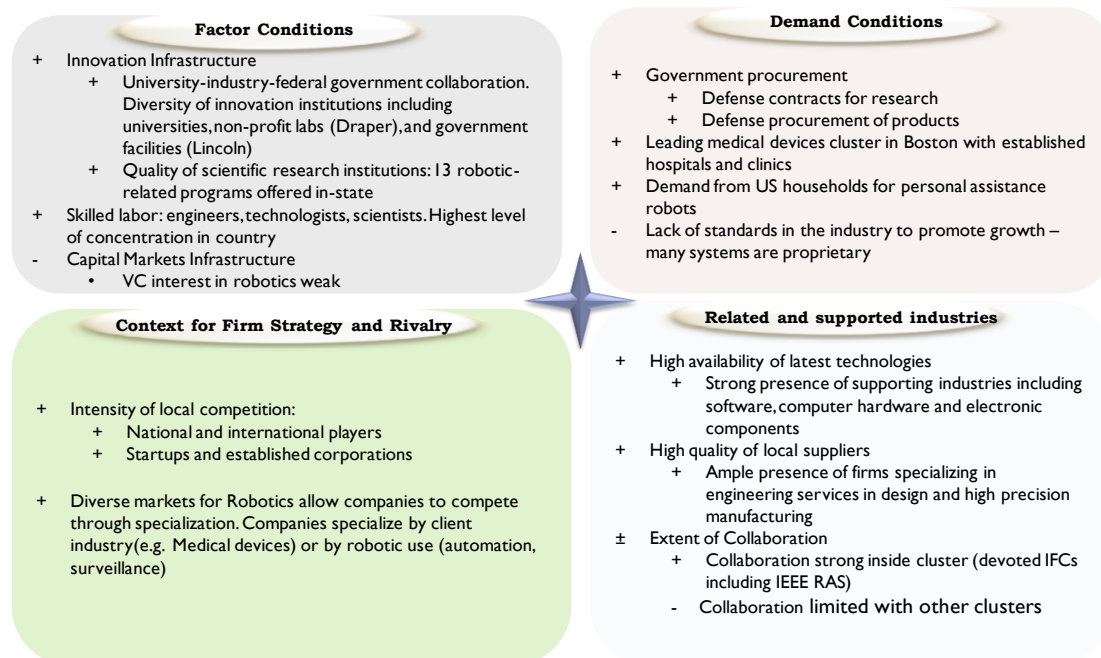## Massachusetts Robotics Cluster: Quality of the Business Environment

Factor Conditions
+ Innovation Infrastructure
    + University-industry-federal government collaboration. Diversity of innovation institutions including universities, non-profit labs (Draper), and government facilities (Lincoln)
    + Quality of scientific research institutions: 13 robotic-related programs offered in-state
+ Skilled labor: engineers, technologists, scientists. Highest level of concentration in country
- Capital Markets Infrastructure
    • VC interest in robotics weak

Demand Conditions
+ Government procurement
    + Defense contracts for research
    + Defense procurement of products
+ Leading medical devices cluster in Boston with established hospitals and clinics
+ Demand from US households for personal assistance robots
- Lack of standards in the industry to promote growth – many systems are proprietary

Context for Firm Strategy and Rivalry
+ Intensity of local competition:
    + National and international players
    + Startups and established corporations
+ Diverse markets for Robotics allow companies to compete through specialization. Companies specialize by client industry (e.g. Medical devices) or by robotic use (automation, surveillance)

Related and supported industries
+ High availability of latest technologies
    + Strong presence of supporting industries including software, computer hardware and electronic components
+ High quality of local suppliers
    + Ample presence of firms specializing in engineering services in design and high precision manufacturing
± Extent of Collaboration
    + Collaboration strong inside cluster (devoted IFCs including IEEE RAS)
    - Collaboration limited with other clusters

Figure 17: Robotics Cluster Map

Factor Conditions

Factor conditions are the main competitive advantage of the Massachusetts robotics cluster relative to competing clusters in the US. The strong R&D infrastructure and high R&D budgets are powerful factor conditions when combined with highly specialized human capital and unique industry-academia-federal government integration. Factor conditions are particularly important for the robotics cluster as the success of robotics industry is driven by technology development. The following are the key players in the R&D and human-capital sphere:

National Labs. The MIT Lincoln Laboratory is a federally funded R&D center focused on national security technology. Among its key mission areas are space control, air and missile defense technology, communication systems, intelligence, surveillance, and reconnaissance technology.

