Achieving Global Leadership: A Roadmap for Robotics in Massachusetts

MASS TECHNOLOGY LEADERSHIP COUNCIL

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"Imagine being present at the birth of a new industry. It is an industry based on groundbreaking new technologies, wherein a handful of well-established corporations sell highly specialized devices for business use and a fast-growing number of start-up companies produce innovative toys, gadgets for hobbyists and other interesting niche products… (like the computer industry) …trends are now starting to converge and I can envision a future in which robotics devices will become a nearly ubiquitous part of our day-to-day lives. Technologies such as distributed computing, voice and visual recognition, and wireless broadband connectively will open the door to a new generation of autonomous devices that enable computers to perform tasks in the physical world on our behalf. We may be on the verge of a new era, when the PC will get up off the desktop and allow us to see, hear, touch, and manipulate objects in places where we are not physically present."

Bill Gates*

Mass Technology Leadership Council, Inc.
February 2009

with the support of the Massachusetts Technology Collaborative's
John Adams Innovation Institute

* (**Scientific American**, Special Edition on Robotics, May 2008)

Cover photo: The robot is a GEARS Educational Systems Surface Mobility Platform (SMP)

Acknowledgements

The Mass Technology Leadership Council is grateful for the leadership and support that Governor Deval Patrick has provided to MassTLC's Robotics Cluster and looks forward to working with him and our colleagues at the Massachusetts Technology Collaborative's John Adams Innovation Institute to implement the key recommendations made in this report.

The Council would like to thank Joyce Plotkin, president emeritus of the Council, for her vision, tireless efforts and leadership during the formation of the Council's Robotics Cluster in 2005 and its subsequent growth. Her advocacy with local, state, and federal officials on behalf of the Cluster are instrumental to its success.

This report and initiative would not be possible without the commitment and engagement of many talented leaders and volunteers in the Mass Technology Leadership Council's Robotics Cluster. Cluster participants are included in the appendix to this report.

The Council would also like to acknowledge the support of Pat Larkin, Bob Kispert, and Carlos Martinez-Vela of the Massachusetts Technology Collaborative; Josh Krumholz and Brain Colandreo of Holland + Knight for their sponsorship of the Robotics Cluster; Kathleen Hagan of the Entrepreneurial Resources Group for managing the robotics project and research report; Dan Kara of Robotics Trends for support of the Cluster at RoboBusiness; Colin Angel of iRobot for marketing support; and Helen Hsi, doctoral candidate at MIT, for her help with research on the robotics industry.

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About the Mass Robotics Cluster

The mission of the Mass Robotics Cluster is to raise awareness of the region's robotics industry throughout the United States, attracting thought-leaders and resources, and to grow the robotics industry in Massachusetts by creating opportunities for new and existing companies. The Mass Robotics Cluster is a community of interest within the Mass Technology Leadership Council, Inc., a non-profit organization that fosters entrepreneurship and promotes the success of companies that develop and deploy technology across industry sectors.

"With the great robotics research and educational programs at MIT, Harvard, BU, UMass Amherst, UMass Lowell, Tufts, and Brandeis, along with the raft of existing robotics companies and a strong VC community, there is no better place in the world to start a robotics enterprise than in Massachusetts."

Dr. Rodney Brooks, MIT Computer Science and Artificial Intelligence Lab

"Our world-renowned universities, medical research and commercial and defense R&D communities have been a catalyst in robotics development and in moving robotics from the research lab to everyday use in commercial, health care, and defense applications."

James Shields, CEO of Draper Laboratory

Introduction

The Mass Technology Leadership Council (MassTLC) is Massachusetts' leading high technology organization and represents several hundred companies. In 2005 the Council established a Robotics Cluster to bring together companies, institutions, and individuals engaged in robotics research, education, product design, and commercialization. This work is made possible through the support of the Massachusetts Technology Collaborative's John Adams Innovation Institute, an agency dedicated to enhancing industry sector growth in the Commonwealth.

The Cluster has grown rapidly and is populated by both large leaders in robotics that are selling successfully to consumer, industrial, and government markets, and by start-up and early stage companies that are launching exciting new state-of-the-art products for a range of sectors including: health care and medical, distribution and logistics, marine underwater surveillance, factory and lab automation, defense, consumer, education and entertainment.

The growth of the Cluster has been fueled by advanced research and development at ten leading Massachusetts research institutions and supported by a talent pool of highly skilled engineers graduating from the many world class degree programs in the area of electrical, mechanical, and software engineering. Massachusetts is also home to the country's first-of-its-kind fully integrated undergraduate degree program in robotics engineering at Worcester Polytechnic Institute (WPI).

Hocoma's Lokomat provides functional locomotion therapy with augmented feedback

Advances in technology in electronics, hardware, and components (such as sensors, motion controls and vision systems) have enabled the development of entirely new kinds of specialized automated products such as: robots that perform hazardous military missions; robotics assisted devices for non-invasive surgery and rehabilitation; unmanned underwater vehicles for oceanographic survey and defense applications; and personal service robots for lawn mowing and vacuum cleaning. As new applications emerge creating new market opportunities robotics is having an economic impact in a number of sectors and markets that are strategic to the long-term growth of the Massachusetts economy including: defense and public safety, marine surveillance, health care, industrial automation, distribution and logistics, and consumer.

