

CHARTING THE COURSE

A Regional Assessment of the Marine Science and Technology Sector in Southeastern New England



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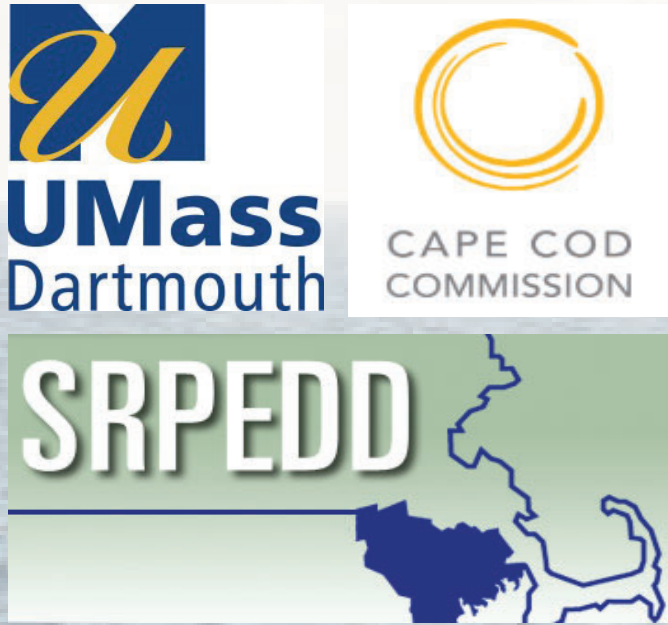
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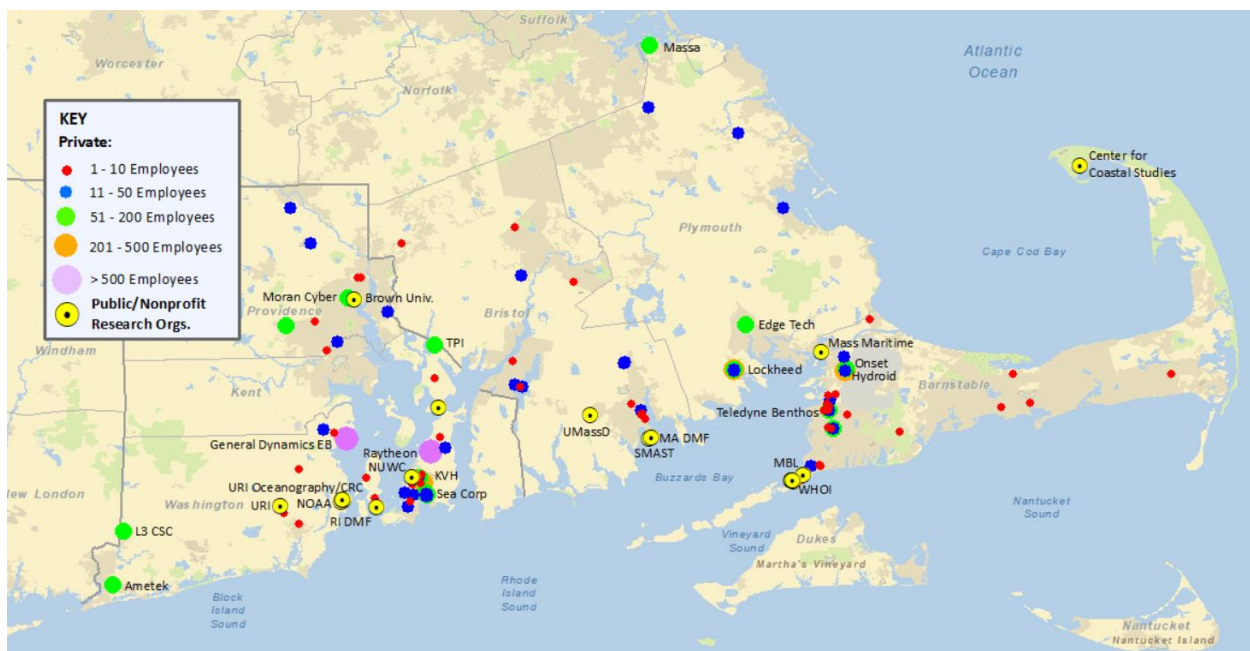
Acronyms

Abbreviation	Meaning
AUV	Autonomous Underwater Vehicle
CCC	Cape Cod Commission
DMF	Division of Marine Fisheries
DoD	Department of Defense
IoT	Internet of Things
IP	Intellectual Property
MBL	Marine Biological Laboratory
MST	Marine Science and Technology
NAICS	North American Industry Classification System
NSF	National Science Foundation
NUWC	Naval Undersea Warfare Center
OECD	Organization for Economic Co-operation and Development
OSW	Offshore Wind
R&D	Research and Development
ROV	Remotely Operated Vehicle
RPA	Regional Planning Agency
SBIR	Small Business Innovation Research
SEMA	Southeastern Massachusetts
SENE	Southeastern New England
SMAST	School of Marine Science and Technology
SRPEDD	Southeastern Regional Planning and Economic Development District
STTR	Small Business Technology Transfer
URI	University of Rhode Island
USDA	U.S. Department of Agriculture
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
WHOI	Woods Hole Oceanographic Institution

EXECUTIVE SUMMARY

This report is an analysis of the Marine Science and Technology (MST) sector in Southeastern New England (SENE), a region composed of Bristol, Plymouth, Barnstable, Dukes, and Nantucket counties in Massachusetts and all of Rhode Island. The sector consists of 115 companies and 21 public and nonprofit organizations that are geographically distributed throughout the region, primarily along coastal waters. There are two areas of concentration: (1) in and around Aquidneck Island in Rhode Island and (2) in Falmouth, Massachusetts. Additionally, there are approximately fifty additional coastal and ocean related public and nonprofit organizations whose primary mission is advocacy, entrepreneurship, K-12 education, monitoring, or environmental protection.

Core Marine Science and Technology businesses and research organizations



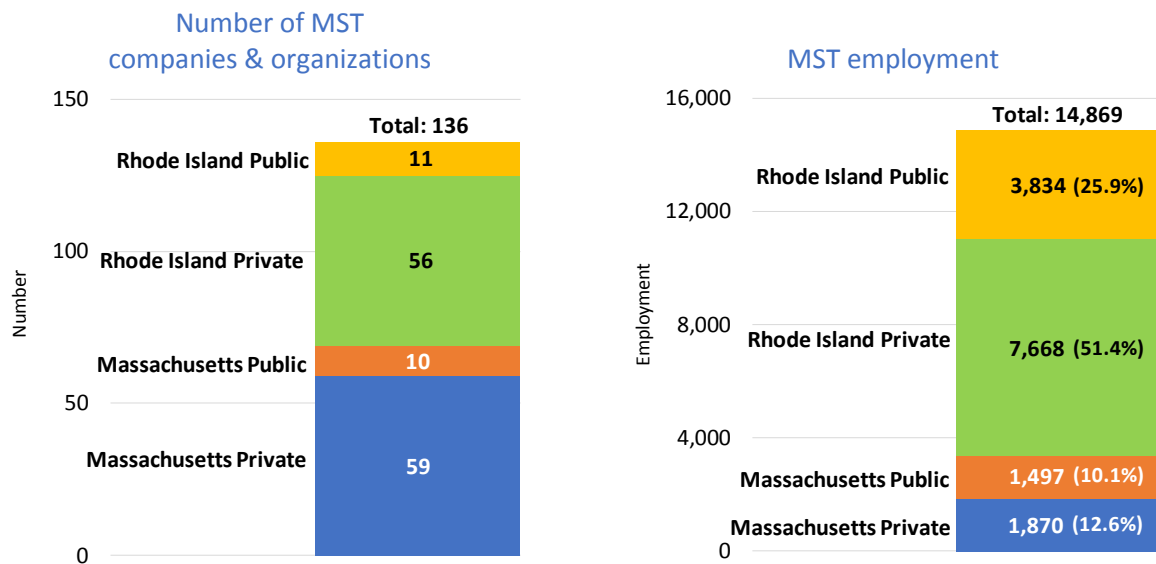
Source: Public Policy Center

Though a Handful of Large Firms Account for the Bulk of Regional MST Employment, the Region's MST Sector Primarily Consists of Small Companies

The sector employs nearly 15,000 workers across 136 organizations. Looking at only private sector employment, we find that MST employs more people than other high-tech sectors, such as medical devices, biopharmaceuticals, and information technology & analytical instruments. However, it still only accounts for 1.1 percent of employment in the region.

The number of companies and institutions in Massachusetts and Rhode Island is similar, but the sector is organized differently in each state. Rhode Island is home to the region's larger employers, such as General Dynamics' Electric Boat, Raytheon, and the Naval Undersea Warfare Center, and accounts for 77 percent of the 11,502 MST workers in the state. The largest employers on the Massachusetts side of the region include Woods Hole Oceanographic Institution, Lockheed Martin, and Kongsberg Hydroid, which employ 45 percent of the 3,367 MST workers in Southeastern Massachusetts and Cape Cod.

Charting the Course: An Assessment of Southeastern New England's Marine Science & Technology Sector



Source: Public Policy Center

Even though a handful of large companies account for the majority of MST employment in the region, the sector is primarily made up of smaller firms. Nearly eight in ten (79%) of companies employ 50 workers or fewer and 46 percent employ ten or fewer workers.

MST private companies by size

Employee Range	Number Companies	Total Employment	% Total	Average Company Size
1–10	53	279	2.8%	5
11–50	38	1,105	11.1%	29
51–200	19	2,122	22.4%	112
201–500	3	822	8.7%	274
> 500	2	5,210	55.0%	2,605
Total	115	9,538	100.0%	85

Source: Public Policy Center from MST Business Survey and Esri Business Analyst

Charting the Course: An Assessment of Southeastern New England’s Marine Science & Technology Sector

What Do These MST Companies Do?

The MST sector spans a wide variety of industries, including, but not limited to robotics, oceanography, renewable and non-renewable energy, biotechnology, communications hardware, information technology, advanced materials, and civil engineering. The following table provides examples of the goods and services produced by the region’s MST companies. These include goods such as ocean instrumentation and sensors, mooring systems, marine hardware, cable assemblies and connectors, data loggers, and services such as systems engineering, software engineering, testing and evaluation, and environmental services.

Examples of MST products and services

Products	Services
Unmanned undersea vehicles (ROVs and AUVs)	Systems and software engineering
Side scan and bottom sonars	Bio-geochemical/physical oceanography sampling
Marine magnetometers	Hydrology, oceanography, and topography mapping
Electrical cables & connectors	Mooring design services
Antifouling paints	Hydrostatic testing
Circuit board assemblies	Imaging algorithms for underwater vehicle systems
Mooring systems & components	Naval architecture (e.g. hull design)
Underwater video systems	Weather and climate change modeling
Acoustic current meters	Safety engineering,
Advanced composites	Composites engineering
Micro-grid platforms	Testing and evaluation
High precision plastics	Sensor system design
Marine stabilized camera systems	Environmental and ocean engineering consulting
Composite wind blades	Cybersecurity solutions
Autonomous underwater gliding vehicles	Prototyping
Current, wave, and tide meters	Pressure sensing
Electro-acoustic transducers	Combat simulations
Underwater optical communications system	Data acquisition
Engineered inflatables	Structural analysis
Syntactic foams	Logistics consulting
Battery power systems	Cables & rigging design

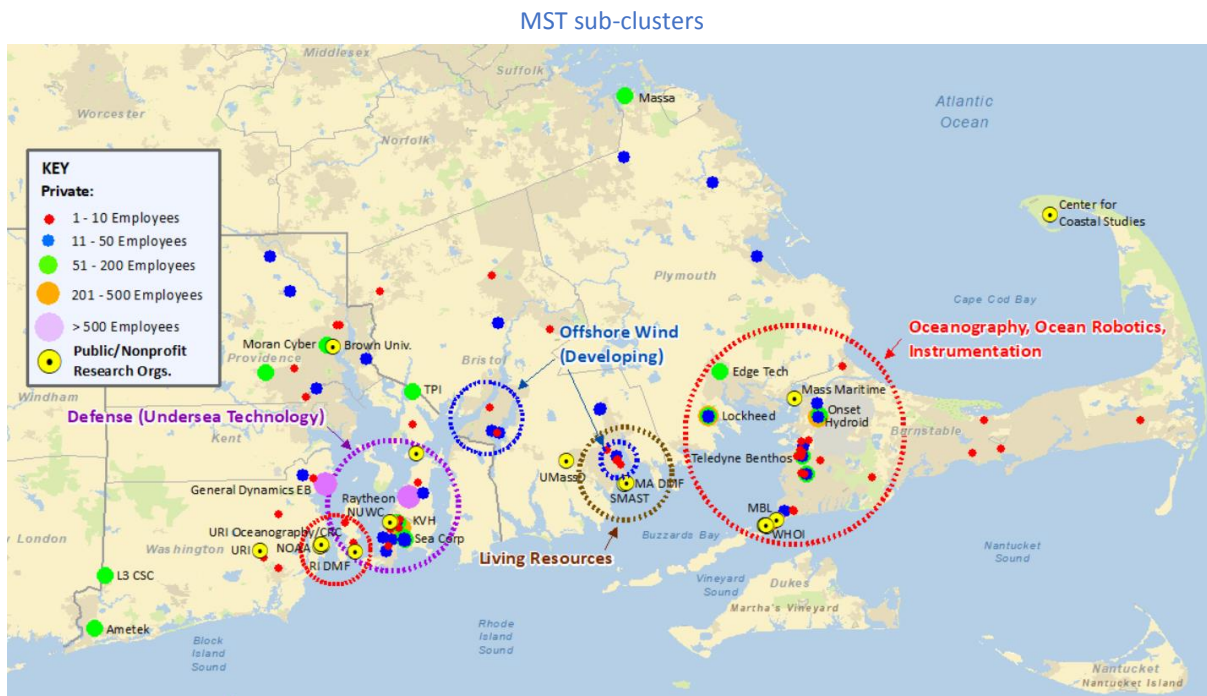
Source: Public Policy Center

Charting the Course: An Assessment of Southeastern New England's Marine Science & Technology Sector

Southeastern New England is Home to Four MST Sub-Clusters That Have Unique Identities and Needs

It is important to recognize that the MST sector is composed of distinct sub-clusters, and therefore there is no “one size fits all” strategy for growing the region’s MST sector. The clusters include:

- **Oceanography, Ocean Robotics, and Instrumentation:** Includes companies and institutions primarily focused on studying the oceans and manufacturing robots and instruments that aid in doing so.
- **Defense (Undersea Technology):** Includes companies and institutions conducting R&D, testing, and engineering services and support for submarines and underwater systems, primarily in support of the U.S. Navy and other Department of Defense agencies.
- **Living Resources:** Includes companies and institutions primarily focused on extracting value from the ocean such as commercial fishing, fish hatcheries and aquaculture, and seafood processing.
- **Offshore Wind (Developing):** Includes companies in the offshore wind energy sector that is developing as a result of the large offshore wind resource in the seven lease areas near Massachusetts and Rhode Island, and recent state-level commitments to procure electricity specifically from offshore wind.



Source: Public Policy Center

Implications for Action

The research presented in this report is designed to inform the development of evidence-based strategies to grow the MST sector in Southeastern New England. Based on our comprehensive analysis of the region’s MST sector, an assessment of research strengths and opportunities, a workforce analysis that identifies current and future high priority occupations, surveys and interviews with regional stakeholders, and an analysis of opportunity areas and challenges for the MST sector going forward, several clear implications for action emerged from our research:

1. Build on the MST sector’s strengths by connecting traditional maritime industries to existing and emerging scientific developments and technological opportunities.

Alignment of MST opportunity areas with regional strengths and growth prospects



Connecting tradition with technology will help to preserve our maritime heritage and support longstanding regional industries that have been areas of comparative advantage for the region (e.g., living resources and water transportation). While efforts should be made to foster the development of emerging and promising marine technologies, aligning efforts with traditional strengths will help to ensure that we are supporting businesses that are well-positioned to grow to scale in the region, rather than elsewhere. Accordingly, approaches to supporting marine technology enterprises should be designed to identify and develop new opportunities, while at the same time meeting the needs of the traditional sectors that have made SENE a center of Blue Economy activities for centuries. Towards these ends, we identified the following opportunity areas for growing the MST sector:

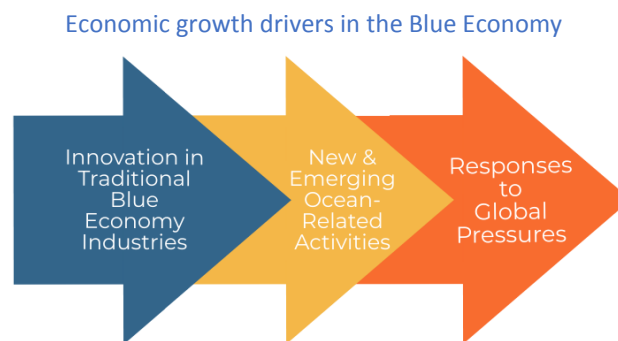
- Connecting defense-related innovation to commercial market opportunities;
- Modernizing and expanding the living resources sector;
- Positioning the region to capitalize on offshore wind;
- Leveraging the region’s expertise in marine science to address the challenges of climate adaptation.

2. Redouble efforts to advocate for federal funding.

The region's MST companies and public and nonprofit organizations are highly dependent on federal research funding for both applied and basic research. In 2017, both WHOI and URI ranked among the top ten largest recipients of oceanographic research funding in the nation. Furthermore, MST firms and research institutions in the region received over \$1 billion in federal contracts from the Department of Defense from 2014 to 2019. Continuous and effective advocacy for federal funds is necessary to maintain support for scientific research and defense-related technological innovation.

3. Organize and respond to the threats presented by climate change and other threats to the Blue Economy.

Our world is confronted with extreme threats to its ocean environment. Issues of food security and water availability, energy security, sea level rise, and ocean pollution require us to think critically about how we relate to, depend upon, and derive value from the ocean. While many of these threats present economic costs, they also present opportunities to the organizations and businesses that find innovative ways to address these challenges. The future success of the MST sector and the prospects for the regional Blue Economy as a whole will depend on the degree to which we are successful in predicting, adapting, and responding to these challenges.



4. Focus educational and workforce development efforts on both emerging and long-standing gaps in the regional labor force.

MST employers indicated concerns about labor supply in two essential fields. MST employers responding to the business survey emphasized the importance of degrees in engineering disciplines over other credentials. Specifically, employers reported they have difficulty hiring in subfields such as systems and software engineering, acoustics, artificial intelligence, and ocean engineering. Overall, these responses reflect the increasing prevalence of autonomous robotics, IoT, and instrumentation in the MST sector. Given ongoing and expected developments in new technology, the demand for software engineers and other computing-related engineers is expected to grow both within and well beyond the MST sector. Increasing demand for this kind of talent is not unique to SENE. Therefore, a sustained effort to both “grow our own” engineering talent and to make the region appealing in ways that serve to both attract and retain these workers and their families will be required if this gap is to be filled.