With a technical staff of about 1,500 and a budget of $600+ million[19], it operates a main complex in Lincoln, MA, with nine facilities.

University Labs. The large number of universities in Massachusetts include a number of labs related to robotics. Examples include the MIT Media Lab, the MIT Artificial Intelligence Lab (the originator of iRobot), Harvard University's robotics lab, Northeastern University's Marine Science Center, and UMass–Lowell's robotics lab. These facilities operate under a wide range of budgets and have been instrumental in nurturing the specialized human capital in robotics.

Nonprofit Organizations. The Draper Lab is a key player in the MA robotics cluster. It is a not-for-profit R&D center focused on advanced technology in security, space exploration, healthcare, and energy. With a staff of +1400 (70% of whom are technical) and 2010 revenues of $493 million[20], it is a leading facility for the advancement of robotics technology. Draper is, additionally, very engaged in the technology sphere in Massachusetts, organizing science festivals, speaker events, scholarships, and financial contributions.

Academic Programs. The educational research institutions in MA provide thirteen robotics-related programs (list included in MTLC report, 2009). These programs supply the skilled talent pool for the robotics cluster. A case in point is Worcester Polytechnic Institute, which became the first university in the nation to offer a bachelor's degree in robotics engineering and offering PHD in 2010.[21] The 13 main academic institutions within the cluster produce approximately 2,000 computer science graduates each year.

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[19] Postol, T. A. (2012). "Opinion: MIT's Missile Defense Cover-Up." [MIT] Tech Online Edition. 5 February. Available at http://tech.mit.edu/V127/N66/postol.html; accessed April 2012.
[20] Draper Lab (2011). "Profile: Draper Laboratory—Who We Are." The Charles Stark Draper Laboratory. Available at http://www.draper.com/profile.html; accessed April 2012.
[21] Worcester Polytechnic Institute (2010). "WPI to Offer a PhD in Robotics Engineering." 6 April. Available at http://www.wpi.edu/news/20101/rbephd.html. accessed 22 April 2012

Venture Capital. One disadvantage in terms of factor conditions is weak attention that venture capitalist give to robotics[22]. Most top VC firms—including Matrix Partners, Polaris Venture Partners, North Bridge, Prism, and FlyBridge Capital—have no dedicated robotics platform[23]. Robotics products are spread across a wide range of industries (e.g. defense, healthcare, home appliances) and these various industries have separate investment platforms within VC firms. This results in a lack of dedicated investment platforms for robotics with a deep understanding of the products, their market potential, and their technological developments. Robotic entrepreneurs complain that there is no go-to VC partner specializing in robotics. This is particularly a problem due to the networking-intensive nature of capital-raising environment. VCs voice concerns about market risk; the market risk—the fact that roughly half of robotics revenue comes from defense—will change due to the higher expected growth rates in non-defense segments. While robotics is generally capital intensive, continuing government and nonprofit grants will help with initial capital needs, and creative business model will result in lower capital intensity. Recent success stories will also encourage investment with iRobot's market cap near $1 billion and Kiva's being acquired by Amazon.com for near $775 Million (CapitalIQ, 2012). In summary, as the cluster grows, product development cycles shorten, and companies generally become more profitable the concerns voiced by venture capitalists will be mitigated.

Context for Firm Strategy and Rivalry (CSR)

CSR in the MA robotics cluster is generally positive. The diverse related clusters—education, medicine, and defense, for example—provide ample markets for companies to compete through specialization. Robotics cluster is a vibrant one that encourages many start-ups (40% of companies -

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[22] In 2011 $160-200 million was invested in robotics nationally compared to $6.9 billion for internet startups (GigaOm.com)
[23] As indicated on individual companies websites

MTLC, 2009) and spin-offs from established labs and/or companies, often giving birth to national and international players over time.