Working closely with representatives of the robotics industry, the MassTLC shaped this Robotics Roadmap Initiative. The goal of this initiative is to: a) define the make-up of the robotics industry in Massachusetts, b) assess the current "state of robotics" in Massachusetts and the industry's potential, and c) work with Cluster leaders to develop a vision and a plan for the future growth of this dynamic sector. This is the first effort of its kind to define and assess robotics in Massachusetts as a distinct industry cluster with its own needs and growth potential.

This report summarizes the Council's findings and lays out a vision for the growth of the robotics sector in Massachusetts. We are grateful for the leadership and support that Governor Deval Patrick has provided the MassTLC's Cluster Development initiative and look forward to working with him and our colleagues at the MTC's Innovation Institute to implement the key recommendations made in this report.

Thomas Hopcroft

President & CEO
Mass Technology Leadership Council, Inc.

The Robotics Industry

Defining the Industry

A Transformative Technology — Driving Change in Many Industries

"Robotics is the science and technology of designing, making, and applying robots, including technology from many contributing fields. A robot is a mechanical or virtual artificial agent. It is usually an electrical mechanical system which by its appearance or movements conveys a sense that it has intent or agency of its own." (Science Encyclopedia)

Global competition with increasingly skilled workers offshore is driving demand for cost effective non-labor-intensive technologies and business processes.

There are as many different working definitions of "robotics" as there are applications…from "*automation with motion*" to "*computers that move*" (Michael Kuperstein, founder of Symbus). There are "**stationery robots**" for factory and laboratory automation and a new class of "**mobile robots**" for transportation, distribution, and military uses. There are also "sub-sea robots" for underwater surveillance and "medical robots" for robotic-assisted surgery, rehabilitation, and home health care.

Robotic systems essentially involve the integration of electrical and mechanical systems, and hardware and software engineering to create a machine that can take independent action with multiple degrees of motion, control, and capability to sense its environment and sometimes make decisions based on sensing.

Rapid advances in technology have facilitated the development of more useful, economical, and agile robots and robotics-assisted devices in a wide range of industries. For example, advances in laser sensing, computer vision, and autonomous navigation enable robots to quickly sense and react to environments. New software tools make it easier to integrate systems using different kinds of hardware. Also, decreases in the cost of processing power enable roboticists to build networks of wireless robots that can tap into the power of desktop PCs to work together as a team.

"Robotics" is *both* a distinct industrial sector and an enabling technology for many industries. Twenty-first century robotics provides a technology tool-kit for the integration of advanced software, hardware, electronics, and mechanical systems in exciting new ways creating new products, processes, and systems that bring intelligent automation into the clinical setting, the factory, the laboratory, the warehouse, the battlefield, the underwater environment, the retail setting, the classroom, the office, and the home.

The Robotics Industry

Robotics Value Proposition

Demographic trends globally are creating population profiles skewed to the aged and aging populations that will require more services with fewer people to provide them. Service robots have the potential to meet this social need. Global competition with increasingly skilled workers offshore is driving demand for cost effective non-labor-intensive technologies and business processes. Robotics can help to keep U.S. industry competitive. Moreover, advanced robotics technology has created new products that provide precision for specialized applications such as robotic assisted surgery or field operations in difficult-to-access or dangerous locations such as underwater, on battlefields, or in hazardous terrain.

Governor Deval Patrick meets with Massachusetts robotics leaders at MassTLC Robotics Cluster Meeting (July 2008)

Types of Robots and Applications

The Robotics industry is comprised of the following types of robots and robotics components:

Industrial Robots

Stationary robots that automate for a range of industries including: automotive, chemical, food, machinery, pharmaceutical, manufacturing, heavy industry, semiconductor fabrication and materials handling.

Service Robots

Robots that are *mobile* and function autonomously, or semi-autonomously, performing tasks in a variety of settings:

- **Professional Use** (Business/Government)
  Defense, public safety/security, inspection systems, underwater systems, medical, distribution/logistics, materials handling and facilities maintenance
- **Personal Use** (Consumer/ Home)
  Toys, home use (vacuums, lawn mowers, security), home health assistance and assistive or rehabilitative devices

Components

Elements of robotics systems include: sensors, actuators, controllers, vision systems, man-machine interface and software/hardware design/development and systems integration.

Massachusetts Robotics Cluster Profile: A Young, Innovative and Rapidly Growing Sector

Tradition of Innovation

Massachusetts companies have been leaders in robotics and have pioneered commercially successful products:

- *First* industrial robots for semiconductor manufacturing
- *First and leader* in ground robots to support U.S. troops
- *First* therapeutic robots
- *Leader* in home use robots such as vacuum cleaners, floor washers, and physical therapy
- *Leader* in service robots for use in distribution/logistics and inventory management
- *Leader* in underwater robotics for oceanographic survey, defense, and security
- *Leader* in educational robots
- *First* behavior-based robots

Kiva Systems' robotics system provides a breakthrough approach to the movement, storage and sortation of inventory

Massachusetts has a **young, vibrant, and diverse** robotics cluster. The Commonwealth is home to more than **80** companies and **10** universities (with 13 university robotics research laboratories) representing ***all*** segments of the robotics sector including: component suppliers; developers of cutting edge robotic systems for defense, marine, health care/assistive technology, factory, and lab automation; aerospace; consumer; and educational robotics.