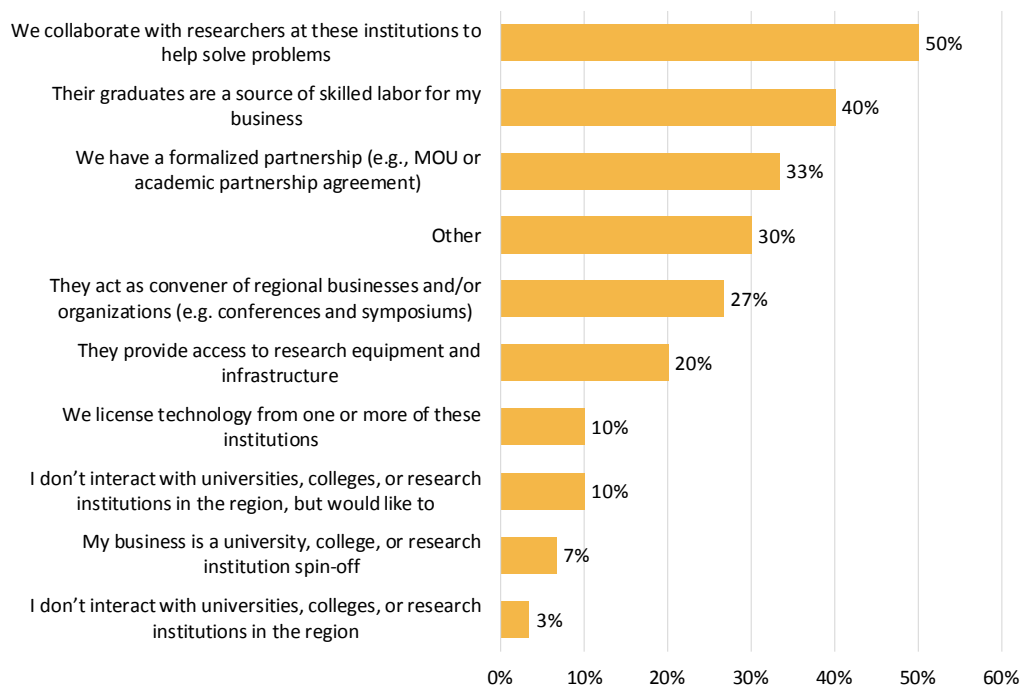
Our analysis also reveals that the workforce needs of the MST sector in SENE extend well beyond the engineering disciplines. The demand for production workers was at the forefront of workforce issues raised by MST

employers in key informant interviews. While much of the MST sector’s output is grounded in scientific research and technological innovation, a very significant portion of the employment in the sector and in the businesses that support the sector involves production and manufacturing oriented occupations. Consequently, supporting and developing sustainable workforce pipelines from regional vocational schools, community colleges, and universities to regional MST employers will be essential if the MST sector is to continue to grow and thrive in SENE. Meeting this challenge would help enable well-paying job opportunities for SENE workers, which are in short supply in the region in comparison to Greater Boston.

5. Reduce barriers that inhibit collaboration between regional research institutions and private industry.

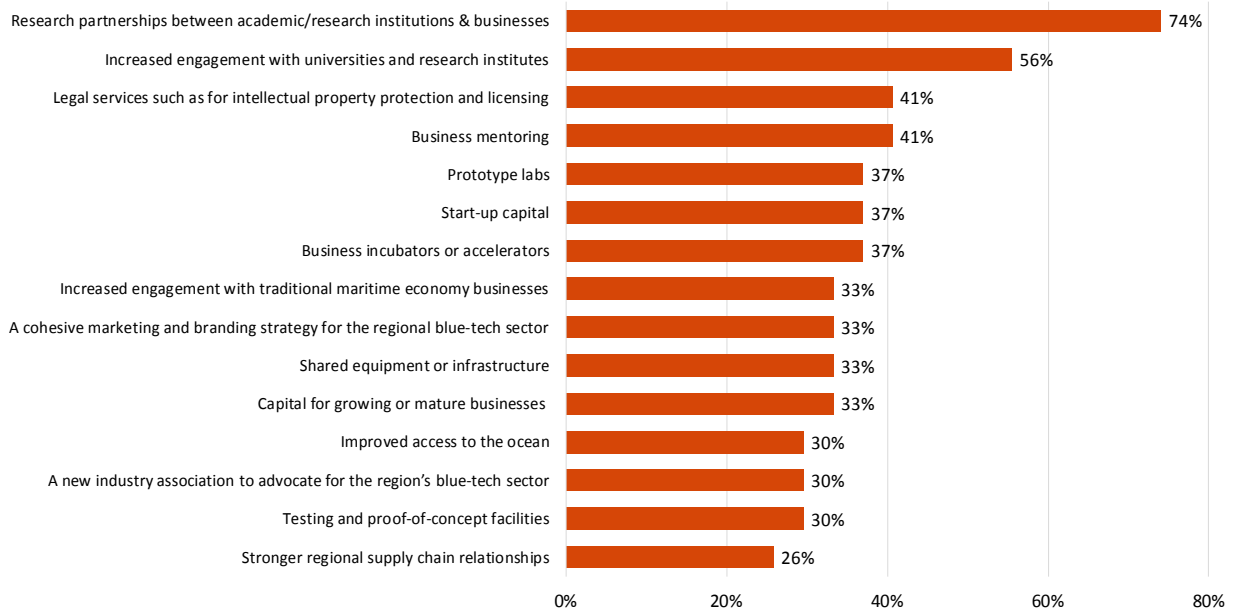
MST companies in SENE report a strong desire to improve collaboration with the region’s universities (see charts below). Key informants noted that past efforts to work with the region’s universities have been frustrating because the university bureaucracy makes collaboration difficult and time consuming, and key institutions lack an ethos that encourages and rewards industry-university partnerships. More flexibility and openness to collaboration from academic research institutions, as well as practical solutions to bureaucratic obstacles will be needed if these collaborations are to be more effective and regionally impactful. This is not a new problem and addressing it will require a sustained and intentional effort to encourage a more entrepreneurial and collaborative culture within and between the region’s major research institutions as well as fundamental changes to the ways in which these institutions relate to each other and to industry. Left unaddressed, it is unlikely that SENE will be able to yield more economic value from its sizable and highly relevant research enterprise.

How would you describe your business’s relationship with universities, colleges, and research institutions in the Southeastern New England region?



Source: MST Business Survey

Thinking of the MST sector as a whole and not just your business, which of the following would make it possible for more MST firms to thrive in the region?



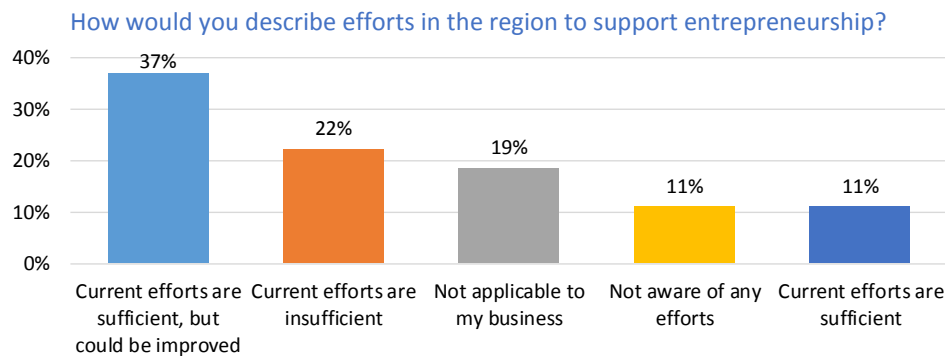
Source: MST Business Survey

6. Yield more economic value from the regional MST research enterprise.

The region’s marine science research institutions and firms are focused primarily on basic science, which historically has rarely translated into meaningful commercial opportunities in SENE. Going forward, the region’s universities and other research institutions will need to focus more on applied research and improve the capacity and performance of institutional technology transfer operations if university-industry spin-offs are to develop and translate into meaningful job growth for the region. This is not a new challenge and will also require meaningful cultural and institutional change if SENE is to meaningfully increase the local economic development impacts of the regional research activity.

7. Reimagine and transform the regional support systems designed to promote entrepreneurship.

The transition from idea or prototype to product is not straightforward and many commercially valuable technical innovations can result from research carried out without commercial application in mind. Evidence from key informant interviews suggests that regional entrepreneurs and companies need more and better support to assist them in scaling their ideas and bringing their products to market. For instance, 41 percent of survey respondents report that legal services such as IP protection and licensing would make it possible for more MST firms to thrive in the region. In addition, many regional MST businesses are best described as “lifestyle businesses,” which are typically led by scientists and engineers working full-time elsewhere and who tend to lack the time, resources, or know-how to move an idea or product from concept to reality.



Source: MST Business Survey

8. Educate the investor community.

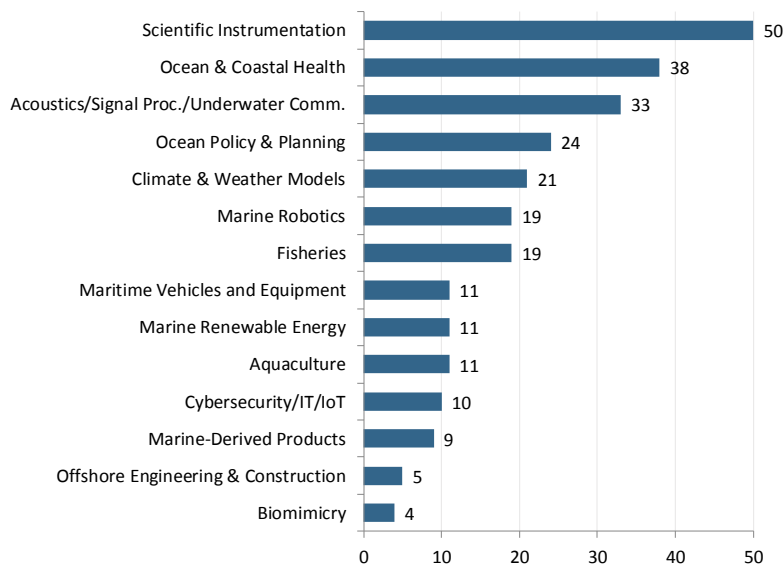
Regional MST stakeholders report that access to capital is an impediment to commercialization, since venture capitalists and large banks do not generally fund small projects that do not have a clear path to scale. This is especially challenging when competing for investment capital against larger, more developed industries such as Information Technology and Biotechnology. Also, while Massachusetts is one of the leading states in the nation for access to venture capital funding, in practice most of this investment finds its way to other sectors such as life sciences, and venture capitalists are hesitant to work with businesses outside of the Greater Boston region. Notably, investors often do not see the market potential for marine technology, which is generally viewed—sometimes correctly—as having a low return on investment. Consequently, there is a need for strategies that connect entrepreneurs and developing businesses to the investor community and those that educate investors about the commercial prospects of marine science and technology. These educational efforts will only be successful to the extent that they are able to present commercially meaningful business opportunities to a community of skeptical investors that remains largely unpersuaded that such opportunities exist in SENE.

9. Align the region's research capacity with emerging Marine Science and Technology opportunities.

SENE has deep and meaningful research expertise in a number of MST fields including scientific instrumentation, ocean & coastal health, and underwater communications. However, seizing emerging MST opportunities will require building expertise in additional areas, such as marine microbiology, offshore engineering and construction, and aquaculture. If individual institutions elected to grow strategically in one or more of these areas through, for example, strategic “cluster hiring” designed to capitalize on those opportunities, it would benefit both the individual institutions and increase the potential economic development benefits for the larger region.

Aligning the region's research agenda with emerging MST opportunities will also require the deliberate exploration of industry-sponsored research activities. For instance, improving communication and facilitating more substantive interactions between research institutions and industry would benefit all parties and help to maximize more commercially relevant research and regional entrepreneurial activity. Facilitating these connections will require a significant change in the culture and practices of the region's major research institutions.

Number of scientists and staff engineers by applied research interest, all institutions, 2018



Source: Author's Calculations

10. Learn from the mistakes of other industry cluster initiatives.

Misdirected efforts in the implementation phase of this project could thwart efforts to significantly grow SENE's MST sector. Cluster initiatives can go awry for a variety of reasons, including emphasizing attracting new businesses over supporting existing firms and startups, where most new job growth will likely occur. Cluster initiatives also frequently fail to identify the correct clusters, or see the sector as a monolith rather than acknowledging that it contains several distinct types of firms that have unique needs, interests, and goals. Acknowledging these issues and building evidence-based strategies for overcoming them will be a key to sustaining this initiative and achieving the goal of a more competitive and prosperous regional economy.

1 BACKGROUND

In 2018, UMass Dartmouth and two regional planning agencies (RPAs)—the Southeastern Massachusetts Planning & Economic Development District and the Cape Cod Commission—were awarded an EDA grant to facilitate the development of a “Marine Science and Technology Corridor.” This project was designed to be a 3-year initiative coordinated under the direction of the UMass Dartmouth, in collaboration with the RPAs, Chambers of Commerce, colleges and universities, businesses in the marine industry, and others.

The project is broken out into three, year-long phases. The execution of a comprehensive study of the MST sector is the first phase, the results of which are summarized in this document. This work attempts to lay the foundation for the second phase of this project, which is expected to include the development of a strategic plan. The original project proposal called for year three and beyond to be devoted to implementation and the development of funding mechanisms to make the larger initiative self-sustaining beyond the life of the EDA-funded portion of the project.

This initiative is premised on the idea that the region has not benefitted economically from the extraordinary success of the Greater Boston innovation economy as evidenced by its ongoing struggle to contend with higher unemployment, lower income and wages, and lower educational attainment levels as compared to the state of Massachusetts as a whole. This report documents that the Southeastern New England region has unique strengths in Blue Economy sectors and a relatively high concentration of activity in Marine Science and Technology (MST) fields. A central goal of the initiative is to build on these strengths to create more well-paying jobs and increase the overall prosperity of the region and its communities. Accordingly, our research and the implications that are drawn from it are designed to help regional leaders craft an effective strategy for closing the regional performance gap and creating meaningful economic opportunities for the region's people, businesses, and communities.

1.1 WHY NOW, WHY BLUE?

Historically, our understanding of the ocean's role in the economy was largely centered on traditional maritime sectors such as fishing, shipping, and boat building. Today, we are expanding how we think about the ocean's role in society to include new and emerging industries, such as aquaculture and offshore wind, as well as ocean ecosystem services, the value of which are not fully captured by the market. The Organization for Economic Co-operation and Development (OECD) notes that "ocean bioresources are no longer seen solely as a source of food but are being viewed as a vast reservoir of organisms and genes with virtually unlimited potential for development and exploitation."¹

Terminology has also changed to reflect this broader understanding—instead of talking about the maritime economy, we now talk about the Blue Economy. The concept of the Blue Economy challenges us to reconsider the ocean as an economic resource worthy of preservation and stewardship alongside the economic opportunities of the traditional maritime economy. This is the sentiment captured by the World Bank's definition of the Blue Economy as the "sustainable use of ocean resources for economic growth, improved livelihood and jobs, and ocean ecosystem health."² The Blue Economy is thus analogous to the green economy in that both represent a synergy between environmental and economic ambitions.

Our view of the ocean as a resource has changed as the public has become more aware of the potential effects of climate change and we have shifted towards more sustainable approaches to natural resource management. Trends such as ocean warming, acidification, and ocean plastics have threatened our traditional uses of the ocean and brought more attention to the needs of the Blue Economy. Furthermore, coastal communities around the world are looking to the sea as a way to transform their economies. According to the OECD, ocean-related industries contributed more than \$1.5 trillion in value added to the overall global economy in 2016 and that value is expected to double by 2030.³

Interest in the Blue Economy permeates multiple levels of government, including international organizations such as the United Nations and the OECD, at the national level through the U.S. Senate Oceans Caucus, at the state level through Massachusetts' Seaport Economic Council, at the regional level such as through the Cape Cod Blue Economy Initiative, and at the local level through such efforts as the New Bedford Ocean Cluster. While there is vast opportunity, how much of that opportunity is converted to economic gains remains to be seen, particularly since much of the opportunity will be created or captured by businesses that do not yet exist or by current businesses who in many cases to date have been hesitant to change.

Concurrent with developing new approaches to sustainably extract economic value from the oceans, substantial economic opportunities are expected that are related to the search for new ways to sustain the ocean ecosystem. As the Economist Intelligence Unit notes, "the world is in many ways at a turning point in setting its economic priorities in the ocean. How this is done in the next years and decades, in a period when human activities in the ocean are expected to accelerate significantly, will be a key determinant of the ocean's health and of the long-term

¹ Organization for Economic Co-operation and Development. 2013. *Marine Biotechnology: Enabling Solutions for Ocean Productivity and Sustainability*, OECD Publishing, p. 14.

² World Bank Group (2017). Blue economy infographic. Retrieved from <http://www.worldbank.org/en/news/infographic/2017/06/06/blue-economy>.

³ Organization for Economic Co-operation and Development. 2016. *The Ocean Economy in 2030*, OECD Publishing. <https://doi.org/10.1787/9789264251724-en>.

benefits derived by all from healthy ocean ecosystems.”⁴ With its traditional maritime industries and world-renowned MST firms and institutions, the SENE region is in many ways well-positioned to capitalize on this transformation.

Scientific and technological innovation developed by the region's MST firms and research institutions have already led to increased efficiency and productivity in traditional Blue Economy industries including fishing and boat & shipbuilding. Throughout this comprehensive assessment of the regional MST sector, we demonstrate how targeted and strategic efforts to support the MST sector have the potential to improve the competitiveness and the performance of the larger regional Blue Economy.

This report is organized into nine sections. Section 1 covers the background of this project. In Section 2, we present our operational definition of the MST sector. The geography of the study region and our methods for determining it are discussed in Section 3. Section 4 contains an assessment of the MST sector based on secondary data, a survey of local MST businesses, and key informant interviews with regional stakeholders. In Section 5, we assess the workforce needs of the sector and identify high value skills and credentials for MST occupations, which are based on our discussions with regional employers, the business survey, and a review of employment trends and occupational requirements. Section 6 reviews trends in MST research and development, which are based on results from our survey, interviews, a review of funding sources, and analysis of MST-relevant patent activity. In Section 7, we present opportunities to facilitate economic growth in the regional MST sector, which is followed by a discussion of potential obstacles and hazards in Section 8. This report concludes with Section 9, in which we discuss the implications of this research for the forthcoming planning and implementation phases of the larger initiative.

⁴ The Economist Intelligence Unit (2015). *The blue economy: Growth, opportunity and a sustainable ocean economy*, Briefing paper for the World Ocean Summit. P. 8.

2 DEFINING MARINE SCIENCE AND TECHNOLOGY

Our research team adopted an inclusive approach in defining the Marine Science and Technology (MST) sector. This decision was informed by a recognition that marine technology could have roots in non-marine industries and that innovative solutions to marine-specific problems do not always come from traditional technology sectors. In the absence of an existing, widely accepted, and clear-cut definition of marine technology, we define it as the following:

Marine technology is any technology specifically developed to enable a range of activities in or on the water, is inspired by or makes direct use of ocean or coastal resources, or promotes ocean and coastal sustainability.

This includes technologies not traditionally considered “blue,” but for which the Blue Economy represents a new market opportunity. In this way, marine technology is not a distinct category of technologies per se, but rather a convenient way to refer to all technologies developed with the ocean playing a key role. For example, marine technology includes a broad array of information technology developments (internet of things (IoT), artificial intelligence, autonomous systems, etc.) that are optimized for marine environments and operations. Likewise, it includes the biotechnological advances that are enabling the next generation of food and fuel production that does not compete for land use.

Similarly, MST crosses many academic disciplines and is not confined to the “marine science” or “oceanographic” wings of our research institutions. Engineers develop new ways of producing marine renewable energy, mathematicians and computer scientists develop new methods for understanding undersea communication signals, and microbiologists develop new strains of algae or other organisms that can be used to produce a range of products, such as fuels and plastics, or clean polluted water.