Demand Conditions

The MA robotics cluster has sophisticated demand conditions. In the medical sector, leading medical devices companies cluster in Boston around established hospitals and clinics and therefore represent a source of demand for robotics. Furthermore, DOD contracts for R&D and procurement demand high quality due to the sensitivity of the expected application. In terms of personal robots, US consumers are increasingly demanding quality personal-assistance robots as these consumers age and the nature of home assistance tasks becomes sophisticated. One weakness expressed by service robot companies is the lack of service robot-wide standards. Such standards would allow for a larger number of companies to develop products which in turn increase complements, and eventually the range of product offering and total sales.

Related and Supporting Industries (RSI)

RSI for MA Robotics has strengths and weaknesses. The availability of latest technology is high and comes from three sources: first in-state developed robotic-specific knowledge and technology (e.g. iRobot service robot technology), second technology brought in by robotic MNCs (e.g. Adept), and finally technology transferred horizontally from other industries (e.g. batteries). As for local suppliers, the cluster is home to a large collection of product (e.g. electronic component) and service (e.g. engineering firms) suppliers. However, industry professionals mention the lack of standardized robotic-specific components in the supplier marker; most components are either custom developed for a robotic company or already exist to serve other industries. This problem is traced to the lack of standardization in the design of robotics themselves. IFCs are active in promoting the robotics cluster (see IFC discussion to follow), but inter-cluster collaboration remains weak as expressed by industry participants.

Institutes for Collaboration in the MA Robotics Cluster

Institutes for collaboration (IFCs) related to the robotics cluster in MA are a key factor in insuring the long-term success of the cluster. These institutes play different roles; the groups of cluster entities included in the collaboration are unique to each IFC.

Business Associations: Mass Technology Leadership Council (MassTLC or MTLC): MTLC is a business association that addresses the critical leadership issues of innovative technology and technology-enabled companies. The organization aims to support entrepreneurship and companies that develop and deploy technology across multiple industry sectors.

- **Impact on factor conditions**: MTLC is organizes educational programs and speaker and industry events which help raise the level of specialization within technology industries.

- **Impact on CSR**: MTLC is engaged in lobbying for technology policies that promote innovation, entrepreneurship and competition.

- **Impact on RSI:** the programs and events held by MTLC facilitate networking between professionals in the various technology-driven industries in MA. This helps expose robotics to related and supported industries.

Professional Bodies: IEEE Robotics and Automation Society: The IEEE Robotics and Automation Society (IEEE RAS) is a professional society of the IEEE, the world's largest professional association for the advancement of technology. The IEEE RAS objectives are scientific, literary, and educational; the society's main benefits are publications and conferences[24]. Given IEEE RAS's focus, its impact on the MA robotics cluster is mainly in factor conditions, where its publications and conferences help advance the specialized robotics human capital.

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[24] IEEE (2012). "About Us." IEEE Robotics and Automation Society. Available at http://www.ieee-ras.org/society.html; accessed April 2012

National Robotics Technology Consortium (RTC): The RTC is a nonprofit industry organization formed in 2008 to speed the creation and deployment of ground robotics technology for defense and government applications. Its membership includes over 200 corporations, universities, and nonprofit organizations involved in the robotics industry (RTC, 2012). In 2008, the RTC won a seven-year, $170 million award from the Department of Defense for research to be performed by RTC members (RTC, 2012). Aside from promoting research, RTC holds a small number of events to support robotics and encourage collaboration between various entities in the robotics value chain.