The industry in Massachusetts has experienced rapid growth in: defense and security robots; marine underwater robots for security and other applications; and health care robotics for assistive/rehabilitative applications. Growth rates of annual sales among the leading robotics firms in defense, marine science, and health care range from 39%–100% year over year for the past three years. (*Source: MassTLC Survey of 75 leading robotics firms, May 2008. Note: additional robotics companies were identified after the completion of the MassTLC survey.*)

Massachusetts Educational Institutions and the Robotics Industry

Massachusetts not only has a unique concentration of innovative robotics companies but also benefits from a local constellation of renowned academic centers of excellence in robotics education, research, and technology commercialization.

Ten leading educational research institutions in the Commonwealth host thirteen world-class robotics programs that provide the **intellectual driver** for research and development, and supply the **skilled talent pool** for the robotics sector. The Massachusetts cluster environment is unique with its number and variety of academic research institutions, and its combination of both world-class robotics research and development know-how and product development expertise.

UNIVERSITY ROBOTICS PROGRAMS	
Boston University **Robotics, Dynamics and Control Research Group** **BU Departments of Aerospace and Mechanical and Manufacturing Engineering**	The Robotics Group is part of the university's Intelligent Mechatronics Lab and sponsors cutting edge research in: medical robotics, contact sensing, structural dynamics, tactile display, friction analysis, and mobile robot communications.
Brandeis University **Computer Science Laboratory**	Dynamical & Evolutionary Machine Organization Lab is focused on machine learning ("artificial life") and integrated robotics bodies and brains built by automated manufacturing systems.
Harvard University **Robotics Lab, Division of Engineering and Applied Sciences**	The Robotics Lab focuses on analog computation, choreography of dynamical systems, and control of quantum systems, pattern generation, and robotic system identification.
Massachusetts Institute of Technology (MIT) **Computer Science and Artificial Intelligence Laboratory (CSAIL)** **Mechanical Engineering Dept.** **Media Lab** **Personal Robots Group** **MIT Sea Grant AUV Lab**	CSAIL conducts cutting edge research on autonomous flight in GPS-denied environments, autonomous locomotion in unknown terrains, natural language dialogue for assistive technology, and adaptive sensing for weather prediction. MIT Newman Lab for Biomechanics and Human Rehabilitation focuses on physical therapy devices. The Lab conducts cutting edge research on dexterous sociable robots, robotic companions for interaction in health, education, and social communication including: human-robot interaction, social cognition, and natural multi-modal communication interfaces. The AUV Lab is a leading developer of advanced unmanned autonomous marine vehicles.
Northeastern University Marine Science Center **Biomimetic Underwater Robot Program**	The Center employs biomimetic approaches to confer the adaptive capabilities of marine animal models to engineered devices. These devices include: sensors, actuators, adaptive logic systems, and electronic nervous systems.
Olin College of Engineering	Olin educates future leaders in robotics through an innovative engineering education that bridges science and technology, enterprise, and society. Olin's robotics group is currently working in the areas of unmanned ground, surface and air vehicles.
Tufts University **Advanced Technologies Laboratory**	The Lab focuses on "biomimetic soft-bodied robots" and incorporates biomaterials, neuromechanical controllers, and compliant microelectronics. Tufts also focuses on: mobile robot navigation, endoscopic surgery, and educational robots. Tufts works with teachers and schools around the world in bringing robotics into the classroom as a way to teach math, science, and engineering.
UMass Lowell Robotics Lab	The Lab focuses on human-robot interaction including: interface design, robot autonomy, and computer vision. Applications include: assistive technology, search and rescue.
UMass Amherst **Laboratory for Perceptual Robotics**	The Lab focuses on computational systems that solve sensory and motor problems. Experimental platforms include sensor networks, mobile manipulators, and integrated bimanual humanoids.
Worcester Polytechnic Institute (WPI)	WPI is the first educational institution to design and implement an undergraduate robotics degree program.

Note: Brown University's (Rhode Island) award winning Robotics, Learning, and Autonomy Lab and Woods Hole Oceanographic Institute (WHOI) collaborate with Massachusetts institutions as part of the local robotics research community.

Cluster Companies and Environment

There are more than 2,500 people employed in the Massachusetts robotics sector and annual sales exceed $942 million, including approximately $496 million in government contracts and $446 million in commercial sales.

Massachusetts has successfully commercialized many new robotic applications for the marketplace—from robotic vacuum cleaners and assistive health care service robots to unmanned undersea surveillance robots and military field robots.

While the core group of robotics companies in Massachusetts consists of at least 80 companies and growing, the broader robotics ecosystem consists of over 150 companies, institutions, and research labs with involvement directly or indirectly in robotics.

There are **more than 2,500 people employed in the Massachusetts robotics sector and annual sales exceed $942 million**, including approximately $496 million in government contracts and $446 million in commercial sales. (This does not include $1.5 billion in sales of national robotics companies with representative offices in Massachusetts/New England such as ABB Systems, nor does it include companies in New Hampshire and Rhode Island, such as Segway, Mobile Robots, and Valde Systems, that are part of the extended Massachusetts robotics economy.)

A recent survey conducted by the Mass Technology Leadership Council of 75 of the leading robotics firms in the Commonwealth found that the Cluster is heavily populated by young firms with the majority having been established in the past 10 years. The average age of surveyed companies was nine years. Moreover, 40% of the company respondents indicated that they are either start-ups or under 6 years old.