As a result, any attempt to gain an understanding of the MST activities that take place in a region cannot make use of the standard categories by which data collection agencies sort and report information. While an industry-based definition is suitable for many traditional maritime industries, a list of MST businesses based solely on an industrial sector definition would include non-MST businesses and misleadingly exclude others that may not conform precisely to a NAICS-based classification.⁵

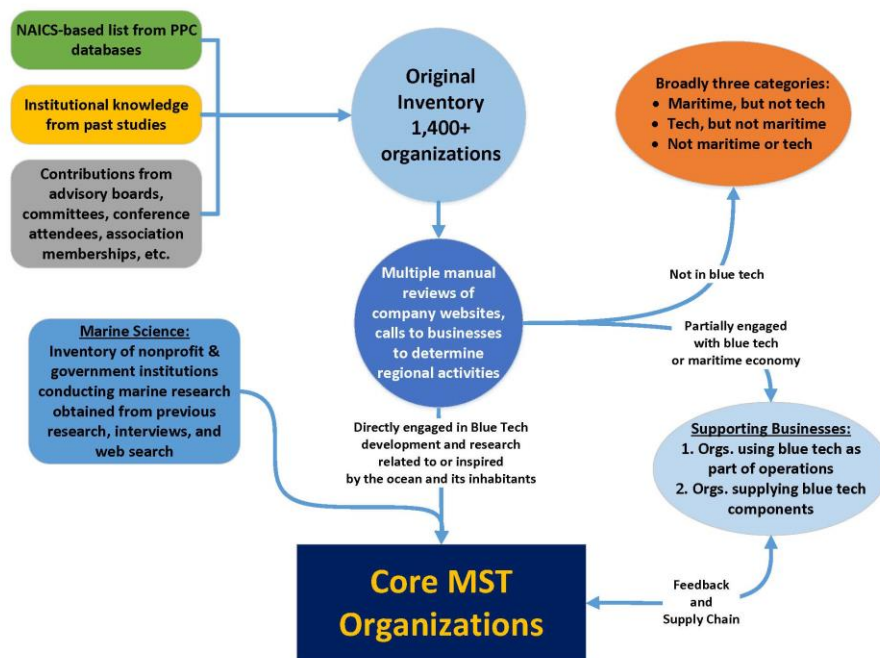
Therefore, in order to produce a satisfactory inventory of core MST businesses and institutions for the purposes of this and future phases of the study, the research team manually developed a list using multiple sources and refined it create an inventory of core MST businesses and institutions. The refining process involved the following steps:

1. An initial inventory of businesses engaged in blue or marine technology was produced from NAICS-based databases, such as Business Analyst and InfoUSA; the local institutional knowledge of the project advisory committee members, insights gained from previous work done on the regional and state maritime economy; survey data; and an analysis of attendees and members of relevant local conferences and industry associations. This stage produced an inventory of over 1,400 business.

⁵ The NAICS (North American Industry Classification System) was developed by Federal Statistical Agencies for the collection, analysis, and publication of statistical data related to the US Economy. Each business is classified into a six-digit NAICS code number based on the majority of activity at the business. The Census Bureau tabulates the data into summary totals at the two-digit down to six-digit NAICS levels.

- The inventory was then culled through an iterative review process, in which each organization’s status as a core marine technology firm was verified through phone calls, review of related news items, and web searches. This process was repeated by various members of the research team and resulted in organizations being sorted into three groups: **1) core marine technology organizations** directly engaged in marine technological development or research related to or inspired by the ocean and its inhabitants; **2) supporting organizations**, such as machine shops, composite manufacturers, and environmental consulting firms that either use marine technology as part of their business operations or supply components for marine technology manufacturers; **3) unrelated organizations**, which were captured under a marine technology-related NAICS code, but after thorough investigation and repeated vetting, were determined to be a maritime business not engaged with technology, a technology business not engaged in maritime activities, or neither.
- Concurrently, the research team reviewed the activities of staff employed at SENE universities, colleges, government/nonprofit organizations, and research institutions to determine the number of **core marine science organizations**. These connections were verified through interviews, literature reviews, and web searches.
- Combined, the core marine technology and core marine science organizations comprise what we termed the **core MST organizations**, which is the universe of organizations surveyed as part of this research and the inventory used to describe the economic scale and significance of the MST sector and MST research activity in SENE in detail. This inventory also is designed to support organizational outreach in the planning and implementation phases of the project, even as it demonstrates the diverse collection of relevant organizations in the region and underscores the opportunities for cross-sector regional collaboration.

Figure 1
How we identified Marine Science and Technology firms and organizations



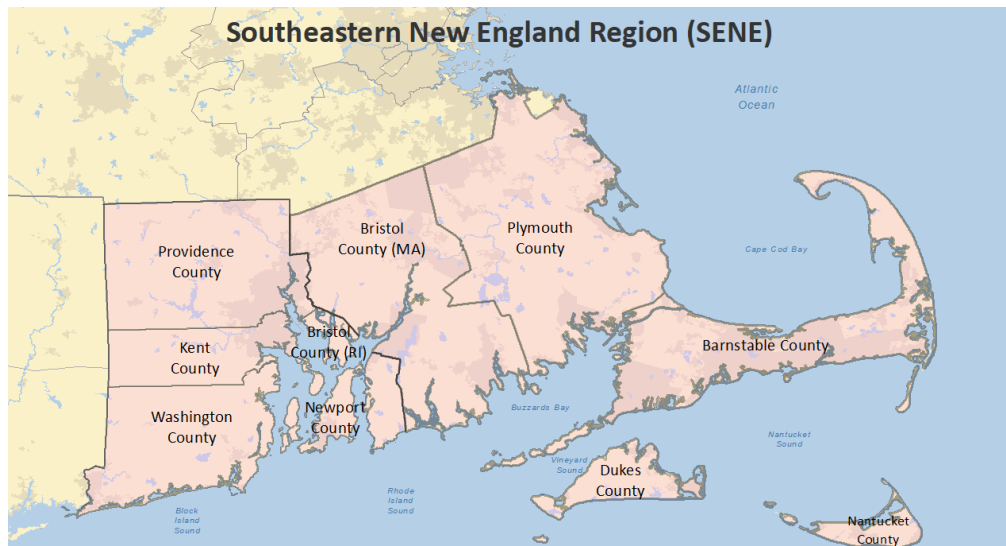
3 GEOGRAPHIC SCOPE

This report is an analysis of the MST sector in Southeastern New England (SENE), a region composed of Bristol, Plymouth, Barnstable, Dukes, and Nantucket counties in Massachusetts and all of Rhode Island (see Figure 2).

This project was initiated by UMass Dartmouth and two of the Bay State’s regional planning agencies—the Southeastern Massachusetts Regional Planning & Economic Development District (SRPEDD) in Taunton and the Cape Cod Commission (CCC) in Barnstable. Each of these regions is home to prominent MST research institutions, including Woods Hole Oceanographic Institution (WHOI) and UMass Dartmouth School of Marine Science and Technology (SMAST), as well as many firms operating in the MST sector. Thus, Southeastern Massachusetts and Cape Cod and the Islands was the starting point for our exploration and identification of the regional economic geography for this initiative.

Rhode Island was included in the study region because of the strong and well-documented economic connections between Massachusetts and the Ocean State. In *The Economic Geography of SouthCoastal New England*,⁶ the Public Policy Center (PPC) assessed the economic geography of Massachusetts and neighboring states. A detailed analysis of commuting patterns, industrial composition, and media markets revealed that much of Southeastern Massachusetts and the vast majority of Rhode Island are part of a shared functional economic region. The cities and towns in this region are home to a common labor force, a common media market, and rely heavily on ocean resources, which fuel significant economic and scientific activities on both sides of the border. Rhode Island is also home to several MST research institutions including the URI Graduate School of Oceanography as well as many large MST firms, which cooperate and collaborate in various ways with its neighbors in the Bay State.

Figure 2
The Southeastern New England region



Source: Public Policy Center

⁶ <http://publicpolicycenter.org/wp/wp-content/uploads/2019/08/TheEconomicGeographySCNE.pdf>

4 SECTOR ASSESSMENT

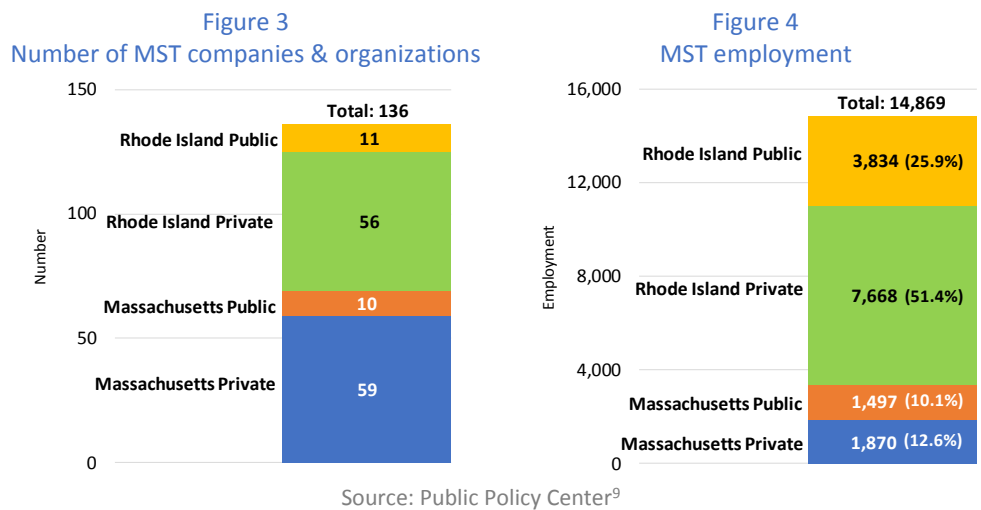
Our assessment of the MST sector involved a holistic analysis of the regional economy, including an overview of the MST landscape, the identification of regional sub-clusters, an analysis of supporting industries, and the identification of both the challenges and opportunities facing the sector in SENE. We also examined existing collaborations and partnerships between MST universities, government, and companies and the ways in which these relationships help to strengthen and sustain the sector.

4.1 HOW ECONOMICALLY SIGNIFICANT IS THE MARINE SCIENCE AND TECHNOLOGY SECTOR?

SENE’s MST Sector Consists of 115 Companies and 21 Public and Nonprofit Research Organizations That Employ Nearly 15,000 Workers⁷

Massachusetts and Rhode Island contain about the same number of MST companies and organizations. However, the Ocean State is home to many of the region’s larger employers, including General Dynamics Electric Boat at Quonset Point, Raytheon in Portsmouth, and the Naval Undersea Warfare Center (NUWC) in Newport. Consequently, Rhode Island accounts for 77 percent of total MST employment in the region, or 11,502 employees (7,668 private and 3,834 public) (see Figure 3 and Figure 4).⁸

The largest MST employers in Massachusetts are Woods Hole Oceanographic Institution (WHOI) in Falmouth, Lockheed Martin in Marion, and Kongsberg Hydroid in Falmouth. These three alone account for approximately 45 percent of Massachusetts’ total MST employment of 3,364 (1,870 private and 1,497 public). Notably, the region’s MST employment can fluctuate greatly over time due to the substantial reliance on Department of Defense funding and the subsequent ramping up or down of the workforce as major projects begin or end.



⁷ For universities, only MST-related workers were included in job count numbers.

⁸ “Public organizations” include government, university, and nonprofit research institutions whose primary mission is to conduct research that advances the MST field. Organizations whose primary mission is advocacy, entrepreneurship support, K-12 education, monitoring, and conservation are discussed later in this section.

⁹ Employment was derived from several sources, including self-reported employment from the business survey, Esri Business Analyst, state economic development organizations, and news stories.

The Region’s MST Sector Primarily Consists of Small Firms

Despite having some large employers, SENE’s MST sector primarily consists of small companies; 79 percent of companies employ 50 workers or fewer and 46 percent employ ten workers or fewer. However, large companies still account for the majority of employment in the sector, with five companies (General Dynamics Electric Boat, Raytheon, Lockheed Martin, KVH Industries, and Hydroid) accounting for 64 percent of total employment (see Table 1).

The average MST company size in the Massachusetts portion of SENE is 31 employees and the average company size in Rhode Island is more than four times that average, at 141 employees. Public/nonprofit MST organizations are, on average, larger than private MST companies; the average public/nonprofit organization size is 150 in the Massachusetts portion of SENE (driven primarily by employment at WHOI) and 349 in Rhode Island (primarily driven by employment at NUWC).

Table 1
MST private companies by size

Employee Range	Number Companies	Total Employment	% Total	Average Company Size
1–10	53	279	2.8%	5
11–50	38	1,105	11.1%	29
51–200	19	2,122	22.4%	112
201–500	3	822	8.7%	274
> 500	2	5,210	55.0%	2,605
Total	115	9,538	100.0%	85

Source: Public Policy Center from MST Business Survey and Esri Business Analyst

4.2 WHERE ARE THE REGION’S MST COMPANIES AND INSTITUTIONS LOCATED?

MST Companies Are Concentrated in and Around Aquidneck Island in Rhode Island and WHOI in Falmouth

Figure 5 displays the geographic distribution of the region’s MST companies and institutions, which are located primarily along coastal waters throughout the region. While proximity to the ocean might appear to be a competitive advantage for SENE’s MST companies, there are other large and successful MST companies outside the region that are not located in a coastal zone.¹⁰ These companies overcome their non-shore location by using in-house test facilities (e.g., large tanks), leasing space at off-location test facilities, or owning/leasing test areas with direct ocean access.¹¹ In addition, many of the region’s MST companies develop software, provide other engineering solutions, or manufacture products that do not require testing in an ocean environment. In fact, we find that co-location with other maritime industries may be more important than direct water access for supporting a thriving MST sector. We explore this issue in more detail in Section 4.5.

¹⁰ For example, Boston Engineering in Waltham, Triton Systems in Chelmsford, and Oasis Systems in Lexington.

¹¹ Factors that might prevent companies from locating on or near the water who would like to do so include land prices, land availability, and environmental regulation.

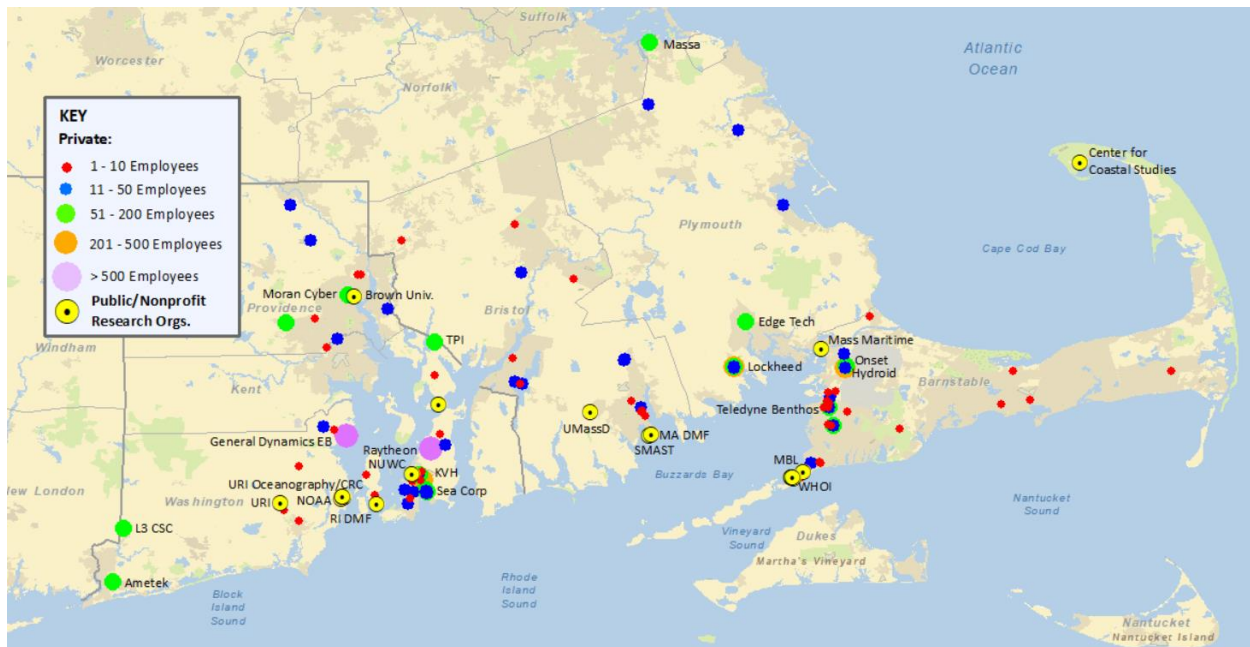
Spotlight

WHOI’s Test Facilities Recreate Deep Sea Conditions on Land

WHOI’s Center for Marine Robotics is home to a cutting-edge pressure test facility. Opened in 2019, the facility will allow WHOI and other companies and researchers to simulate deep ocean pressure and stress-test their materials and marine robotics engineering solutions. This will “triple the project capacity of its existing manually-operated system” as well as “allow for unattended 24/7 operations,” supporting innovation and new marine robotics startups in the region.

The region’s public and nonprofit research institutions rely more heavily on direct ocean access, including WHOI, UMass Dartmouth School for Marine Sciences (SMAST), the Massachusetts and Rhode Island Divisions of Marine Fisheries (DMF), the National Oceanographic and Atmospheric Administration (NOAA), and the University of Rhode Island (URI) Graduate School of Oceanography. WHOI, SMAST, and URI have shore-side infrastructure that provides direct ocean access, including dockage for research vessels. However, co-location is also important to these institutions, as much of their oceanographic research is connected in important ways to issues of great interest to SENE’s traditional maritime industries (e.g., fishing).

Figure 5
Southeastern New England’s Marine Science and Technology employers



Source: Public Policy Center

4.3 HOW BIG IS BIG?

The MST Sector Is Larger Than Other High-Tech Sectors in the Region, but Currently Represents a Small Fraction of the Total Regional Employment, Particularly in Massachusetts

In order to understand the scale of the SENE MST sector, it is helpful to compare it to some of the region’s other high-tech industries. In this analysis, we compare MST sector employment (defined as described in Section 2) to some high-tech industries frequently targeted by economic development practitioners, as defined by the U.S. Cluster Mapping Project at Harvard Business School using NAICS-based data.¹² Unlike MST, these three industries fit more neatly within a NAICS-based definition.

Table 2 shows that MST is a larger sector in terms of regional employment when compared to other major tech sectors in SENE. If we apply a NAICS code based definition of MST and a traditional cluster analysis approach, MST does not appear to be an area of regional strength. This, however, is misleading. When interpreting these data it is important to keep in mind that in practice these tech sectors frequently overlap; for example, we have found that the Information Technology and Analytical Instruments industry contains many companies that specialize in marine-related products. While MST has higher employment than some of the region’s other high-tech industries, the industry still only represents about 1.1 percent of total employment in the region.¹³

Table 2
Employment by high-tech industry, SENE, 2018¹⁴

Region	Industry	Employment	Share of Total SENE Employment
SENE Total	MST, Private Sector	9,538	1.1%
	Biopharmaceuticals	1,535	0.2%
	Medical Devices	4,095	0.5%
	Information Technology & Analytical Instruments	6,365	0.7%
Rhode Island	MST, Private Sector	7,668	0.9%
	Biopharmaceuticals	1,187	0.1%
	Medical Devices	1,252	0.1%
	Information Technology & Analytical Instruments	2,922	0.3%
Southeastern Massachusetts & Cape Cod	MST, Private Sector	1,870	0.2%
	Biopharmaceuticals	348	0.0%
	Medical Devices	2,843	0.3%
	Information Technology & Analytical Instruments	3,443	0.4%

Source: Emsi and Author’s Calculations

¹² In order to enable comparability, we only examined private-sector employment.

¹³ Based on 2018 annual QCEW private employment from the Bureau of Labor Statistics.

¹⁴ Information Technology & Analytical Instruments includes some companies in the MST sector.