Competing Clusters

Several robotics clusters exists in the US and the three prominent ones are located in Boston, Pittsburgh, and Silicon Valley. Despite their geographical location difference, these clusters share two common features. Firstly, the clusters are fueled by R&D work undertaken by leading universities in each region. Secondly, they depend heavily on government contracts for research and procurement. In terms of

	Boston	Pittsburgh	Silicon Valley
Large Companies	• iRobot • Foster-Miller • Boston Dynamics	• RedZone Robotics • RE2	• SRI International • Adept Technology
Factor Conditions	• MIT and other universities supplying talents and research • high patent/capita, Boston 1st in US	• Carnegie Mellon University (CMU) as anchor school • High patent/capita, Pittsburgh area 23rd in US	• Stanford and Berkeley producing top talents • Vibrant VC sectors • high patent/capita, San Fran bay area 2nd in US
Demand Conditions	• Government procurement • Household, retail and medical consumers	• Government/Defense • Commercial and medical application	• Government/Defense • Industrial and personal robots
Related and Supporting Industries	• Healthcare • Education • Specialized component firms	• Medical • Software and design companies particularly vision learning	• Internet companies and start-ups
Context for firm strategy and rivalry	• Vibrant start-up and spin-off • National and international players • Proactive tax incentives for R&D and investment	• Many spin-off companies from CMU • Recent large grant from Govt ~$500mn • Proactive tax incentives	• Entrant by big tech company like Google • Proactive incentives • Strong entrepreneurial mentorship

Table 4: Competing Clusters

cluster maturity, Boston ranks first, having started in early 1960s, followed by Pittsburgh and then Silicon Valley. Boston has the most robotics companies in the cluster, numbering more than 80, greater than the two other clusters combined. Silicon Valley has one key advantage: large internet companies like Google are fueling the growth by investing in robotics-related technology and

application, away from their core internet based business. It can be concluded from the comparison that the key competitive advantage for Boston relative to competing clusters is the strong presence of related and supporting industries. This has been discussed in detail in the preceding MA Robotics cluster competitiveness analysis.

Recommendations

Our recommendations span the level of action of national and state governments, national IFCs, and a cluster-specific IFC. The table below is a summary of the recommendations which are subsequently discussed in detail.

Area of Competitiveness	Challenge	Current Situation	Recommendation	Level of Action	Priority
Social Infrastructure and Political Institutions	Human Development – Primary and Secondary Education	MA student interest in STEM fields lower than national average.	- Increase spending and promotion - Update Curriculum - Invest in teachers	State	2
Factor Conditions	Administrative Infrastructure	National administrative infrastructure losing relative competitiveness.	- Simplify and rebalance taxes - Simplify litigation and compliance procedures	National	1
RSI	State of Cluster Development	Mass Tech LC is currently home to the Robotics Cluster initiative, but weak.	- Formalize cluster initiative - Increase human and financial resources - Clarify agenda and priorities	Cluster	1
Demand Conditions	Market Size	Small but growing market. Large range of potential buyers not yet connected to robotic producers.	Cluster Initiative to travel nationally and internationally promoting MA Robotics products to potential buyers in various industries.	Cluster	1
RSI	Suppliers	Good quality and quantity of suppliers, but no robotic-specific standard components.	Cluster Initiative to coordinate effort among cluster companies to devise best ways to standardize robotic design.	Cluster	1
RSI	Extent of Cluster Collaboration	Collaboration strong inside robotics cluster but weak across other clusters.	Cluster initiative to engage with IFCs of other related clusters, including international ones.	Cluster	2
CSR	Cluster Visibility	Robotics low priority on publicized political agendas.	Cluster Initiative to lobby political leaders at the state and national levels.	Cluster	2
Factor Conditions	Capital Markets Infrastructure	Relatively low levels of VC in robotics.	The VC issue will be addressed by the above recommendations as they aim at increasing market demand and company profitability, and reducing product development cycle length. This should be complemented by some programs to familiarize VCs with Robotics.	Cluster	1
Demand Conditions	Presence of Demanding Regulatory Standards	Labor health and safety standards in the US are stringent, which is an opportunity robotics are yet to fully capture.	IEE RAS to lobby policy makers to mandate robot use in tasks risky to humans.	National-level IFC	1

Table 5: Summary of Recommendations

At the national level, our recommendation for the federal government is to work at ensuring the country restores its leadership as an attractive location for companies to do business with particular attention to the administrative infrastructure. The tax system in the US is convoluted and ranking for 'Doing business, Paying Taxes' has slipped by 9 ranks in the last 11 years (HBS ISC 2012). Federal government should launch a review of the tax system with the goal of rebalancing the tax burden and simplifying tax rules and processes. Moreover, the burden of procedures and regulations surrounding running a business must be addressed. Regulatory costs in the US to companies are rising; the perceived rank of US competitiveness in the area dropped by 20 ranks over the past 10 years. Our recommendation is to review the healthcare, litigation, and compliance costs to companies and devise ways to simplify overregulation[25]. This revision will translate into higher company profitability and leaner company operations in the long term.