This young sector is also notable by its exceptionally high rate of growth. Of the firms responding to the Council's survey (25% response rate) **the average rate of annual growth was 47% (not including one company leader that has an extraordinary 800% rate of growth!)** In addition, the rates of growth are consistently high across both established firms and younger firms launching new products for new applications in a variety of markets. While this rapid growth has been driven in part by large government contracts in recent years for military, security, and safety applications, there is strong growth in commercial sales for a number of key applications including: health care, distribution services, factory automation, and service robots for consumer/personal use.

State of Robotics in Massachusetts

The recent emergence of young robotics companies with very high rates of growth is a clear indication of the increasing market demand for advanced robotics systems and components. The rapid growth in robotics sales also confirms that Massachusetts has both the intellectual infrastructure and entrepreneurial capacity to design innovative, highly functional, and cost effective products and the skilled workforce to meet market demand.

SURVEY HIGHLIGHTS

- Sales exceed **$942 million**
- Employ **2,500** in Massachusetts
- **40%** companies are startups or less than **6** years old
- Average annual growth rate **47%**
- **90%** of all hires are **local hires**
- **70% plan to hire** in next 1–2 years (if funding is available)

Survey: MassTLC Survey of 75 leading robotics firms, May 2008

Brooks Automation's Razor® Atmospheric Transfer Robot

The Cluster environment also includes access to a wide variety of experienced venture capital, legal, and financial resources as well as state sponsored incentives to businesses such as: workforce training grants, investment R&D tax credits, and R&D and recruiting partnerships with universities and community colleges. *However, only 4 out of 20 respondents to the MassTLC robotics survey reported having been funded with venture capital.*

SUPPORTING CLUSTER INFRASTRUCTURE

Associations

- Mass Technology Leadership Council
- IEEE Society for Robotics Automation
- Defense Technology Initiative

Academic Institutions

- Boston University
- Brandeis University
- Brown University
- Harvard University
- MIT
- Northeastern University
- Olin College of Engineering
- Tufts University
- UMass Lowell
- UMass Amherst
- Worcester Polytechnic Institute
- Woods Hole Oceanographic Institute

Other Organizations

- Massachusetts Technology Transfer Center
- MIT & WPI Enterprise Forums
- FIRST (For Inspiration & Recognition of Science & Technology)
- BotBall (Institute for Practical Robotics)

Informal Networks

- MassTLC's Robotics Cluster
- Venture Capital Community
- University Alumni
- Company Alumni

Economic Development

- Massachusetts Technology Collaborative
- Massachusetts Technology Development Corporation
- Massachusetts Office of Business Development

Joint Research Initiatives

- CIMIT Center for Integration of Medicine and Technology
- Regional Research Centers

Note: Table based on Harvard Business School Professor Michael Porter's Framework for Institutions for Collaboration in Cluster Environment

The Competitive Advantage of the Robotics Industry in Massachusetts

Massachusetts has the brainpower to innovate, the technical talent to design and manufacture robotic systems for many applications, and **a track record of success** in the development and sales of exciting new robotics components and systems for both government and commercial markets.

Massachusetts has a competitive advantage in robotics with its:

- **critical mass of universities**
- **innovative companies in varied robotics applications**
- **world-class robotics research and development**
- **highly skilled workforce**
- **related and supporting industries**

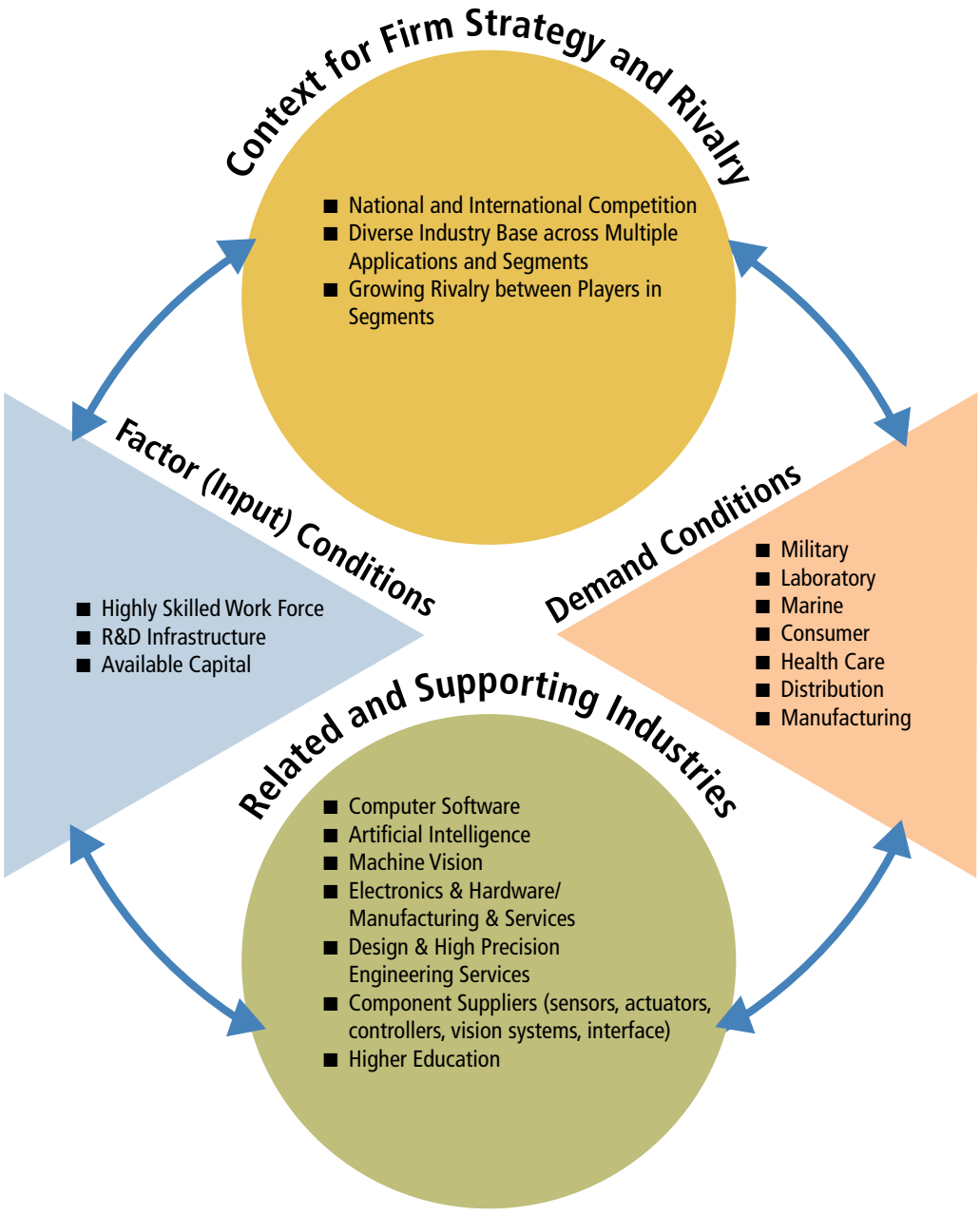
Massachusetts also has special robotics competency in high growth industries of strategic economic interest to the Commonwealth including: defense technology, marine science, and health care technology. In addition, Massachusetts is well positioned to take advantage of the long-term explosive growth expected in personal robotics having already developed commercially successful consumer robotics for home use.