As can be seen in Table 3, with the exception of higher education, all of the top industries in SENE primarily serve local markets and consumers, and are not considered traded industries. Traded industries are an important part of the economy because they bring new money into the region by selling goods and services to outside markets, and consequently play a disproportionate role in driving regional income growth. Thus, even though the MST sector employs far fewer people than the health and education sectors, it nevertheless represents a genuine opportunity for SENE to become a center of activity in an emerging sector of the innovation economy that could directly benefit from a number of durable regional competitive advantages and assets.

Table 3
MST and top 10 ranked industries, share of total employment, SENE, 2018¹⁵

Industry	Share of Total SENE Employment
Restaurants and Other Eating Places	8.1%
Local Education	4.8%
General Medical and Surgical Hospitals	3.2%
Local Government, Excluding Education	2.8%
Grocery Stores	2.5%
Colleges, Universities, and Professional Schools	2.4%
Services to Buildings and Dwellings	2.1%
Individual and Family Services	2.0%
Nursing Care Facilities (Skilled Nursing Facilities)	1.9%
Management of Companies and Enterprises	1.7%
MST Public and Private	1.3%

Source: Emsi and Author's Calculations

¹⁵ Industries defined as 4-digit NAICS.

4.4 WHAT DO MST COMPANIES AND INSTITUTIONS IN SENE DO?

The MST Sector Is Diverse and Produces a Wide Variety of Goods and Services

The MST sector spans a wide variety of industries, including, but not limited to, robotics, oceanography, renewable and non-renewable energy, biotechnology, communications hardware, information technology, advanced materials, and civil engineering. Coding these private companies into their respective NAICS codes, we find that the region’s largest MST industry by employment is Shipbuilding & Repairing (see Table 4), which primarily consists of employment at General Dynamics Electric Boat at Quonset Point. The next largest MST industry is Engineering Services, with many of the larger companies in this industry providing systems engineering, software, and hardware engineering services to the U.S. Navy.

Table 4
Top ten MST industries by employment and NAICS code

Code	Description	# Companies	Employment
336611	Ship Building & Repairing	3	3,872
541330	Engineering Services	36	2,707
334511	Search, Detection, Navigation, Guidance, Aero, Nautical System & Instrument Mfg.	33	1,148
334418	Printed Circuit Assembly (Electronic Assembly) Mfg.	1	320
517919	All Other Telecommunications	1	272
334419	Other Electronic Component Mfg.	4	184
333611	Turbine & Turbine Generator Set Units Mfg.	3	182
334519	Other Measuring & Controlling Device Mfg.	5	172
541690	Other Scientific & Technical Consulting Services (except environmental)	6	156
335929	Other Communication & Energy Wire Mfg.	2	108

Source: Public Policy Center from MST Business Survey and Esri Business Analyst

The third largest MST industry is Search, Detection, Navigation, Guidance, Aeronautical, Nautical System & Instrument Manufacturing. Companies engaged in this industry primarily develop, manufacture, and test marine robotics, including unmanned underwater vehicles (UUVs) to serve military, research, and commercial customers. Many companies in this sphere also develop and manufacture instrumentation and sensor solutions that are installed in UUVs or on other apparatus that explore and measure the undersea environment. Southeastern Massachusetts is widely acknowledged as an international leader in the marine robotics industry, with two of the three leading manufacturers of autonomous underwater vehicles (AUVs)—Kongsberg Hydroid and Teledyne Benthos—located in the region, and the remaining company, Bluefin Robotics, located in nearby Quincy.¹⁶

¹⁶ All three firms were founded using technology developed at WHOI (Hydroid and Teledyne) and MIT (Bluefin) respectively.

Spotlight

C. Raymond Hunt and the Regional Legacy for Innovation in Ship and Boat Design

In 2016, *Boating Magazine* ranked the 60 greatest boating innovations of all time. Topping that list was deep-V hull, which was developed by C. Raymond Hunt in New Bedford in the 1950s. As *Boating* remarked, “Hunt’s development comprises a variety of elements that result in much more than just a smooth ride at high speeds in rough waters.” The new hull allowed for a smoother, safer, and drier ride as a result of its even distribution of displacement and high chines. Hunt’s innovation changed boating design in ways that are still evident today, allowing recreational boaters to have a longer range and greater versatility than they would otherwise. C. Raymond Hunt’s legacy for innovative, thoughtful designs lives on in New Bedford, with the naval architecture firm that bears his name, Ray Hunt Designs, designing single-engine powerboats, custom-built yachts, and commercial boats to this day.

Table 5 provides examples of the goods and services produced by MST companies. These include ocean instrumentation and sensors, mooring systems, marine hardware, cable assemblies and connectors, data loggers, and systems engineering, software engineering, testing and evaluation, and environmental services.

Table 5
Examples of MST products and services

Products	Services
Unmanned undersea vehicles (ROVs and AUVs)	Systems and software engineering
Side scan and bottom sonars	Bio-geochemical/physical oceanography sampling
Marine magnetometers	Hydrology, oceanography, and topography mapping
Electrical cables & connectors	Mooring design services
Antifouling paints	Hydrostatic testing
Circuit board assemblies	Imaging algorithms for underwater vehicle systems
Mooring systems & components	Naval architecture (e.g. hull design)
Underwater video systems	Weather and climate change modeling
Acoustic current meters	Safety engineering,
Advanced composites	Composites engineering
Micro-grid platforms	Testing and evaluation
High precision plastics	Sensor system design
Marine stabilized camera systems	Environmental and ocean engineering consulting
Composite wind blades	Cybersecurity solutions
Autonomous underwater gliding vehicles	Prototyping
Current, wave, and tide meters	Pressure sensing
Electro-acoustic transducers	Combat simulations
Underwater optical communications system	Data acquisition
Engineered inflatables	Structural analysis
Syntactic foams	Logistics consulting
Battery power systems	Cables & rigging design

Source: Public Policy Center

- **Oceanography, Ocean Robotics, and Instrumentation:** Includes companies and institutions primarily focused on studying the oceans and manufacturing robots and instruments that aid in doing so. As noted, the Massachusetts portion of SENE is an international leader in the development and manufacture of AUVs and ocean instruments and sensors, and WHOI is the largest oceanographic research center in the U.S. Several of the larger employers in this cluster, including two marine robotics firms, are WHOI spinoffs.

This cluster overlaps with the Defense sub-cluster described below, particularly in terms of a shared focus on the design, and manufacture of underwater robotics, sensors, and other instrumentation. Both of these clusters are excellent examples of how oceanographic research, much of it publicly funded, can inspire and fuel private sector ventures.

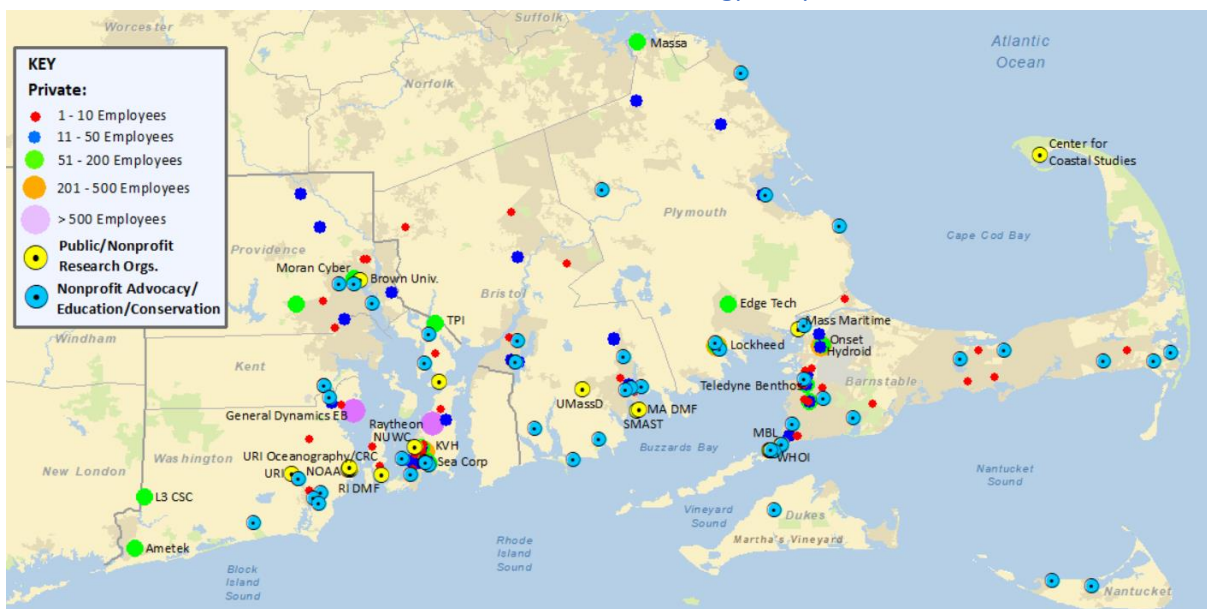
- **Defense (Undersea Technology):** Includes companies and institutions conducting R&D, testing, and engineering services and support for submarines and underwater systems, primarily in support of the U.S. Navy and other Department of Defense agencies. Accordingly, this cluster is very dependent on federal funding; many of the companies in this cluster primarily conduct contract work with the NUWC or other Department of Defense agencies. MST firms and research institutions in the region received over \$1 billion in federal contracts from the Department of Defense from 2014 to 2019. In some cases, these companies are actually satellite offices for firms with headquarters or major operational centers located outside the region, but the presence of NUWC and its procurement activities (as well as other MST companies) makes it crucial for them to have a presence in the immediate vicinity.
- **Living Resources:** Includes companies and institutions primarily focused on extracting value from the ocean such as commercial fishing, fish hatcheries and aquaculture, and seafood processing. While most of the industries in this cluster are considered traditional maritime economy industries, pressures on natural resources are requiring these industries to think in new ways and to employ emerging technologies to improve their viability, particularly in light of climate change and its repercussions and a challenging regulatory environment.
- **Offshore Wind (OSW) (Developing):** Includes companies in the offshore wind energy sector that is developing as a result of the large offshore wind resource in the seven lease areas near Massachusetts and Rhode Island, and recent state-level commitments to procure electricity specifically from offshore wind. The future job creation potential in this industry is substantial, particularly from the development of a domestic offshore wind supply chain along the East Coast of the U.S. The SENE region has a number of natural advantages but will face stiff competition from other regions and neighboring states who are already working intensively to persuade European manufacturers of the merits of their jurisdictions.

4.6 HOW DO THE REGION'S PRIVATE, NONPROFIT, AND PUBLIC ORGANIZATIONS INTERACT?

There Are a Wide Variety of Nonprofit Organizations That Play a Role in the MST Ecosystem

Along with the 21 public institutions identified earlier, there are approximately fifty additional coastal and ocean related public organizations whose primary mission is advocacy, entrepreneurship, K-12 education, monitoring, and conservation (see Figure 7). While these organizations do not generally conduct original research or develop new products, they play a vital role in the region by stimulating interest in MST careers, collecting data about marine ecosystems, fostering entrepreneurial activity, or collaborating with the region's other MST organizations.

Figure 7
The Marine Science and Technology ecosystem



MST companies interact with these organizations and the region's universities, colleges, and research institutions in several ways. Figure 8 presents results from the MST Business Survey and shows that only ten percent of respondents do not interact at all with universities, colleges, and research institutions in SENE. Companies most commonly interact via problem-solving collaboration (50%) or by using these institutions as a source of skilled labor (40%). Notably, one in three (33%) of the MST businesses surveyed report a formal partnership with a university, college, or research institution. Many companies selected "other," and these respondents were primarily companies that sell their products or services to universities and other research institutions.

Key informants we interviewed spoke about the desire to strengthen these relationships, particularly as it relates to aligning the research capabilities of these various institutions with both MST and traditional maritime industries and in developing more research partnerships in general. We also heard from some stakeholders that private industry has a number of needs that cannot always be satisfied in-house, but it is not always clear how to identify and engage institutions to meet these needs within the region. This leads to missed opportunities for mutually beneficial collaborations that have the potential to enhance innovation and regional growth. This problem merits the serious attention of regional leaders and relevant stakeholders.

Figure 8

How would you describe your business’s relationship with universities, colleges, and research institutions in the SENE region?

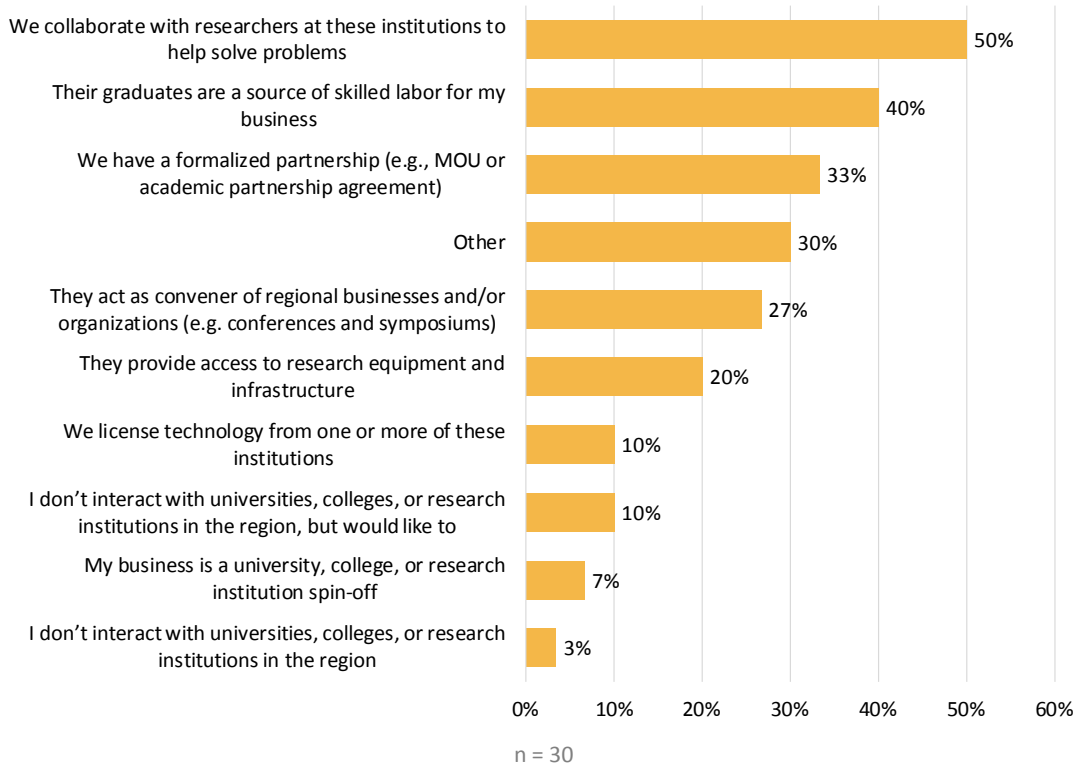


Table 6 shows the percentage of respondents who reported working with each major research institution in SENE. Respondents report working most often with the WHOI (52%), followed by the University of Rhode Island (38%), and NUWC and UMass Dartmouth SMAST (both 33%).

Table 6

Government and nonprofit organizations that MST companies collaborate with, SENE, 2019

Institution	Percent (n=21)
Woods Hole Oceanographic Institution	52%
University of Rhode Island	38%
Naval Undersea Warfare Center	33%
UMassD School for Marine Science and Technology	33%
Other	33%
UMass Dartmouth	24%
Marine Biological Laboratory	19%
Massachusetts Maritime Academy	19%
Brown University	14%
Massachusetts Division of Marine Fisheries	14%
North East Fisheries Science Center	14%
U.S. Naval War College	10%

Source: MST Business Survey

4.7 PRIVATE SECTOR SUPPLY CHAIN RELATIONSHIPS

MST Companies and Institutions Procure from Other Technology and Fabrication Companies in the Region

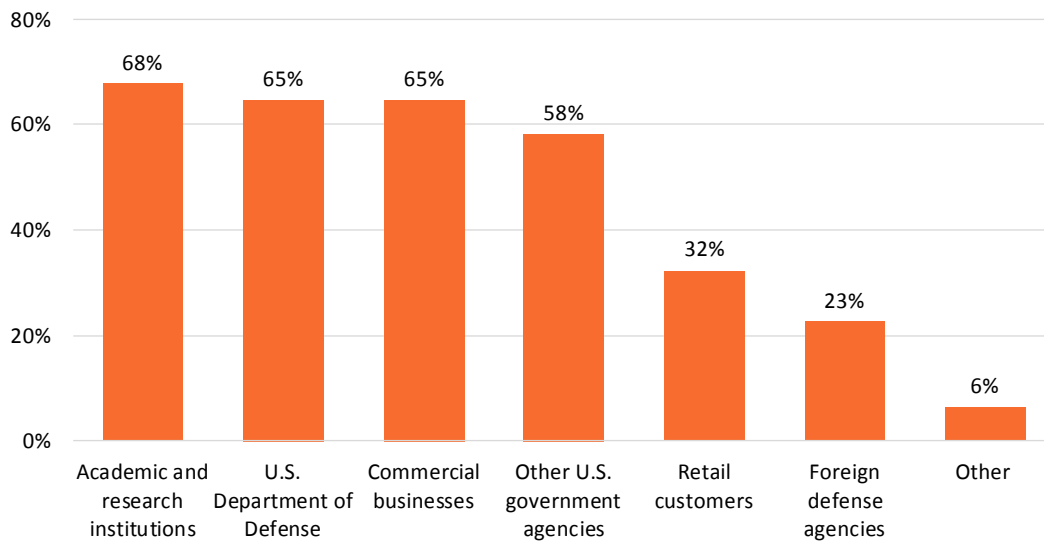
MST companies and institutions purchase products and services from local MST and non-MST technology companies such as electronics (circuit boards, water-tight wire connectors, etc.); analytical instruments (e.g. underwater sensors); search, detection, navigation, and nautical instruments; engineering services; computer programming services; and communications equipment. In addition, interviews revealed that many MST companies in the region work with local fabricators to manufacture custom parts and components. For example, companies in the marine robotics industry work with local machine shops to make the metal cylinders that comprise the body of the vessels. Similarly, companies report purchasing custom-molded products, such as buoys and other flotation devices on which to deploy scientific equipment, as well as locally produced marine paint and fiberglass composites.

Some interview subjects reported that MST companies would like to purchase more components locally, but that many are simply not available in the region. Key informants noted that they would like to purchase locally produced batteries, rubber parts such as hoses and fuel bladders, magnets, and some mechanical/engine components. Even when local products are available, price and availability sometimes prevent companies from buying more of their parts from regional suppliers. One interviewee reported that often their preference was for the best available component at the best price, which in their case frequently meant purchasing from a foreign manufacturer. One exception to this are defense contractors, who are encouraged, and in some cases required, to buy their components from American manufacturers. Defense manufacturers we interviewed reported long-standing, mutually beneficial relationships with a number of regional suppliers. Another industry which is under some pressure to procure locally is offshore wind, which must often compete for power purchase contracts in part on the basis of their expected state and local economic development impacts.

MST Companies Rely Heavily on the Academic and Military Markets

Looking downstream to where finished products are sold, the top three markets in which MST Business Survey respondents report selling their products include academic and research institutions (68%), the U.S. Department of Defense (65%), and commercial companies (65%). As noted, SENE is home to WHOI and NUWC, both of which purchase a significant amount of goods and services from local MST and other companies. Additionally, the marine robotics and instrumentation industry, which at one time primarily served the oceanographic community, now increasingly serves commercial and military markets.¹⁹ While a similar share of companies report selling to all three markets, interviews and our review of the relevant research literature suggest that overall sales are smallest in the commercial market for MST companies and a heavy reliance on government procurement is widespread. Future business growth in many cases may depend on finding new customers in the commercial marketplace, with offshore wind and climate adaptation efforts representing clear opportunities for some firms. This may prove to be a difficult proposition for number of MST firms, particularly those in product areas (UUVs for example), that are very specialized and expensive and currently have limited commercial appeal outside their traditional markets (e.g., defense and scientific applications).