At the state level, we find the secondary school system an area of concern. Specifically, student interest in Science, Technology, Engineering, and Math (STEM) subjects, while growing, is behind national average by 8.7%[26]. This issue threatens the robotics cluster as current secondary school students represent part of the supply of future robotics engineers and researchers in MA. Our recommendation in this area is threefold: 1. Increase spending on secondary education including larger budgets for the promotion of STEM subjects to students, 2. Update current curriculum to adapt to latest technology developments, and 3. Invest in training teachers to improve the quality of education and familiarize with revamped curriculum.

At the cluster level, our central recommendation is for MTLC to formalize the Robotics Cluster Initiative by increasing human and financial resources. The newly enhanced initiative should have the following objectives: increase robotics market size, improve company profitability, and attract

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[25] This recommendation is based on Michael E. Porter's interview on CNBC. http://video.cnbc.com/gallery/?video=1689952568&play=1
[26] Mass Tech Collaborative (2011). *Index of the MA Innovation Economy*. http://web27.streamhoster.com/mtc/index_2011.pdf accessed 3 May 2012

venture capital. To achieve these objectives, it must first target buyers and suppliers. In terms of buyers, members of the Cluster Initiative should travel nationally and internationally to promote the products of the MA robotics companies to potential new buyers in many sector including automotive, manufacturing, and healthcare. This service will reduce the burden on startups in particular as they lack the marketing resources. Component suppliers are vital to the success of robotics companies. The cluster initiative should work with suppliers and robotics companies to devise way forward to standardizing robotic design. This in turn will lead to lower component supply costs and shorter produce development lifecycles – attributes favored by VCs. Another role of the newly enhanced Cluster Initiative is collaboration with IFCs outside the cluster boundaries. While cluster-specific IFCs are strong in MA, inter-cluster collaboration is relatively weak. Enhanced collaboration will result in new market opportunities for robotics as well as tech and skill transfer between clusters. Such collaboration should also include robotics IFCs internationally. While the growth of robotics market, increased profitability of companies, and shorter product development cycles will naturally form a force pulling VC to robotics, a complementary push force is also recommended. This will come in the form of VC education including the promotion of successful robotics company exits (e.g. Amazon's acquisition of Kiva). Finally, the Cluster Initiative should take responsibility for robotics' visibility. This includes lobbying state and national politicians for increased attention to robotics and portraying a positive image of robotics to the public (a complement as opposed to substitute to humans).

Robotics and National Safety Standards. National safety standards are stringent, resulting in higher costs to companies in meeting them and in turn lower productivity. This opens up an opportunity to include robotics as a means to more efficiently meeting these standards. For example, mandating the assistance of robotics in handling chemicals or conducting dangerous processes such as welding and chemical coating will make these processes more efficient. We believe it is the role

of IEEE RAS as a professional association to lobby policy makers to mandate the inclusion of robots for the performance of specific tasks. This will result in a larger robotics market as well as improved productivity in execution of these tasks.

List of Interviewees

Thomas Frost, Sloan Fellows 2012 at Massachusetts Institute of Technology Sloan School of management;

John Dyer, Chief Strategy Officer of iRobot Corporation;

Helen Greiner, Founder & CEO of CyPhy Works;

Thomas Hopcroft, President/CEO of Mass Technology Leadership Council, Inc.;

Elizabeth Newstadt, Community Manager, Energy & Robotics, Mass Technology Leadership Council, Inc.;

Tom Ryden, Co-Founder & COO of VGo Communications, Inc.

Kathleen F. Hagan, Founder and President of Hagan & Company.

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