Boston Dynamics "Big Dog" Quadruped Robot

Exploiting robotics potential to accelerate economic growth in defense, marine, and health care technology—as well as in service robots for consumer use—will be critical not only to the growth of the robotics industry in Massachusetts but also to the future competitiveness of the State's leading industries.

The opportunity to grow market share for existing Massachusetts robotics innovators and create new robotics products to meet increasing global demand for advanced robotics components and systems is enormous and ripe for exploitation. Advances in technology along with trends in demographics and global competition for skilled labor will continue to drive adoption and demand for non-labor-intensive technologies and business processes.

The Competitive Advantage of the Massachusetts Robotics Industry



Note: Table based on Harvard Business School Professor Michael Porter's Framework for Competition in Cluster Environment

The Opportunity: A Rapidly Growing Global Marketplace

Global Marketplace Opportunities

The global market for new robotics products, components, and systems is growing rapidly as advances in robotics technology make robotics a cost effective alternative to labor intensive systems. Robotics as a platform technology for a wide range of vertical industry applications is driving growth through innovations that create markets for new applications.

Industrial Robots Market Facts

According to the International Federation of Robotics, the current market size for industrial robots is $18 billion, and growing globally at 4.2 % a year. Currently, it is the largest segment of the robotics industry.

Service Robots Market Facts

The global market for service robots is currently $9.1 billion, a more than four-fold increase since 2004. (International Federation of Robotics)

The market for service robots is growing rapidly at a rate of

- 17.5% for professional use
- 11.5 % for personal use
- 19% for health care, assistive technology

(e-Marketer and International Federation of Robotics)

Service robots for personal use is the area of robotics with the strongest predicted growth. While the market for consumer robots is currently smaller than the market for industrial robots, personal robotics are projected to overtake industrial robotics and gain a dominant share of the estimated total robotics market in 2010. (Future Horizon)

The global market for service-consumer robots is expected to be worth $15 billion by 2015. (ABI Research)

The Japanese Robot Association has predicted that the personal robot industry will reach sales of $50 billion a year by 2025. This explosive growth will be driven in good measure by the demographics and demands of aging populations requiring more services with fewer people to provide them.

Components Market Facts

The global market for components for robotics such as processors, sensors microcontrollers, and servers is estimated to reach $12 billion by 2015. (ABI Research)

In North America sales of industrial robotics grew by 24% last year.

The global market for **industrial robots** (stationery robots used in factory automation and assembly lines) is currently $18 billion (including software, peripherals, and systems) according to the International Federation of Robotics.

In the North American market orders for industrial robotic systems for American manufacturing companies rose 24% in 2007 to $1.07 billion. This growth is driven in large measure by demand for advanced robotics systems from the automotive, packaging, food, and chemical sectors. These sectors, particularly the automotive sector, are cyclical and, therefore, demand can fluctuate.

Nevertheless, demand is expected to grow as new technologies and applications emerge. There are 178, 000 robots now at work in U.S. factories and laboratories, placing the U.S. second only to Japan in overall robot use. According to the Robotics Industry Association, 40% of all installed industrial robots worldwide are in Japan and more than one million robots are installed worldwide.

Defense, Marine and Medical Robotics Markets:

The Military, Defense, and Public Safety market is huge and growing

A significant market for robotics in the U.S. currently is the military market driven by the Armed Forces' needs for unmanned combat, utility, and surveillance vehicles. The Department of Defense is making large investments in development of unmanned, remotely controlled robotic systems and is expected to spend $1.7 billion in ground based robots alone over the next five years. (ABI Research)

The Opportunity: A Rapidly Growing Global Marketplace

Marine Robotics Are Growing for Underwater Operations

Acceptance is growing for marine robots (Autonomous Unmanned Vehicles—AUVs) that perform key underwater tasks as they are more cost effective than previous technology. In addition to hydrographic survey and military applications, the use of marine AUVs is expected to grow for: oil and gas exploration; underwater inspection (pipelines, cables, vessel hulls, etc.); ocean monitoring for fish stock, health and environmental conditions; and harbor patrols and civilian security networks.