Figure 9
MST companies' primary customers



Source: Public Policy Center (n=31)

¹⁹ Bellingham, J.G. 2015. "Marine Robotics: Opportunities for the Commonwealth of Massachusetts." Center for Marine Robotics. Woods Hole Oceanographic Institute. Falmouth, MA.

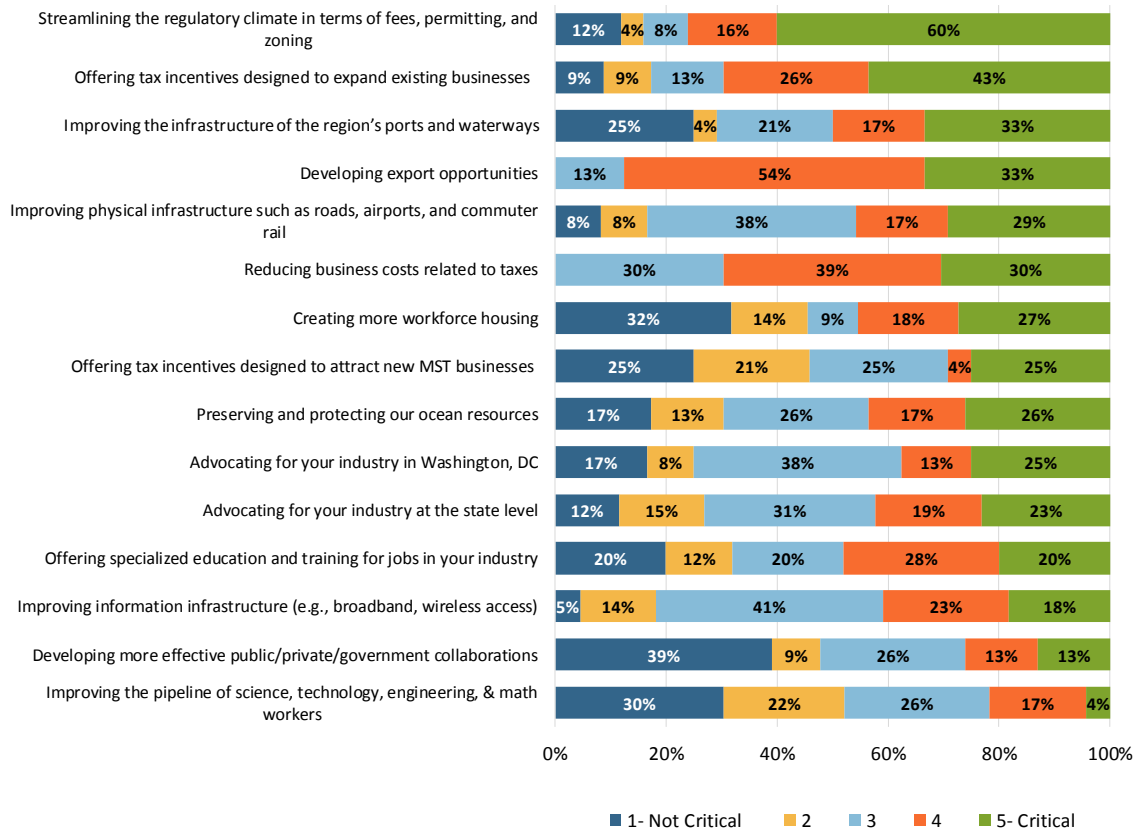
4.8 WHAT ARE THE MAJOR CHALLENGES AND OPPORTUNITIES FACING THE MST SECTOR IN SENE?

Existing Businesses Want Streamlined Regulations, Tax Incentives, Better Infrastructure, and Export Assistance

The Business Survey asked respondents to identify how critical a number of policy actions would be to their individual company on a scale of one (not critical) to five (critical) (see Figure 10). Options deemed the most critical by respondents include streamlining the regulatory climate, offering tax incentives to expand operations, improving the infrastructure of the region’s ports and waterways, and developing export opportunities.²⁰ The need for improved infrastructure, such as port improvements and harbor dredging, is a recurring theme in much of the research conducted by the PPC. A streamlined regulatory environment has been highlighted as being particularly important to offshore wind and aquaculture, which currently face sizable regulatory barriers to securing ocean access and obtaining permission to operate.

Figure 10

Please indicate how critical each of the following policy actions is to your business on a scale of 1 to 5, with 1 being not critical and 5 being critical (table sorted by percent critical)



n varies per item from 25 to 26

²⁰ Streamlining the regulatory climate was also a top priority of respondents in the Blue Economy survey conducted by the PPC for its statewide maritime economy study. See Borges et al. (2017), *Navigating the Global Economy: A Comprehensive Analysis of the Massachusetts Maritime Economy*, The Public Policy Center at UMass Dartmouth.

Workforce training ranked low on this scale, but was mentioned frequently by interview subjects, who reported major workforce concerns. However, many of these interview subjects are from traditional Blue Economy industries. These industries hire a large number of production workers, which are currently in short supply. In addition, many of the MST companies in SENE are small operations without much motivation to expand. Moving forward, some of the new MST opportunities, such as offshore wind and aquaculture, overlap with traditional industries and are expected to increase the demand for maritime products and services. Therefore, advocating for and adopting policies that encourage the MST industry to expand will likely further increase the demand for engineers and people with technical skills in advanced manufacturing and skilled trades.

Spotlight

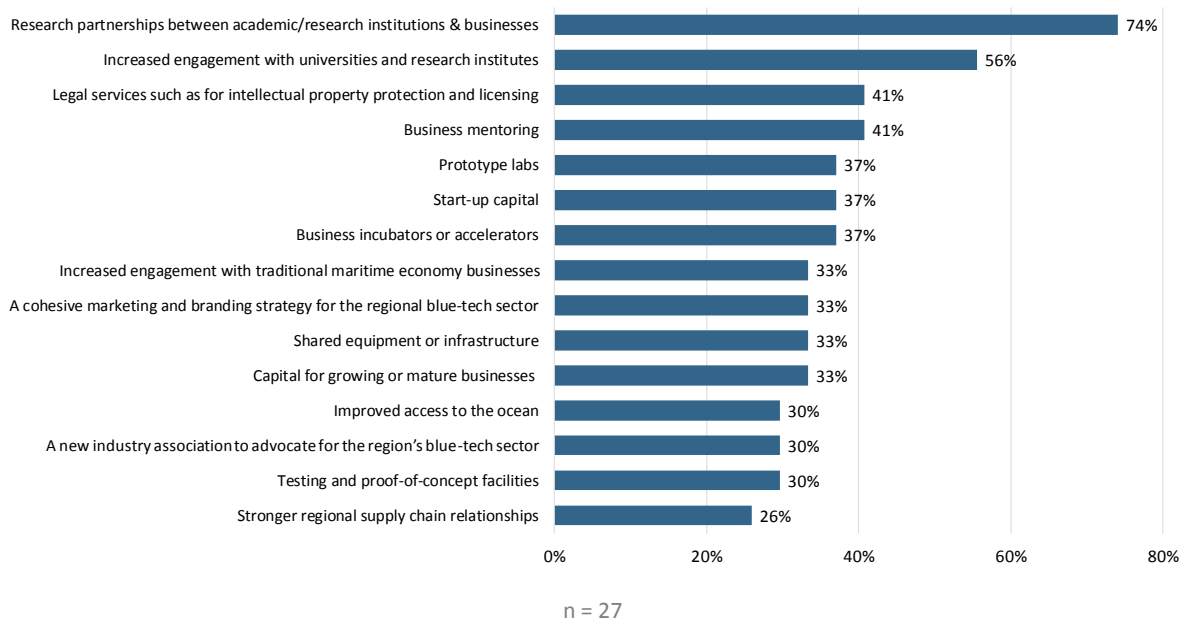
The New Bedford Marine Commerce Terminal

The Massachusetts Clean Energy Center manages the New Bedford Marine Commerce Terminal to support the construction, assembly, and deployment of offshore wind projects. In October 2018, a lease was signed with offshore wind developer Vineyard Wind, which will pay \$6 million to use the facility for 18 months. The first of its kind in North America, the terminal also handles bulk shipping and specialty marine cargo. Its strategic location on the Atlantic Coast opens up more opportunities for shipping in New Bedford.

MST Firms Seek Increased Engagement with Research Institutions & Support for Technology Commercialization

The MST Business Survey asked respondents to rate various activities and actions that would make it possible for more MST companies to thrive in the region (see Figure 11). “Research partnerships between academic and research institutions and businesses,” was the most frequent response (74%), which underscores the importance of research and academic institutions to the MST sector. This is followed by the “increased engagement with universities and research institutes,” (56%), again highlighting the desire for more effective collaboration. Other top choices included activities that support technology commercialization, such as legal services for intellectual property, business mentoring, and prototype labs. All choices were selected by at least 25 percent of respondents, a consistent finding that underscores the need to improve connections between SENE MST firms and research institutions.

Figure 11
Thinking of the MST sector as a whole and not just your business, which of the following would make it possible for more MST companies to thrive in the region?



Spotlight

The UMass Innovation Institute Streamlines Collaboration Between Academia and Industry

The UMass Innovation Institute (UMII) acts a single point of contact between researchers at UMass Amherst and potential outside collaborators. This model allows the Amherst campus to easily facilitate industry-sponsored basic and applied research, and to produce science that aligns with national, state, and regional priorities. For example, through the support of the UMII, polymer scientists Ryan Hayward and his team received a \$7.5 million grant from the Office of Naval Research in 2018 to design materials that convert light into power for remote-controlled microrobots. The UMII approach enables academic researchers more easily disseminate their innovations and discoveries with the rest of society in way that genuinely impacts regional economic growth, while allowing them focus on their primary interest—research.

5 WORKFORCE ASSESSMENT

This section identifies the sector's high priority occupations, workforce challenges, and workforce training and educational needs using insights gained through interviews with key informants, survey results, and secondary occupational and industry databases. Similar to other high-tech sectors, MST companies employ a diverse set of workers including highly educated engineers and software developers who design and program products, skilled production workers such as metal fabricators, assemblers, and machinists, and scientific experts whose research provides a foundation for technological advancement. Overall, these jobs require higher levels of education and/or training and offer higher wages than most other sectors in the SENE region, which has long struggled with low levels of educational attainment, relatively low incomes, and high poverty rates in comparison to the Greater Boston region, which is home to a more highly educated workforce and a more innovation-intensive economic base.

Greater Boston's innovation economy draws talent from around the world, so it is not surprising that many of the graduates of SENE's colleges and universities relocate there to begin their professional careers. The so-called brain drain has been a persistent obstacle for the SENE region for decades. Simply put, there are fewer high-paying, high-skill jobs in the region when compared to the Greater Boston. The region has some advantage in the MST sector, which like other sectors within the innovation economy tends to employ more highly-skilled and educated workers who earn wages well above state averages.

Spotlight

Greater New Bedford Voc-Tech's Post-Secondary Education Programs Offer New Opportunities

In 2019, the Greater New Bedford Regional Vocational Technical Institute began offering post-secondary courses and certificate programs. Officials expect the program to grow in the next few years with the introduction of an associate's degree for applied science. The school's adult education program offers more than 80 courses on a trimester schedule. Courses offered at the Greater New Bedford Voc-Tech Institute include licensed and non-licensed trades, language programs, and the practical arts. There are courses in engineering, plumbing, electrical, medical, automotive, computers, languages, and special interests. As early as 2022, the school plans to offer tuition-based associate's degree programs in nursing, information technology, engineering, renewable energy, and other fields.

Earlier this year, the Greater New Bedford Voc-Tech Institute's new Marine Technology Certificate Program became a Chapter 74-approved vocational technical education program. The certification is designed to prepare students to work in commercial and recreational marine industries through training in boat handling and safety, marine electrical systems, engines, customer service, and marine welding. This post-secondary certificate is focused on expanding opportunities in the marine technology field, with options for a Scuba Diver Certification as well as the American Boat and Yacht Club Certified Advisor and Technician credentials. Regarding the significance of the program, Director Rick Quintin cited the high need for marine trades in the region, as well as an industry demand for technical credentials. The program is also planned to extend into the high school level in order to meet students' needs related to college and career readiness in marine industries.

5.1 HIGH VALUE CREDENTIALS AND SKILLS

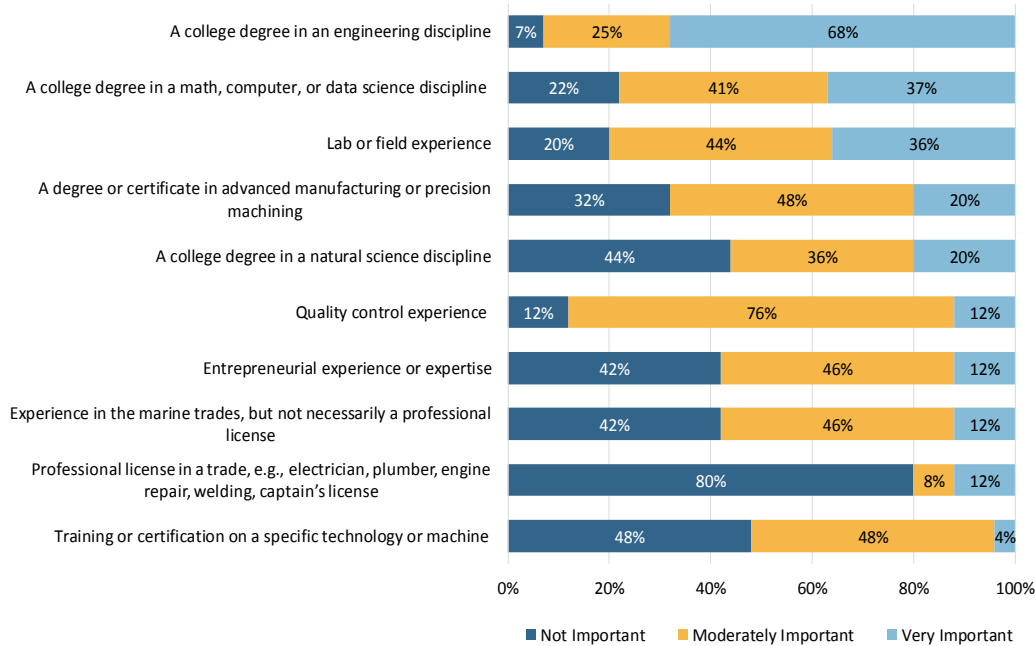
The MST sector relies on a variety of occupations, from those that require specialized knowledge gained through undergraduate and graduate degree programs, to skilled work in precision production and fabrication settings. However, we have identified key occupations that warrant priority attention; these high priority occupations encompass professions that are both crucial to the operations of MST firms and are also in short supply.

Employers Value Engineering Degrees Over Other Credentials

Interviews and the respondents to our MST Business Survey reveal that employers value a degree in an engineering discipline over other credentials; 68 percent rated engineering degrees as a very important worker qualification. This compares to 37 percent who rated a degree in a math, computer or data science discipline or 36 percent who rated field experience as very important (see Figure 12).

Respondent reports also underscore the importance of production workers to the MST sector in SENE. Two in three survey respondents (68 percent) report that a degree or certificate in advanced manufacturing or precision machining is moderately or very important, while nearly six in ten (58 percent) identified experience in the marine trades as moderately or very important. While respondents do not appear to consider professionally licensed trade workers as important (80 percent indicated that a professional license in a skilled trade is not important), key informants we interviewed for this report and in previous research conducted by the PPC validates this finding and makes it clear that employers are able to train up employees to do various jobs and that professional licensure is not generally required as an entry point into most occupations in MST relevant fields.

Figure 12
Importance of various worker qualifications in MST

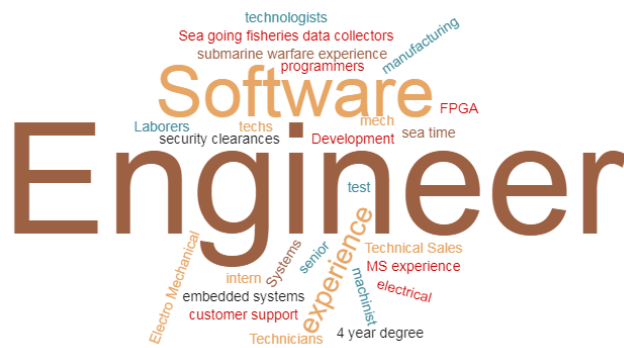


Source: MST Business Survey

MST Employers Report a Shortage of Engineers in SENE

The MST Business Survey included several open-ended questions related to workforce. When asked for which positions, if any, they had experienced difficulty hiring, most respondents reported difficulty hiring engineers, with a notable subset specifically mentioning software engineers (see Figure 13). The challenge of hiring and retaining engineers was also a theme throughout the interviews. However, the engineering subfields employers require are more specialized than basic mechanical or electrical engineering, and they face competition both within MST and with other industries. As one interviewee said “outside of mechanical and electrical, [engineers] are not produced in large quantities anywhere in the country, so there is constantly a high demand for them through the industry and elsewhere.” Specifically, employers mentioned engineering specialties related to embedded systems and software engineering, acoustics, artificial intelligence, and ocean engineering. Overall, these responses appear to reflect the increasing prevalence of autonomous robotics, IoT, and instrumentation in the MST sector.

Figure 13
For which positions do you have difficulty hiring, if any?



Source: MST Business Survey

Key informant interviews indicate that software engineers are in high demand throughout the economy, not just in the MST sector. Employers in SENE must compete with technology firms in Greater Boston and throughout the country to attract and retain these highly sought-after workers. Furthermore, software, computing, and autonomous systems are being integrated into traditional maritime industries in the form of smart ports and shipping, and improved, interconnected sensory equipment on vessels, a clear signal that the demand for software engineers and other computing-related engineers can be expected to grow over time.

These conditions have resulted in intense competition for relevant engineering talent in SENE. One key informant noted that there is a significant amount of firm to firm movement of engineers within the region, with engineers jumping from company to company in exchange for higher wages, better benefits, or other reasons. This workforce churn is exacerbated by grant funding cycles which lead firms to ramp up their hiring up as new contracts are awarded and down as projects and contracts are completed. One key informant also noted a “graying” of the region’s current MST-related engineering workforce and highlighted the need for a more robust regional workforce pipeline in order to meet the need for new engineers to enter MST fields to replace those expected to retire in coming years.

Spotlight

The New Bedford Ocean Cluster Uses Big Data, Software, and the Internet of Things to Create New Opportunities for Collaboration with Commercial Fisheries

To connect maritime businesses, scientists, and technology entrepreneurs, the New Bedford Port Authority and Spherical Analytics partnered to establish the New Bedford Ocean Cluster (NBOC). The NBOC then formally joined the Iceland Ocean Cluster Network after an official partnership was created between the New Bedford Harbor Development Commission and the Iceland Ocean Cluster in 2017. As a result of the partnership, New Bedford is now part of a global network of Ocean Clusters, which aid in increasing efficiency and add value to the maritime sector by creating and testing new ideas and technologies. The network is comprised of member organizations committed to sharing information and creating business opportunities.

The NBOC is in the process of creating a cloud-based Marine Data Bank to provide participating organizations with access to shared data, as well as the ability to share, trade, and license their own data. Fishermen can use the information to improve their operations, and increase environmental resiliency by sharing data with other organizations. The data bank will involve the partnership of local and regional stakeholders and utilize Internet of Things (IoT) sensor networks. The establishment of the New Bedford Ocean Cluster presents new business opportunities in the sector, increased innovation in marine science and technology, and promotes environmental and coastal resilience.

Employers Report Difficulty Finding Production Workers with Technical Skills

While much of the MST sector’s activity has a foundation in scientific research and technological innovation, a significant portion of the occupations in the sector are related to the production, manufacturing, and deployment of the technology developed by the region’s engineers and scientists. This result was confirmed through interviews with business owners, who noted a difficulty in hiring workers with specific technical skills to work in production and fabrication settings such as welders, fiberglass and canvas workers, marine tradespeople, and workers with relevant advanced manufacturing skills. Underscoring this, over half (52 percent) of MST employers we surveyed reported difficulty in finding employees with the requisite “technical skills” that constrain the growth of their business (see Table 7).

Table 7
Which of the following workforce-related issues would present constraints for your business's growth?

Issue	Percent
Difficulty in finding employees with the requisite technical skills	52%
Difficulty in finding employees with the requisite educational credentials	32%
There are not any workforce-related issues that would constrain business growth	24%
Potential employees are not willing to move to the area from their current area	16%
Other	12%

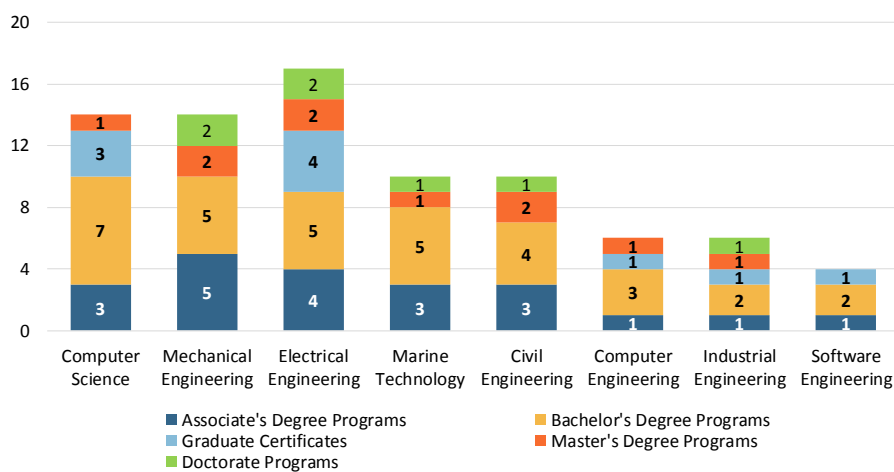
Source: MST Business Survey

5.2 EDUCATION AND TRAINING GAPS

SENE Computer Science and Software Engineering Programs Are Not Well Aligned with MST Workforce Needs.

The PPC assessed the extent to which education programs in SENE are aligned with occupational requirements of the MST sector. We find that, for the most part, area programs are well-aligned with industry needs, with some notable exceptions. Among engineering degrees, computer science, mechanical engineering, and electrical engineering are the most common degree programs offered in SENE. Computer engineering, industrial engineering, and software engineering are the least common (see Figure 14).

Figure 14
Number of degree programs by type, SENE, 2019



Source: Public Policy Center

Software engineering is an occupation of increasing importance that is in demand throughout the tech sector as a whole, even in cities with many high-skilled tech workers such as Boston.²¹ Importantly, much of the MST work in SENE involves working with robotics and scientific instrumentation, requiring software engineers with skills appropriate for these specialized electronic systems. Referred to in the software development field as “low-level” skills (not to be confused with easy),²² these include knowledge of assembly language, embedded systems, device drivers, and operating systems. These skills are necessary because engineers in MST are not always working with the standard personal computers or servers that one might find at a traditional business.

Although computer science is the most common MST-related program available across the SENE region, with seven bachelor’s degree and three associate’s degree program options, only two institutions—UMass Dartmouth and the New England Institute of Technology—have programs specifically dedicated to software engineering, which is a related but different concentration. At UMass Dartmouth, software engineering is available as a concentration within the computer science degree. Although these classes generally match up with the skills necessary for software development, they only match some of the skills for *embedded* or *systems* software development, specifically. For

²¹ Enwemeka, Z. (2017). “Tech is Booming in Mass., but Diversity and Hiring Remain a Challenge.” WBUR. November 17, 2017. Retrieved from: <https://www.wbur.org/bostonmix/2017/11/17/mass-tech-economy>.

²² In this context, “low-level” means that the coding is at a lower level of abstraction from the native programming language of a machine.

example, the UMass Dartmouth curriculum does not focus on operating systems, computer organization, embedded systems, or system monitoring, which encompasses much of the work involved in software engineering for MST. This appears to reflect a strategic choice. As UMass Dartmouth's software engineering department's homepage states "The SWE [software engineering] option may not be right for you if... you are primarily interested in working on operating systems, device drivers, embedded software, or similar systems."²³ These are critical areas for MST software engineers. The associate's and bachelor's degree programs at the New England Institute of Technology have adopted a similar curricular approach.

Training Programs for Production and Skilled Trades Workers Do Not meet Demands Within MST and Other Manufacturing Sectors

Without a doubt, engineers and scientists are crucial to the development of a robust MST sector. However, many stakeholders told us that skilled production workers account for the bulk of their labor force. These jobs require a skills related to production, such as the ability to read schematics, experience operating production machinery, and quality control. As one interviewee stated, there are "no unskilled jobs...and even lower skilled jobs require a knowledge of the larger [production] process." We heard similar statements from other employers involved in manufacturing and production, with another interviewee from a firm heavily reliant on DoD contracting saying that compared to engineers, "production workers are easier to find, but still need some skills in critical thinking and maybe an Associate's degree." The hands-on nature of skilled production work means that gaining experience is often required before obtaining employment.

The route to becoming a skilled production worker varies depending on the specific job. Bristol Community College and other 2-year institutions in the region offer programs in CNC machining and programming. Previous studies of the workforce needs of advanced manufacturing employers in Southeastern Massachusetts conducted by the PPC revealed that vocational high school training in machine technology provides many of the skills needed to become an advanced production worker. However, some employers noted that skilled vocational students are now going on to college, rather than entering the field directly from high school.

In the skilled trades such as welding and electrical, unions offer a pathway for training and developing a production workforce. The traditional career pathway into many trades is through a union apprenticeship, which typically includes on-the-job experiences over a multi-year period of employment. Union apprenticeships often also require several hundred hours of classroom instruction and most programs are completed after four years of full-time commitment. Entering a union-sponsored apprenticeship program to obtain a skilled trades job at an MST company requires a great deal of foresight, and it is unclear how prevalent union employment is in the MST sector. In fact, many larger employers we spoke to said that their companies are not union shops and that they rely on in-house training for skilled trades positions.

Overall, creating and expanding apprenticeships or other means of early career exploration in the MST sector could expand the pipeline of new workers. Employers would have an opportunity to present production occupations as a way to earn a wage above the regional median without attending a four-year college. Nevertheless, one employer defined their manufacturing operation as "engineering-supported production," which highlights the importance of production knowledge in combination with an engineering education. This implies that entering a production occupation does not necessarily mean foregoing a college education, as there is a potential career ladder from

²³ UMass Dartmouth College of Engineering – Software Engineering Option. Retrieved from: <https://www.umassd.edu/engineering/cis/undergraduate/software-engineering-option/>

production worker, to engineering technician with an Associate's degree, and finally, to a member of the engineering team with a Bachelor's or Master's degree.

Long-term Implications for Workforce Development Policy and Programming

As the region's MST industry develops, it will continue to rely on a highly-educated workforce. Fields that overlap with the MST sector include a wide range of engineering disciplines, as well as the physical, natural, and life sciences. New opportunities in aquaculture, cybersecurity, offshore wind, and climate resiliency may require workers with degrees or skill sets that are not offered in SENE's current educational and workforce development systems. In our recent assessment of the workforce needs of the emerging offshore wind industry, *The 2018 Offshore Wind Workforce Assessment*,²⁴ we describe the additional training needed in the near term to seize the opportunities presented by offshore wind energy development, particularly with regard to safety training and construction and operations workers. Like with MST generally, future opportunities presented by offshore wind can be expected to increase the demand for workers with production skills.

²⁴ <http://publicpolicycenter.org/wp/wp-content/uploads/2018/05/2018-MassCEC-Workforce-Study-Corrected.pdf>

6 RESEARCH AND DEVELOPMENT

The presence of research and development (R&D) activities in a region, whether undertaken by private businesses, research institutions, or other organizations, can be a major source of the new ideas that fuel innovation. R&D enables businesses and organizations to translate new ideas (drawn from research) into new or improved products and services (through development) that can find their way into the marketplace and expand regional economic development opportunities.

Traditional taxonomies of research distinguish between basic and applied research. Basic research consists of science for science's sake, which seeks to better understand the world and how it works. Applied research takes the knowledge base developed through basic research and attempts to put it to use solving well-defined problems. The path from applied research to jobs and economic growth is much clearer than for basic research, and therefore many economic development activities tend to focus on supporting applied research. However, it is imperative to support basic research, even though the fruits of those activities are much more difficult to predict or control. Without continued investment in basic research, the source of many of the new ideas from which applied research can gather insight is constrained.

Given the important role R&D plays in driving growth in the MST sector, we carefully examined the available data in an effort to gain insight into the competitive position of the SENE region in this critical area. There are a variety of ways in which R&D is conducted and codified, and consequently we assess R&D in several ways. Information about business R&D was gleaned from the MST Business Survey and a database of Small Business Innovation Research (SBIR) and Small Businesses Technology Transfer (STTR) awards. We also examined the number of MST patents as a measure of R&D activity more broadly. R&D at research institutions in the region was described by analyzing the number and type of marine-oriented faculty and researchers and relevant scientific articles published.

Spotlight

WHOI's Test Facilities Recreate Deep Sea Conditions on Land

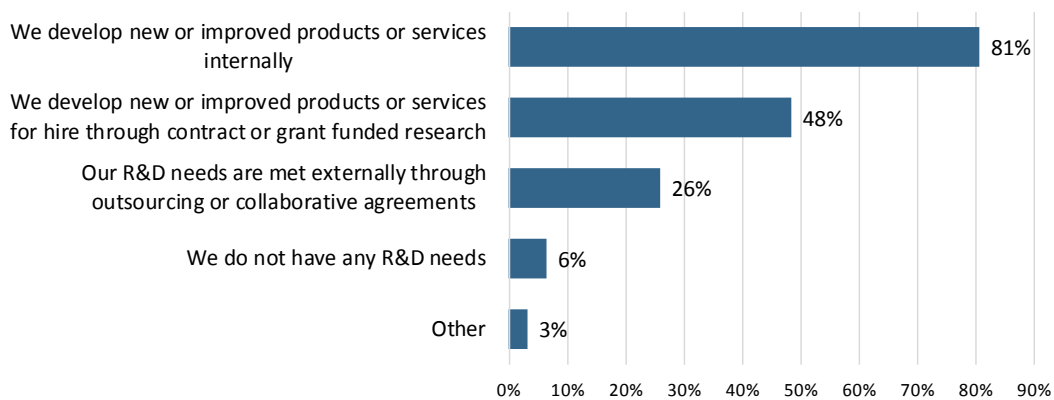
WHOI's Center for Marine Robotics is home to a cutting-edge pressure test facility. Opened in 2019, the facility will allow WHOI and other companies and researchers to simulate deep ocean pressure and stress-test their materials and marine robotics engineering solutions. This will "triple the project capacity of its existing manually-operated system" as well as "allow for unattended 24/7 operations," supporting innovation and new marine robotics startups in the region.

6.1 BUSINESS SECTOR R&D

Companies Report They Are Most Likely to Meet Their R&D Needs Internally

MST companies in SENE we surveyed are most likely to meet their R&D needs internally; 81 percent of companies reported meeting some or all of their R&D needs in this manner. Nearly half (48%) perform research for other entities through contract or grant funded research, while 26 percent meet some or all of their R&D externally through outsourcing or collaborative agreements (see Figure 15).²⁵ More than three-quarters of companies (76%) report that their R&D activities have increased in recent years.

Figure 15
How does your business meet its R&D needs?



Source: MST Business Survey

Federal Programs Are a Major Source of Private Sector R&D Funding, but Funding Is Limited for Non-Defense, Non-Health Applications

Among businesses that have R&D needs, 73 percent use internal funding to support some or all of their R&D activities. Other major sources of funding are mostly government-sponsored, including SBIR/STTR grants, defense industry contracts, and other state or federal funding (see Table 8).

Table 8
Sources of funding for private sector R&D, SENE MST businesses, 2019

Source of Funding	Percent
Internal funding	73%
SBIR/STTR	35%
Defense industry contract	31%
Other state or federal government funding	31%
Industry sponsored	19%
Venture capital or other private financing	8%
Other	12%

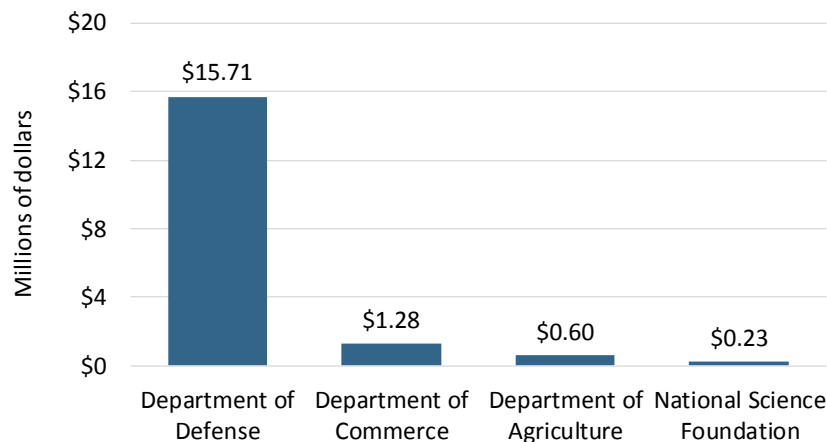
Source: MST Business Survey (n=26)

²⁵ Percentages do not add up to 100 percent since the categories are not mutually exclusive.

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs are competitive federal grants that are meant to help small, for-profit companies of less than 500 employees to develop new technologies. Phase I grants fund proof-of-concept research, while Phase II grants fund prototype development. This research can help companies design products, as well as attract investment capital and partnerships.

As the two agencies with the largest extramural research budgets, the Department of Health and Human Services and the Department of Defense award the most SBIR/STTR funds.²⁶ Therefore, SBIR/STTR awards are not an indicator of the total level of new product development in a region, but rather capture a higher percentage of new products with health or defense applications. Unsurprisingly, the majority of the MST SBIR/STTR funding in SENE comes from the Department of Defense (see Figure 16). Breaking the Department of Defense funding down by agency, we find that roughly \$12 million (>75%) of this funding comes from the U.S. Navy.

Figure 16
MST SBIR/STTR grant funding by government agency, SENE, 2015–2018



Source: SBIR.gov, Awards List 2015-2018

The Total Amount of MST SBIR/STTR Awards in SENE is Modest When Compared to the Greater Boston Region

Between 2015 and 2018, businesses in SENE received a total of 118 SBIR/STTR awards totaling \$17.8 million.²⁷ Of the total grant funding, \$6.5 million or about 36.5 percent went to businesses in Massachusetts, while \$11.3 million or about 63.5 percent was awarded to businesses in Rhode Island.

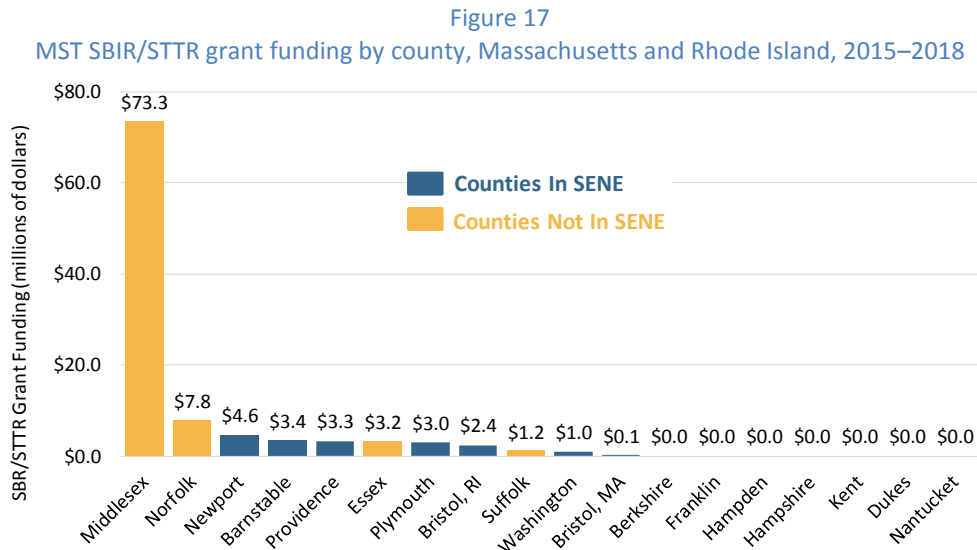
Areas within Massachusetts but outside of SENE receive significantly more MST SBIR awards and SBIR/STTR awards overall (see Figure 17). Within SENE, businesses in Newport County received the highest share of the total, which is not surprising given that most of the awards are made by the Navy and there are many Navy contractors located in that county. However, within Massachusetts and Rhode Island, the largest share of MST-related SBIR/STTR awards

²⁶ In 2017, funding for SBIR grants and contracts was set at 3.2 percent of the extramural research budget for all agencies with a budget greater than \$100 million per year. Likewise, funding for STTR awards was set at 0.45 percent of the extramural research budget for all agencies with a budget greater than \$1 billion per year.

²⁷ The PPC used a two-step process to identify MST SBIR/STTR awards in the region. In the first step, all Navy grants were selected and then vetted to remove Navy awards that are clearly not maritime-related, such as awards in support of the Naval Air Forces. The remaining awards, excluding awards administered by the Department of Health and Human Services and the Department of Education, were then vetted to select awards that clearly are maritime-related. Thus, there was a lower inclusion threshold for Navy awards than for other funding agencies.

Charting the Course: An Assessment of Southeastern New England’s Marine Science & Technology Sector

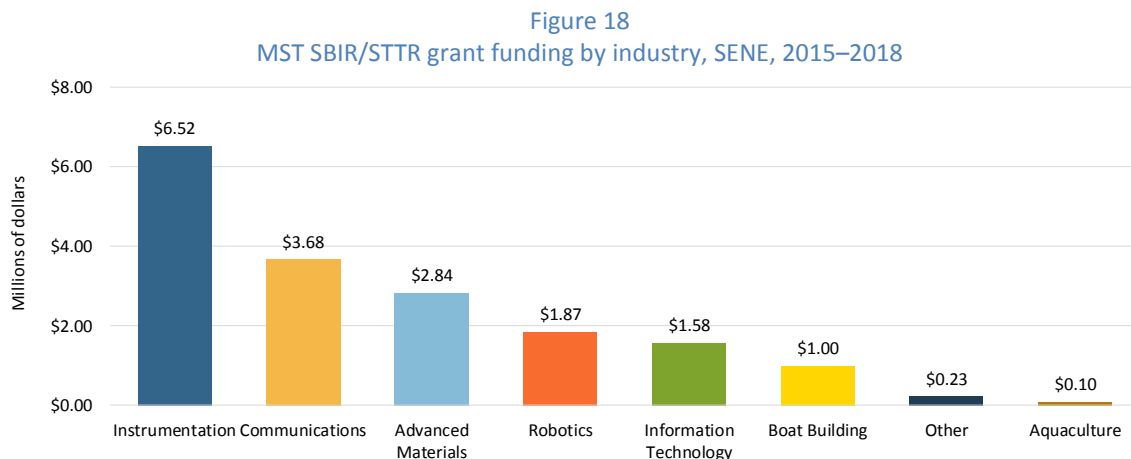
can be found in Middlesex County. Middlesex County is home to a large defense manufacturing and instrumentation industry, anchored by organizations such as MIT Lincoln Labs and MITRE Corporation, which helps explain their dominant position in the competition for these sources of funds.