The market drivers for underwater robotic vehicles have changed. The focus of the world's major naval powers and their contractors has moved from cold water submarine games to near shore waters of local conflicts and the major business opportunities presented by the war on terror. The "most likely" value of the global market for marine AUVs across all applications is estimated to be $1.8 billion by 2017 and a "high case" scenario would make the market worth $3.7 billion by 2017 with 60% of the market driven by demand from the military. (The AUV Gamechanger Report, Douglas Westwood)

Bluefin's leading robotic autonomous underwater vehicle

The market for surgical robot systems will top $14 billion by 2014

In medical applications robotically-assisted surgical systems equipment markets are set to experience rapid growth worldwide. Markets valued at $626.5 million in 2007 are anticipated to reach $1 billion in 2008 and are forecast to reach $14 billion by 2014. (Wintergreen Research—Surgical Robotics Market) Though it took a long time for this market to evolve, robotically-assisted surgeries are now accurate and less invasive than alternative methods, creating broader adoption and greater market opportunity.

According to the International Federation of Robotics the best global market prospects are in the following application areas: defense rescue and security applications, underwater systems, medical robots, laboratory robots, professional cleaning robots, and mobile robotic platforms for multiple uses. These are all areas in which Massachusetts has demonstrated robotics capability.

The Race for National and International Leadership

Massachusetts can seize the opportunity to become **internationally recognized as the leading robotics cluster in the U.S. and a global leader in robotics innovation.** The Commonwealth is the hub for an exciting combination of robotics educational programs, diverse world class research institutions, successful companies in numerous market segments, a rich talent pool and wide variety of specialized component suppliers and support services.

The Opportunity: A Rapidly Growing Global Marketplace

Other regional robotics clusters in the U.S.—such as those in the Palo Alto area near Stanford University and in Pittsburgh near Carnegie Mellon University—have especially strong state and federal support and are better organized to compete for new growth, new jobs and new technology breakthroughs.

Also, global competition is heating up in Asia and Europe. Leading global players are exploiting the emerging market opportunity and foreign government interest is advancing the development and adoption of robotics. For example, the South Korean government has set a goal of having a robot in every home by 2020. Germany leads in heavy industrial automation and Japan remains strong in both electronics and component manufacturing and personal service robots. (International Federation of Robotics)

The U.S. leads in development of defense related robots. Innovative Massachusetts firms including iRobot, Foster-Miller, Draper Labs, Textron, and Raytheon are leaders in robotics with the development of new unmanned robotics for both intelligence and surveillance as well as for battlefield applications. Massachusetts companies have generated hundreds of millions of dollars in sales of state-of-the-art systems to the Army, Navy, Air Force, and the Department of Homeland Security.

Massachusetts also boasts exciting innovators in service robots—both for professional and personal use—and components which represent the strongest growth segments of the global robotics market. In addition, advances in technology have enabled Massachusetts leaders in industrial robotics to remain highly competitive serving important markets locally, nationally, and globally for pharmaceutical, factory, and electronics manufacturing.

MIT's finalist entry in the 2007 DARPA urban challenge

It is critical that the leadership of the robotics community in Massachusetts work pro-actively together to exploit the Robotics Cluster's unique strengths. Doing so will establish Massachusetts' position as an international leader in robotics innovation, education, research, and product development.

Massachusetts Leadership in Robotics

Despite Massachusetts' special advantages, leveraging its robotics know-how for sustainable competitive advantage in the global marketplace will not happen without a concerted and well coordinated effort on the part of the robotics sector's key stakeholders. **There are weaknesses in the Cluster environment that inhibit the growth of the robotics sector in Massachusetts.**

1. The industry is **fragmented** and **the Cluster environment is weak in collaboration. Greater collaboration** among and between robotics companies, researchers and key customers in strategic application areas would enable exciting breakthroughs

with some of the key technical and product design challenges facing the industry and lead to more robust robotics technology commercialization.

2. There is a need for **incentives for increased technology development**. Enhanced technology development in the robotics innovation process will accelerate the growth of key markets, create new markets and establish Massachusetts as a global leader in robotics innovation.

3. There is a need for **stronger business development support** for the robotics cluster community including: greater access to financing for start-ups and early stage ventures; more collaboration within the academic community; more communication between industry and academia.

4. There is a **need for more awareness** on the part of business leaders and government officials of the current strength and future potential of robotics to the economy of Massachusetts.

Foster Miller's new tactical robot for ground warfare protection against IED devices

There is an **opportunity to transform the Robotics Cluster environment into a more dynamic "innovation network"** that gives large companies reason to move robotics work to Massachusetts and keeps medium size companies in Massachusetts. A stronger Robotics Cluster environment will also create more start-ups, educate and train more roboticists, and stimulate significant breakthroughs in applied robotics research and product development.

Robotics is an **enabling technology that is deeply rooted in the Massachusetts economy** by the world class robotics research and development conducted at major research institutions and supported by the talent educated at those institutions. Robotics start-ups, as well as mature companies, will be less likely to migrate to other regions in the U.S. **if** the cluster environment remains vibrant, robust and functions as a dynamic "innovation engine" supplying new ideas, fresh talent, resources, and incentives to continuously advance the study, design, development, and sale of robotics in Massachusetts.