Source: SBIR.gov, Awards List 2015–2018

SBIR/STTR Awards Going to SENE Businesses Reflect a Specialization in MST-Related Topics

Of the 118 SBIR/STTR awards received by businesses in the SENE region between 2015 and 2018, 35 percent are MST-related, while only 9 percent are MST-related in the areas of Massachusetts which fall outside of SENE. SBIR/STTR grants in SENE support companies in a variety of MST industries. The industry with the highest total dollar value is Instrumentation, which received over \$6.5 million over the last four years—about 77 percent more than Communications, which received a little under \$3.7 million. Aquaculture receives the least SBIR/STTR funding in SENE, which could be a sign of low levels of new production innovation, but is due at least in part to the small amount of extramural research funding available from the USDA.



Source: SBIR.gov, Awards List 2015–2018

6.2 R&D AT PUBLIC AND NONPROFIT RESEARCH INSTITUTIONS

MST crosses many academic disciplines and is not confined to the “marine science” or “oceanographic” wings of a university. Engineers develop new ways of producing marine renewable energy, mathematicians and computer scientists develop new methods for understanding undersea communication signals, and microbiologists develop new strains of algae or other organisms that can be used to produce a range of products, such as fuels and plastics, or clean polluted water. As a result, any attempt to gain an understanding of the marine science and technology activities that take place in a region cannot simply make use of the standard categories by which data collection agencies sort information. In order to accurately portray the full scale and diversity of marine related research and development activities, a considerable amount of primary and secondary research was required.

Much of the Marine-Related Research in the Region is Basic Science

To characterize the research activity at area institutions, we categorized all full-time, permanent position faculty and researchers at area institutions based on their self-reported basic and applied research interests and/or activities.²⁸ In total, we identified 413 full-time scientists and staff engineers working at research institutions in SENE who dedicate most or all of their time to marine-related topics (see Table 9).²⁹ Of the 413 researchers we identified, 169 (41%) did not indicate any clear applied research interest.³⁰

Table 9
Number and relative share of MST full-time researchers by research institution, 2019

	# Full-Time MST Researchers	% Full-Time Faculty/Researchers	% With Applied Research Interests
Woods Hole Oceanographic Institution	237	100.0%	57.8%
University of Rhode Island	95	12.6%	83.2%
UMass Dartmouth	53	13.1%	69.8%
Brown University	18	1.4%	61.1%
Marine Biological Laboratory	10	40.0%	50.0%

Source: Author’s Calculations

²⁸ Analysis was based on staff profiles, curriculum vitae, and media appearances.

²⁹ While the Marine Biological Laboratory (MBL) ranks last on this list in terms of the number of full-time researchers, most of the research is conducted by visiting researchers, who come from across the country to access the facilities at MBL. In the summer the number of researchers at the principal investigator level increases from 25 to 70 at MBL. These scientists come by way of the Whitman Fellowship, which covers housing and laboratory costs for researchers.

³⁰ WHOI, the largest research institution in the region by research expenditures, is focused on, according to their mission, “advancing knowledge of the ocean and its connection with the Earth system through a sustained commitment to excellence in science, engineering, and education, and to the application of this knowledge to problems facing society.” In this mission, applied research is incidental and secondary to building foundational knowledge about the ocean.

Seizing Emerging MST Opportunities Will Require More Diverse MST-Oriented Engineering Faculty

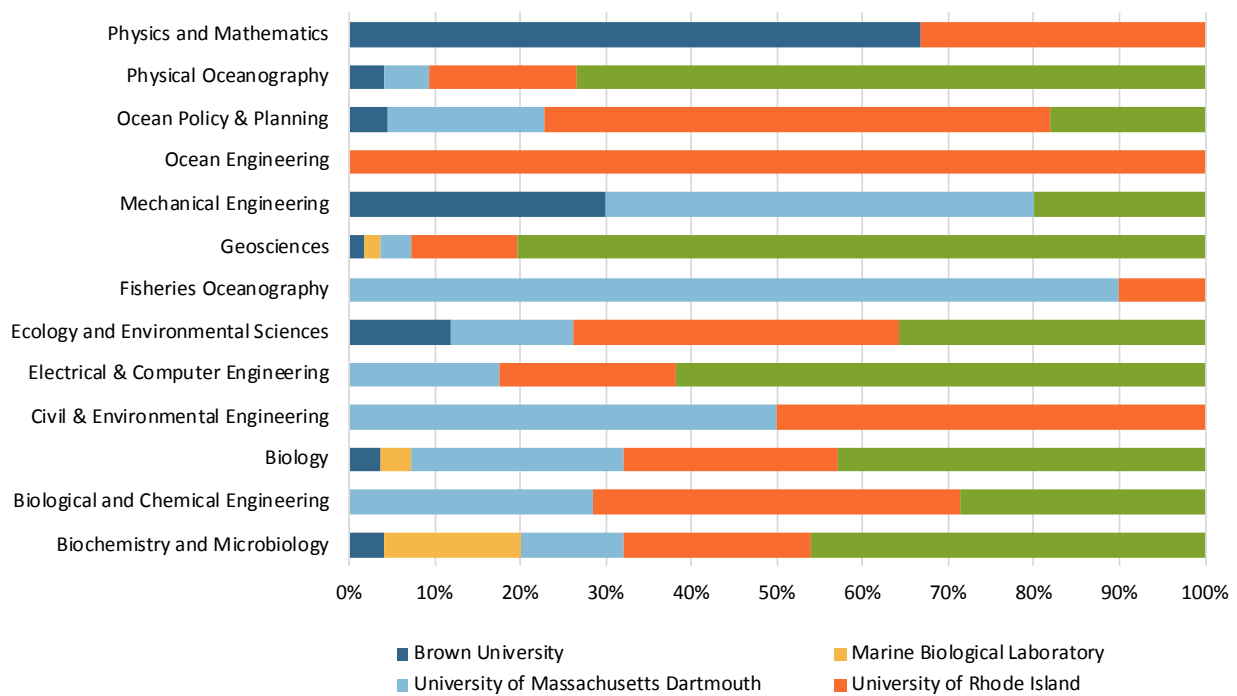
Looking at the primary fields in which the region’s MST-oriented faculty specialize, Physical Oceanography is the most common field, with 75 full-time scientists. The most common application for this type of research at area institutions is the development of weather and climate models. It also overlaps with Fisheries Oceanography and informs research related to marine renewable energy. The dominance of Physical Oceanography is driven largely by WHOI, where 55 full-time scientists conduct research in this field. Physical Oceanography is also major field of research at URI and UMass Dartmouth. URI stands out for being the only university in the region with an Ocean Engineering department, while UMass Dartmouth is home to the most scientists specializing in Fisheries Oceanography. More detail on the distribution of marine-oriented scientists by primary field and institution is presented in Figure 19). Engineering faculty doing marine-related research are concentrated in a relatively small number of fields. While there are many people studying Electrical & Computer Engineering—mainly in the service of developing AUVs and communications and underwater sensing technologies—there are not nearly as many engineering faculty in other relevant fields. More expertise in a broader range of engineering fields will be needed if SENE is to fully capitalize on the opportunities presented by the offshore wind and the living resources sector.

Table 10
Number of marine-oriented scientists by primary field, all institutions, 2019

Field	Count
Physical Oceanography	75
Geosciences	56
Biochemistry & Microbiology	50
Electrical & Computer Engineering	34
Biology	28
Ocean & Coastal Ecology	22
Ocean Policy & Planning	22
Environmental Sciences	20
Ocean Engineering	14
Fisheries Oceanography	10
Mechanical Engineering	10
Biological & Chemical Engineering	7
Civil & Environmental Engineering	4
Physics and Mathematics	3

Source: Author’s Calculations

Figure 19
Distribution of marine-oriented scientists by primary field and institution, 2019



Source: Author’s Calculations

Ocean Instrumentation Is the Top Applied Research Interest, but SENE Has a Presence Is Some Key Emerging Fields

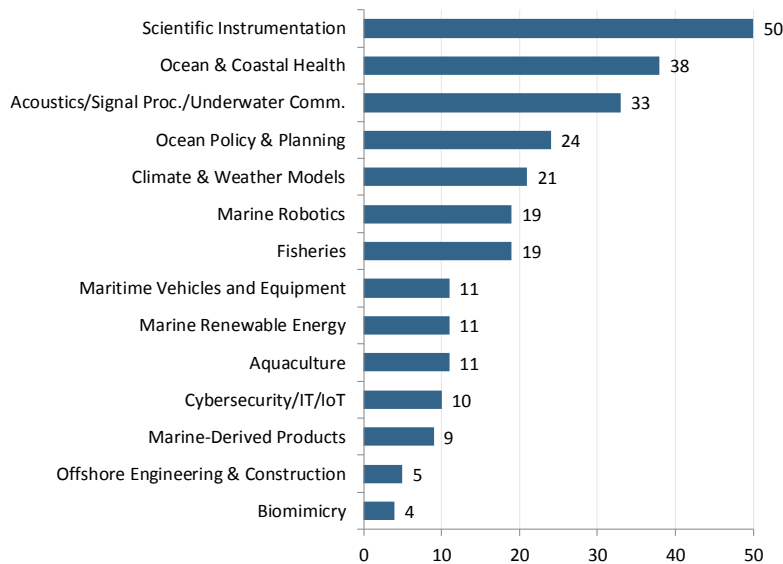
Presently, area institutions have a toehold in some new, emerging blue tech opportunities, but the number of faculty involved in these areas is relatively small. These areas include marine microbiology in support of developing new marine-derived products, offshore engineering and construction, offshore renewable energy, and aquaculture. There is an opportunity to better align the local research expertise with emerging opportunities by hiring strategically in these fields. In order to better “future proof” the MST research enterprise, when preparing strategic plans, area institutions may also consider involving the voices of experts in key emerging fields, including from outside of the region.

In SENE, URI has the highest percentage of MST researchers with a discernible interest in applied fields, at 83 percent (see Table 9). The most popular areas for applied research at URI include Ocean & Coastal Health and Ocean Policy & Planning. Researchers at UMass Dartmouth appear to have the strongest connection to traditional maritime economy industries, with 29 percent of MST researchers doing research related to Fisheries. Acoustics, Signal Processing & Underwater Communications is a traditional MST field that is studied at all research institutions in the region except MBL and Brown. A full listing of the applied researcher interests of MST faculty by research institution is provided in Appendix C.

While historically most attention to marine-related technology commercialization is focused on WHOI, it is important to note that most technology development done there is in the furtherance of their basic science mission. Thus, scientific instrumentation is the number one applied field for researchers at WHOI. The advanced instrumentation that is developed there, such as remote sensors and marine robotics, has attracted interest from defense and academic markets, but commercial applications are limited and currently the total market for these innovations is

small. (Although, offshore wind may present a new market in the near future.) The number two applied field at WHOI is research on ocean & coastal health, which is also closely tied to basic research and may have more commercial applicability as threats from climate change increase.

Figure 20
Number of scientists and staff engineers by applied research interest, all institutions, 2018



Source: Author’s Calculations

Spotlight

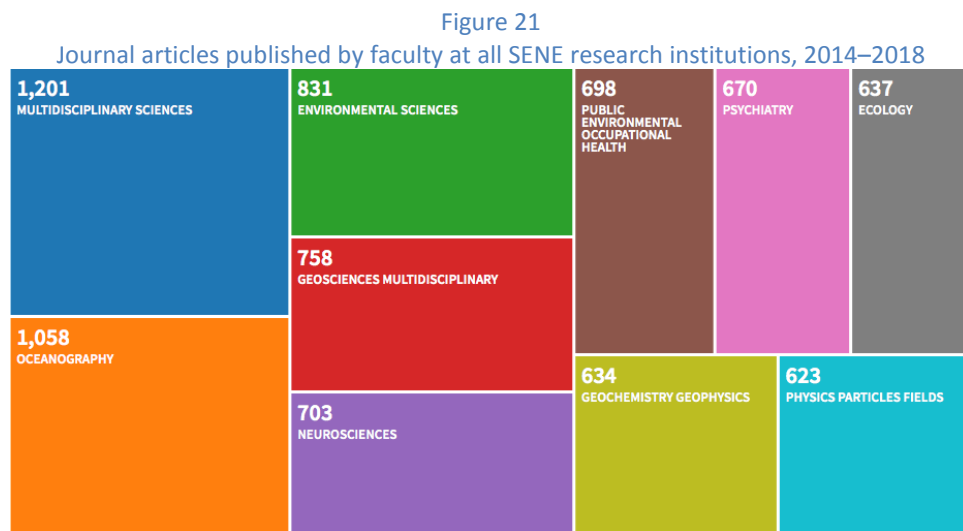
WHOI’S DunkWorks Supports Collaboration and Technological Innovation

The Center for Marine Robotics at WHOI recently launched DunkWorks, a “rapid-prototyping facility that facilitates collaboration and enables development and testing of new technology before being deployed.” One of DunkWorks’ main goals is to increase innovation in the region by allowing others to quickly and cheaply develop new advancements in marine robotics. These advancements will then serve to grow investment, output, revenue, and jobs in the MST sector. In addition, by making prototyping facilities and coaching widely available, DunkWorks strives to create a creative and collaborative community of technologists.

The facilities at DunkWorks include a variety of laser scanners, milling machines, lathes, 3D printers, CNC machines, and other workstations. DunkWorks offers a variety of memberships to suit the needs of different groups such as private companies, government organizations, laboratories, and even students. Current DunkWorks projects include the development of novel bio-logging tags for squids and other soft-bodied invertebrates, and the prototyping of a vision-guided AUV.

Marine-Related Fields Make Up a Large Share of All Journal Articles Published

The publication of peer-reviewed scientific articles is a standard measure of research output and allows us to identify the scientific fields in which regional researchers are making a discernible impact. Research institutions in the region published a total of 18,533 peer-reviewed articles across all disciplines during the five years from 2014 to 2018. Outside of multidisciplinary studies (1,201), the top three fields that SENE faculty and researchers publish in are oceanography (1,058), environmental sciences (831), and multidisciplinary geosciences (758), representing 5.7 percent, 4.5 percent, and 4.1 percent of all articles respectively. The total number of articles grew steadily year-to-year over this time, growing 12.7 percent from 3,520 in 2014 to 3,966 in 2018. During 2014–2018, the number of articles published by SENE faculty in the field of oceanography (1,058) represented 13.1 percent of all articles published in this field nationwide (9,194). WHOI alone was involved in 8.3 percent of the national total, with researchers authoring or co-authoring 763 articles, some of which were the product of collaborations with researchers at nearby institutions. Among institutions in the SENE region, researchers at Brown University are the least likely to publish in the marine sciences. An overview of the top fields by research institution is provided in Appendix C.



Source: Web of Science, Clarivate Analytics
Total = 18,533

The National Science Foundation (NSF) conducts an annual survey of R&D expenditures at research institutions around the country. Since MST spans many fields, the categories used by the NSF do not allow one to measure the full span of MST research activity, but it is possible to specifically measure oceanographic R&D spending.³¹ A large percent of the nationwide spending on oceanographic research takes place in SENE, at about 16 percent. In 2017, WHOI and URI made the list of the top ten institutions nation-wide for the total amount of money spent on oceanographic research.

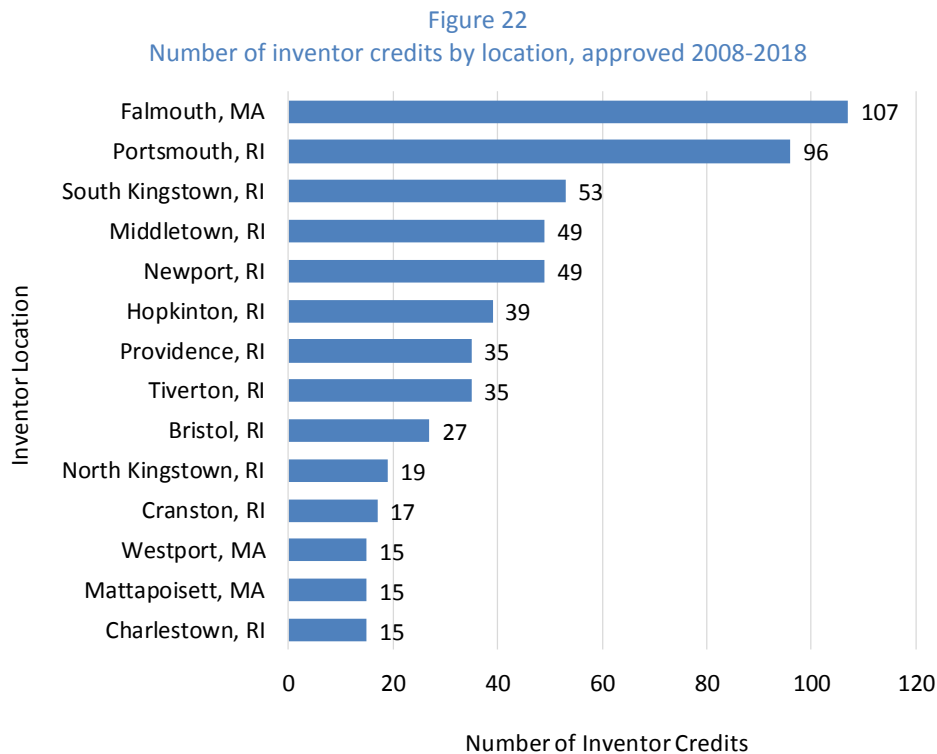
³¹ Importantly, this leaves out R&D conducted in engineering departments, which tend to have a more applied focus.

6.3 BLUE TECHNOLOGY PATENTS

The volume of MST patents held by SENE organizations gives a sense of the number of new inventions in MST-related fields that could be the source of new revenue and/or new business ideas. As with most measures, MST patents cannot be accurately identified solely by using standard patent classifications. Consequently, PPC researchers developed and used a web scraping program to pull patents from the USPTO database that contained words included in an extensive list of MST-related terms developed by the research team. The PPC also searched for all patents owned by the businesses and organizations contained in our inventory of MST firms, organizations, and institutions. The final list was then manually vetted to remove false positives.

The MST Sector in SENE Produces About 47 Patents per Year, With Most Owned by the Navy

During 2008 to 2018, the U.S. Patent Office approved 519 patents associated with businesses and/or inventors in the Southeastern New England region, which averages to about 47 patents per year (47.1).³² Among these patents, there were 1146 inventor credits in the SENE region.³³ The inventors receiving these credits reside in 279 unique locations. Many of the locations with the most inventor credits are located on Aquidneck Island in Newport County, RI, which is home to a division of Raytheon as well as NUWC. There are also a large number of inventor credits associated with Falmouth, MA.



Source: USPTO Patent Full-Text and Image Database (PatFT)

³² The invention must have been developed by at least one inventor from SENE or assigned to an organization in the region in order to be counted here.

³³ An “inventor credit” is simply the listing of an inventor’s name and location on the patent filing. Since the same inventor can be listed on more than patents, these numbers should not be interpreted as unique individuals.