The innovations of this cluster are already enhancing the competitiveness of the leading industries in the Commonwealth that it supports such as: defense technology, marine, and health care technology. Furthermore, innovation in Massachusetts with the highly successful commercialization of popular consumer robots and educational robot applications positions the State strategically for dynamic growth in the area of robotics that is expected to experience the strongest growth globally in the next 10–15 years.

Robotics can play a strategic role in enhancing the long-term competitiveness of the State's economy by enabling innovation across a range of leading industries and by creating high value-added jobs in the Commonwealth.

A Vision for the Future

The robotics industry in Massachusetts has high potential for growth both in size and product innovation in the next 5–10 years.

Achievable Goals

- ***Double employment and sales in robotics by 2013*** through new start-ups and company expansion. Double private investment in start-ups by venture capital and private equity by 2013. Make Massachusetts an attractive location for new and growing robotics companies and headquarters for the world's fastest growing robotics companies.
- Establish a globally recognized ***Academic Consortium for Robotics Research and Development*** and increase investment in robotics research and development by 50% (by government and corporations) with links to leading robotics centers around the globe.
- Establish Massachusetts leadership in innovative ***product development for service robots*** particularly in defense technology, marine, and medical/health care thereby making Massachusetts an attractive location for new and growing robotics companies.

i-Robots "co-worker" brings robotics to the office environment

To realize this vision, the Mass Technology Leadership Council will work with the Cluster leadership to strengthen the Cluster infrastructure by:

Enhancing Academic Research and Collaboration

- **Attract** new R&D research investment and **build** more dynamic partnerships among universities, and between universities and industry.
- **Facilitate** development of a regional robotics consortium that could be a catalyst for regional pilot projects in education, research, and product development.

A Vision for the Future

Building Cluster Identity and Creating Connections

- **Connect** talent and ideas with industry.
- **Improve** networking and **remove** impediments to collaboration.
- **Establish specific links** within the State between the robotics Cluster and its key customers and applications, in particular leveraging the Commonwealth's strengths in defense technology, marine, and health care technology.
- **Establish links with national and international robotics** associations and centers.

A robotic tractor designed and developed at Olin College in Needham, Massachusetts

Accelerating Economic Development

- **Expand** employment in robotics by creation of **more company start-ups** and attraction of commercial investment for early stage robotics companies.
- **Retain** and support existing companies… robotics creates high value jobs that can stay in Massachusetts close to strategic sources of R&D, the talent pool, and investment.
- **Raise** awareness with external stakeholders (public, educators, government officials, business community at large) to the current strength and future importance of robotics to the economy of Massachusetts.
- **Track** the Cluster's growth through development of a robotics "growth index".

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Scientific American Reports, Special Edition on Robotics (May 2008)

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Appendix A – Alphabetical List of Massachusetts Companies and Institutions

Alvamed
Artaic
Aurora Flight Sciences
Autogen
Automated Medical Instruments
Aware
Axis New England
Barrett Technology
Battelle
BBN Technologies
Black I Robotics
Bluefin Robotics
Blueshift
Boston Dynamics
Boston Engineering
Boston University
Brandeis University
Brooks Automation
Brown University
Caliper Life Sciences
CIMTEK
Co-Automation
Cognex
Corindus Vascular Robotics
Cyber-Kinetics
Dangel Robots & Machinery
Deep Sea Systems
Digirobotics
Draper Labs
Electromechanica
Energid Technologies
Falmouth Scientific Inc.
Focus Robotics
Foster-Miller
GE Fanuc
Gears Educational Systems
Genomic Solutions
Gibson Engineering
Gleason Research
Harmonic Drive Technologies
Harvard University
Harvest Automation
Heartland Robotics
Hitec Corporation
Hocoma
Hydroid
Iconics
ID One
Immersive Design
Innovent Technologies
Interactive Motion Technologies
Intersense
iRobot
Kaztek Systems
Kiva Systems
Mass Automation Corp.
Mathworks
Medical Development Partners
Mekinesis
Mercury Computer Systems
Metatomix
MicroE Systems
Microsoft
MIT CSAIL
MIT Lincoln Labs
MIT Media Lab
MITRE
Myomo
Nascent Technology Corporation
NES Technologies
Ocean Server
Northeastern University
Olin College
PTC
Partners Healthcare/CIMIT
Protonex Technology
Q Robotics
Raytheon
Robots and Relax
RPU Technology
Rug Warrior
Salisbury Robotics
Scientific Systems Company
SensAble Technologies
Sippican
Smart Robots
Solid Works Corporation
Teledyne Benthos
Teradyne
Textron Systems
Thermo Fisher Scientific
Tufts University
UMass Amherst
UMass Lowell
Vecna Technologies
Virtual Incision Corporation
Webb Research Company
Woods Hole Oceanographic Institution
Worcester Polytechnic Institute

Appendix B – Robotics Companies and Institutions by Application

Components: 36

Aware (Bedford)

Axis New England (Danvers)

BBN Technologies (Cambridge)

Boston Engineering (Waltham)

CIMTEK (Needham)

Co-Automation (Westborough)

Cognex (Natick)

Deep Sea Systems (Falmouth)

Digirobotics (South Deerfield)

Electromechanica (East Freetown)

Energid Technologies (Cambridge)

Falmouth Scientific Inc. (Cataumet)

Focus Robotics (Hudson, NH)

Gibson Engineering (Norwood)

Gleason Research (Concord)

Harmonic Drive Technologies (Peabody)

Hitec Corporation (Littleton)

Iconics (Foxborough)

ID One (Brookline)

Immersive Design (Acton)

Innovent Technologies (Peabody)

Kaztek Systems (Acton)

Mass Automation Corp. (Bourne)

Mathworks (Natick)

Mekinesis (Cambridge)

Mercury Computer Systems (Chelmsford)

Metatomix (Dedham)

MicroE Systems (Natick)

Microsoft (Waltham)

NES Technologies (South Easton)

Protonex Technology Corporation (Southborough)

PTC (Needham)

RPU Technology (Needham)

Salisbury Robotics (Cambridge)

Solid Works Corporation (Concord)

Valde Systems (Brookline, NH)

Consumer: 5

Gears Educational Systems (Concord)

iRobot (Burlington)

Q Robotics (Groton)

Robots and Relax (Boylston)

Rug Warrior (Wellesley)

Factory Automation/ Distribution: 10

Artaic (Boston)

Barrett Technology (Cambridge)

Blueshift (Andover)

Brooks Automation (Chelmsford)

Dangel Robots & Machinery (Bedford)

GE Fanuc (Foxboro)

Harvest Automation (Groton)

Heartland Robotics (Cambridge)

Kiva Systems (Woburn)

Smart Robots (Dalton)

HealthCare/ Medical/Assistive Technology: 13

Alvamed (Waltham)

Automated Medical Instruments (Reading)

Barrett Technology (Cambridge)

Corindus Vascular Robotics (Natick)

Cyber-Kinetics (Walpole)

Hocoma (Rockland)

Interactive Motion Technologies (Cambridge)

Medical Development Partners (Reading)

Myomo (Charlestown/Boston)

Partners Healthcare/CIMIT (Boston)

SensAble Technologies (Woburn)

Vecna Technologies (Cambridge)

Virtual Incision Corporation (Boston)

Lab Automation: 5

Autogen (Holliston)

Battelle (Duxbury)

Caliper Life Sciences (Hopkinton)

Genomic Solutions (Holliston)

Thermo Fisher Scientific (Waltham)

Military/Aerospace/ Public Safety: 20

Aurora Flight Sciences (Cambridge)

Black I Robotics (Tyngsboro)

Bluefin Robotics (Cambridge)

Boston Dynamics (Waltham)

Draper Labs (Cambridge)

Foster-Miller (Waltham)

Hydroid (Pocasset)

Intersense (Bedford)

iRobot (Burlington)

MIT Lincoln Labs (Lexington)

MITRE (Bedford)

Nascent Technology Corporation (Lexington)

Ocean Server (Fall River)

Raytheon (Waltham)

Scientific Systems Company (Woburn)

Sippican (Marion)

Teledyne Benthos (North Falmouth)

Teradyne (North Reading)

Textron Systems (Wilmington)

Webb Research Corporation (E. Falmouth)

Academic Institutions: 12

Boston University

Brandeis University

Brown University

Harvard University

Massachusetts Institute of Technology

Northeastern University

Olin College

Tufts University

UMass Amherst

UMass Lowell

Woods Hole Oceanographic Institution

Worcester Polytechnic Institute

Appendix C – Robotics Companies and Institutions by Segment

Industrial

Autogen
Barrett Technology
Blueshift
Brooks Automation
Caliper Life Sciences
GE Fanuc
Genomic Solutions
Teradyne
Thermo Fisher Scientific

Service – Professional

Artaic
Aurora Flight Sciences
Barrett Technologies
Battelle
Black I Robotics
Bluefin Robotics
Boston Dynamics
Corindus Vascular Robotics
Dangel Robots & Machinery
Draper Labs
Foster-Miller
Heartland Robotics
Hydroid
Interactive Motion Technologies
Intersense
iRobot
Kiva Systems
MITRE
Partners Healthcare/CIMIT
Raytheon
SensAble Technologies
Virtual Incision Corporation
Sippican
Smart Robots
Teledyne Benthos
Textron Systems
Vecna Technologies

Service – Personal

iRobot
Cyber-Kinetics
Gears Educational Systems
Hocoma
Myomo
Q Robotics
Robots and Relax
Rug Warrior

Components

Diagnostics

Aware
CIMTEK

Software

Aware
BBN Technologies
Co-Automation
Energid Technologies
Iconics
ID One
Immersive Design
Mathworks
Mekinesis
Mercury Computer Systems
Metatomix
Microsoft
PTC
Solid Works Corporation

Mechanics, Motion, and Sensors

Axis New England
BBN
Cognex
Deep Sea Systems
Digirobotics
Gibson Engineering
Harmonic Drive Technologies
Hitec Corporation
Valde Systems (Brookline, NH)

Engineering

Boston Engineering
Electromechanica
Gleason Research
Hitec Corporation
Innovent Technologies
Mass Automation Corp.
Mathworks
Mekinesis
MicroE Systems
Protonex Technology Corporation
Salisbury Robotics

Vision Systems

Boston Engineering
Energid Technologies
Focus Robotics
Gibson Engineering
RPU Technology

Electronics

Co-Automation
Falmouth Scientific Inc
NES Technologies

Training and Support

Kaztek Systems

Notes

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