Spotlight

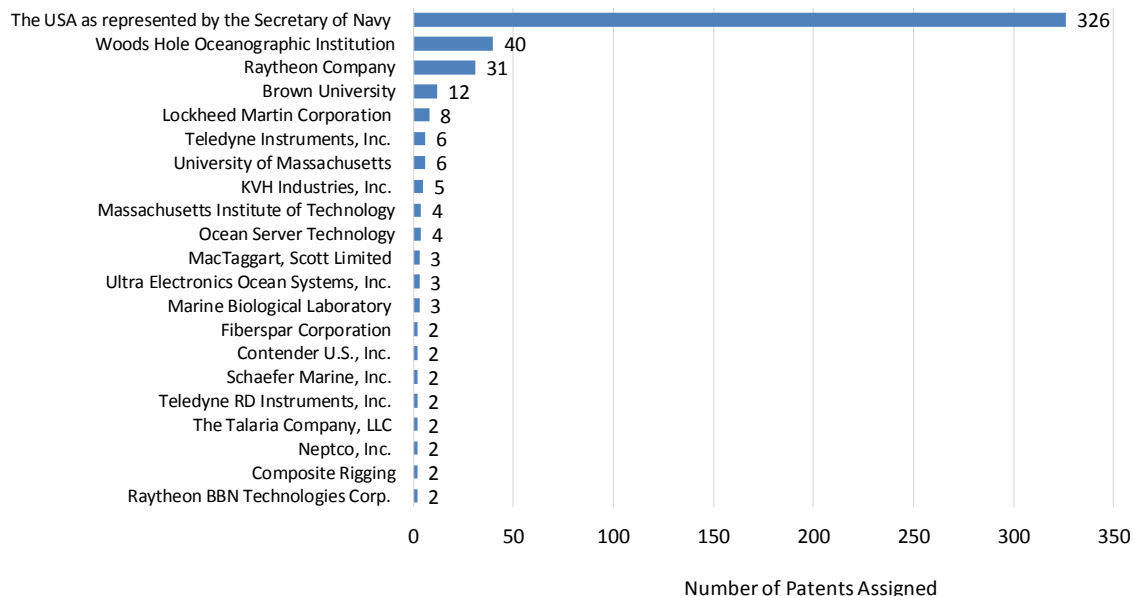
Naval and Academic Research Demand for UUVs Drives Innovation in the Region

Massachusetts is often considered a leader in unmanned underwater vehicles (UUVs) and other marine robotics. Hydroid in Bourne develops marine robotic technology for various applications. In September 2019, the U.S. Navy awarded the company a \$52.3 million contract extension for its MK 18 UUVs, versions of which are equipped side-scan sonar, an acoustic Doppler current profiler, and other technologies. General Dynamics explains that the UUV is ideal for applications in search and salvage, exploration, oceanography, and mine countermeasures. Riptide Autonomous Solutions, LLC in Plymouth developed the Micro UUV, an open source autonomous vehicle that is intended for developers of power systems, subsea sensors, and new payloads.

Based in Fall River, MA, Aquabotix manufactures unmanned underwater vehicles and underwater cameras for commercial and military applications. In early 2019, the company secured a contract with the Navy that involved the development of Aquabotix’s SwarmDiver product. SwarmDiver can be customized for a variety of applications, including environmental monitoring, 3D synoptic data gathering, and autonomous depth sounding. In addition to this product, the company also manufactures video and imaging products such as HydroView, AquaLens Connect, and others.

Most MST patents in SENE are assigned to a small number of prominent, well-funded organizations. Topping the list is “The United States of America as represented by the Secretary of the Navy,” which is the assignee for patents associated with the Naval Undersea Warfare Center Newport Division. NUWC is followed by WHOI and Raytheon. Brown University ranks surprisingly high on this considering that they do demonstrably less marine-related research than other research universities in the region.

Figure 23
Number of MST patents assigned to major institutions, approved 2008–2018



Source: USPTO Patent Full-Text and Image Database (PatFT)

Many Inventions Go Unpatented and Legal Services Could Help Grow the Sector

About half (48%) of businesses responding to the MST Business Survey reported having applied for intellectual property (IP) protection, whether through a patent or other means, during the five years preceding 2019. Another 11 percent reported acquiring IP from another entity through licensing agreements (see Table 11.) Interviews with large MST organizations in SENE revealed that many fail to patent key discoveries or retain the IP rights of discoveries made in the region. It is therefore unsurprising that “legal services such as for intellectual property protection and licensing” was in the top three suggestions of firms responding to our survey for how to grow the MST sector as a whole, with 41 percent of respondents selecting this option (the top two responses were both related to better engagement with universities and other research institutions).

Table 11
Intellectual property activities over the past five years, SENE MST businesses, 2019

Activity	Percent
Applied for intellectual property (IP) protection (patent, copyright, etc.)	48.1%
Transferred IP to other businesses, organizations, or persons through licensing agreements	11.1%
Received IP from other businesses, organizations, or persons through licensing agreements	11.1%
Transferred IP to a spin-off of your business	11.1%
None of the above	37.0%
Not sure	0.00%

Source: MST Business Survey (n=29)

7 STRENGTHS-BASED OPPORTUNITIES FOR SOUTHEASTERN NEW ENGLAND

7.1 ECONOMIC GROWTH DRIVERS IN THE BLUE ECONOMY



There are three main drivers of growth in the Blue Economy: (1) innovation in traditional blue economy industries such as fishing and shipbuilding, (2) the development of new and emerging ocean-related activities, and (3) responses to global pressures such as sea-level rise and meeting the demand for sustainable protein.

Some growth in the Blue Economy will be driven by efforts that improve existing blue economy industries. For example, technologies to improve the processing of fish has the potential to enable the production of difficult to process species, and efforts to reduce the pollution impacts of shipping can be expected to drive improvements in ship and boat propulsion systems. Innovation in existing industries is a necessary component of remaining competitive in a changing economy. For example, much of the world's seafood processing is currently done overseas by low cost labor, which creates competitive pressure to improve the productivity of domestic labor.

In addition, the desire of new businesses to locate near their customers incentivizes technology companies to establish themselves in areas that offer strategic and competitive advantages. This tendency could be leveraged to encourage economic development in living resources, naval defense, or

oceanography, which are well-established Blue Economy industries in SENE and areas of comparative advantage for the SENE region. However, technological innovation in established industries can sometimes prove to be disruptive or labor saving, creating the need for established companies to shift their focus or for displaced employees to retrain and find new opportunities.

Along with supporting and improving the competitiveness of established Blue Economy industries, emerging and new developments, such as in offshore renewable energy, aquaculture, and deep-sea mining, are expected to bring promising new opportunities and the potential for greater diversity in the Blue Economy. The extent to which these opportunities will manifest themselves in SENE, and the extent to which they will benefit from a technology-focused economic development strategy, remains to be seen. There is already some local activity in some of these areas, particularly in offshore wind and aquaculture, but the competition with other regions can be expected to be fierce, with many other shore-side communities along the Eastern seaboard vying to get a piece of this new economic pie.

Finally, climate change and other ecological pressures are transforming our relationship with the ocean. Issues of food security and water availability, energy security needs, sea level rise, and ocean pollution all require a serious reconsideration of how we relate with and derive value from the ocean. While many of these threats present major risks to regional economy, they also present opportunities for organizations and businesses that can discover innovative ways to address and respond to them.

7.2 OPPORTUNITY AREAS IN THE SENE REGION

As stated at the outset, this research is intended to support the creation of more high-paying jobs and to increase the overall prosperity of SENE and its communities. To meet these goals, it is best to focus on MST opportunity areas that have the greatest potential for job creation in SENE. While efforts should be made to foster the development

Figure 24
Alignment of MST opportunity areas with regional strengths and growth prospects



of emerging and promising marine technologies, aligning efforts with existing strengths will help to ensure that we are supporting businesses that are well-positioned to grow to scale in the region, rather than elsewhere.

To identify the areas in which investment in MST-related innovation have the potential to yield economic impacts in SENE, the research team organized MST opportunity areas along two dimensions: (1) the extent to which they build on existing strengths and capacity in the region, and (2) the extent to which supporting business and research activities in those areas would yield significant job growth in the region. This exercise yielded four categories of opportunities: (1) those that are clear high opportunity areas; (2) those that are already well-established in the region but face limited growth potential, deemed “preserve and support;” (3) those that are promising new growth areas, but are not

yet well-developed in the region, deemed “develop & cultivate;” and (4) those that are low opportunity areas because they are not well-established in the region and present limited potential for job growth *in SENE*, though they could be substantial job creators elsewhere.

This section discusses these opportunities in more detail and provides an overview of some of the scientific and technological problem sets that are expected to drive innovation in each area, particularly in areas in which the region has demonstrable expertise and is well-positioned to successfully compete.

High Opportunity Areas

This category includes those opportunities that are tied to existing strengths in SENE and are most likely to yield job growth in SENE if they are supported. They build on deep strengths and have growth prospects that have the strong potential to be captured in the region. Furthermore, they have the potential to drive growth in other MST and Blue Economy industries through supply chain relationships.

Aquaculture

Aquaculture is an opportunity area that was mentioned in nearly all of the key informant interviews. In the United States, marine aquaculture production increased at over 3.3 percent per year from 2009 to 2014, but compared to other countries, the U.S. is still a minor player in terms of total aquaculture production.³⁴ However, the nation is a leader in terms of advanced technology, feed, equipment, and investment capital. Aquaculture production is a growth industry in Massachusetts, where total sales increased by 60 percent from 2005 to 2013, from \$12.1 million to \$19.4 million.³⁵ Key informants credit the success of the local aquaculture industry to “boutique” shellfish, which are actually more marketable than wild caught, unlike in the finfish industry. Efforts to grow this sector will require educating potential customers and streamlining the permitting process.

While the day-to-day business of aquaculture may or may not be a technology-intensive endeavor, depending on the type of system, there are many ways science and technology can improve the profitability of this industry. Some innovation is production-oriented, such as improved feeding systems, cage design, indoor circulating systems, and husbandry. Other opportunities for innovation include finding feed substitutes, environmental toxicology, assays to detect marine disease, ways of preventing or treating infection and the use of selective breeding or biotechnology to cultivate economically important traits, such as body shape and size or disease resistance.

Spotlight

Aquaculture is More than Just Fish and Oysters

Agcore Technologies in Cranston, RI farms spirulina, a sustainable plant protein for human and animal nutrition. Spirulina is a blue-green algae containing 18 amino acids that support good health. The company develops smoothie powders, vegan snack foods, the first grain-free fish food, and a variety of aquaculture products. Agcore makes high quality food products while focusing on environmental, social, and economic sustainability. The company utilizes an enclosed farming system with deep water growth reactors inside greenhouses, which ensures the spirulina is protected from pesticides and other contaminants. Agcore also developed a carbon capture method that separates carbon dioxide from waste emissions and sends it in gaseous form for agricultural use.

³⁴ National Oceanographic and Atmospheric Administration, *Fisheries of the United States*, 2017.

³⁵ USDA Census of Agriculture. “Value of Aquaculture Products Sold by Type—United States and States: 2013 and 2005.”

Offshore Communications

Defense contracting is a primary revenue stream for many of the largest MST firms in the region. In order for the regional MST sector to grow, it needs to connect defense-related innovation and other undersea technologies to commercial market opportunities. Offshore communications has the benefit of being both well-supported by the military and having clear commercial applications.

Advancement in maritime communications networks severely lags behind its land counterparts. Basic communication access that most people have grown accustomed to, such as mobile phone networks, is either unavailable or much more expensive at sea than on land. Meanwhile, increasing data collection out at sea has driven a commensurate need for improved, secure offshore communications to relay that information back to shore. Legacy solutions, such as satellite communication and VHF, have limitations in terms of the amount of bandwidth that is available and the privacy of the networks. New solutions are needed to provide a consistent, secure ability to send large volumes of data.

Undersea communications is another area of research strengths and is more tied to business and research activity in SENE than onboard communications. Optics and acoustics are the main ways in which wireless communication happens underwater, but they each have their advantages and limitations. Sound propagates in water, providing information over long distances, but it travels in long wavelengths that yield only low spatial resolution. Light, on the other hand, scatters quickly in water, but travels in short wavelengths, providing high-resolution information. Additionally, recent research has shown that sonar systems, which use sound to see underwater, can lead to injury or death for marine mammals.³⁶ Integrated systems are being developed that combine these two technologies in networked systems, to hopefully overcome the limitations of each. Many advances in optics and acoustics are driven by advances in data science, such as localization algorithms to precisely identify the locations of sensors along a network, as well as signal processing to make sense of the signals that are collected.

Offshore Wind

The offshore wind industry got its start in Denmark and Germany and then crossed the North Sea to the United Kingdom (U.K.). The movement of the supply chain to U.S. is being driven by the cost of transporting the massive components across the Atlantic and the size of the U.S. market. Positioning the region to capitalize on offshore wind will require preparing our workforce, infrastructure, and business leaders to respond to industry needs and emerging opportunities. Done right, the potential for the region is substantial. Offshore wind development will create thousands of new jobs and average wages for occupations in the industry are over \$80,000, which compares favorably to the Massachusetts average wage of about \$67,000.³⁷ Jobs range from white-collar legal and finance positions; to scientific and technical positions; to well-paying, blue-collar construction jobs; to long-term, stable jobs in operations and maintenance.

SENE benefits from being next to the largest offshore wind resource in the contiguous United States. However, it is now generally accepted that developing offshore wind in the United States will require a network of ports since no one location is ideal for supporting the full range of activities.³⁸ Therefore, while local offshore wind developers have committed to using the New Bedford Marine Commerce Terminal, it is also likely that they have additional locations

³⁶ <https://www.nature.com/news/2008/080801/full/news.2008.997.html>

³⁷ See Borges et al. (2018). *Proposed Vineyard Wind Offshore Wind Energy Project: Estimated Contribution to Employment and Economic Development for 800 MW*. The Public Policy Center at UMass Dartmouth.

³⁸ <https://commonwealthmagazine.org/energy/perfect-port-an-elusive-goal-for-east-coast-offshore-wind/>

in mind. Indeed, investments are already being made in other ports, such as Brayton Point in Somerset, MA and New London, CT. The competition to land the offshore wind industry is fierce and there is a need for bold and quick action if SENE wants to capture a large share of the supply chain.

OSW is an emerging global industry that is constantly innovating and adopting new technology, which presents an opportunity for the region's MST sector as there are still many areas for improvement. Currently, research activities in the region include interactions with offshore communication and navigation systems, wildlife and ecosystem impacts, and resource characterization. Future avenues for research include improved generator technology, advanced materials, foundation design, optimization of operations and maintenance activities, and remote monitoring and surveillance.

Sustainable Seafood

Fishing is a long-established traditional industry in New England and while other parts of the Northeast have seen declines, SENE is home to the most lucrative fishing ports in the country. Despite sustained success, the living resources sector faces challenges related to modernization and competition in a global marketplace. Furthermore, consolidation and automation in the industry have reduced the total number of jobs. However, there are many opportunities to protect and grow the sector, such as increasing the number and types of marine species that are cultivated and harvested, improving the quality of marine habitats, and adopting technologies related to fish traceability.

New technology and practices can be adopted in the fishing industry to increase efficiency, facilitate regulatory compliance, and grow the market for sustainable, locally-caught seafood. Efforts that are currently underway include using sensors and big data to more accurately predict where fish will be, reducing bycatch through gear selectivity, and reducing seabed impacts through gear modification. As consumers begin to demand locally-caught seafood and producers begin to realize the added value they can capture by marketing the sustainability and source of their catch, software and other technologies that facilitate the tracking of fish through the supply chain become increasingly important. For example, genetic testing and block chain technology are being explored as ways to validate fish species and traceability, respectively.

Preserve and Support

This category includes those technologies that businesses and organizations in the region already specialize in, but for which future market growth is expected to be limited. Since SENE has unique strengths in these areas, they should continue to be supported, but targeting these areas may not yield substantial job gains.

Marine Robotics

Marine robotics includes both unmanned surface vehicles (USVs) and unmanned underwater vehicles (UUVs), in addition to other aquatic devices. There are generally two types of UUVs: remotely operated underwater vehicles (ROVs) and autonomous underwater vehicles (AUVs). Massachusetts is widely acknowledged as an international leader in the marine robotics industry, with two of the three leading manufacturers of AUVs—Kongsberg Hydroid and Teledyne Benthos—located in the region, and the remaining company, Bluefin Robotics, located in nearby Quincy.³⁹ Presently, AUVs manufacturers rely heavily on defense and academic markets, in which growth is limited. Future business growth will depend on finding new customers in the commercial marketplace, with offshore wind representing a clear opportunity for some firms.

Areas of technological development that could have the largest impact on this industry include energy sources & propulsion systems, underwater communication, and autonomy & intelligence. Because of battery capacity, AUVs have a limited range and duration. Improved battery technology or the ability to generate and acquire energy on site would increase the usefulness of AUVs.⁴⁰ Improved underwater communication is needed to send the large amounts of data AUVs collect back to shore, as well as to remotely control them if needed.

Scientific Instrumentation

Ocean research and exploration has been greatly enhanced by marine sensing technologies. Sensors have been developed to measure and detect a range of attributes and components of the marine environment, including light, temperature, sound, mass, chemical composition, and particular marine species. New sensors are being developed to enable us to detect more things and in harsher conditions. On a practical level, research is needed to overcome the limitations sensors face, which include available power, wave erosion, saltwater corrosion, and fouling by marine organisms that accumulate on their surfaces.

Scientific instrumentation is a key in strength in SENE, as demonstrated by research faculty expertise and the areas in which SENE businesses receive SBIR awards. However, like with marine robotics, instrumentation companies rely heavily on the defense and academic markets, though offshore wind and aquaculture present potential new sets of customers.

³⁹ All three firms were founded using technology developed at WHOI (Hydroid and Teledyne) and MIT (Bluefin) respectively.

⁴⁰ Ibid.

Develop and Cultivate

This category includes those opportunities that are promising new growth areas, but are not yet well-developed in the region. Capturing these opportunities will be more difficult than for the High Opportunity Areas since they require building additional capacity, whether in terms of businesses that are active in these spaces, researchers doing relevant research, or both. However, these opportunities are related to existing traditional maritime businesses or research activities in the region. Thus, while the technologies and scientific problem sets presented here may not be invented or addressed in SENE, businesses in the region could benefit from adopting technologies or ideas in these categories.

Advanced Seafood Processing

The United States lags behind Europe in terms of the steps that have been taken within the fishing and fish processing industries to maximize efficiency and increase the quality of the final product. Local fishermen and fish processors could improve the efficiency of their operations by incorporating new technology but to date have resisted doing so, reportedly for both financial and non-financial reasons. Quick freezing and high-pressure processing are two recent developments in fish processing. Other technologies include pulsed electric field (PEF) treatment, heat processing combined with microwave (MW) or radio-frequency (RF), intelligent packing with freshness and time/temperature indicators, antimicrobial bio-nanocomposite packaging, biodegradable edible films, and lastly (but perhaps most importantly) the production or extraction of value-added products.

Marine Plants

While most of the economic activity in the living resources sector is in shellfish and finfish, scientists and other groups are taking note of the untapped potential of marine plants. For example, marine micro-algae can produce a range of products (liquid fuels, protein, biodegradable plastics, etc.) without compromising potable water supplies, since they can grow in seawater.⁴¹ In the process, large-scale cultivation has the potential to significantly improve the ocean environment. Take for example, the *Emiliana huxleyi* phytoplankton, which is a main source of food for fish and other ocean life, and can absorb large amounts of inorganic nitrogen, phosphorous, and carbon dioxide as they grow.⁴²

Recently kelp and other seaweed farming have attracted significant interest. Nutritionally dense, some say that “kelp is the new kale.” It is packed with potassium, iron, calcium, fiber, iodine and a myriad of vitamins. However, it is not expected that many people will cook with the whole plant, so others say that “kelp is the new soy” in that it will start appearing as a component in a diverse range of value-added food products. Kelp has been shown to de-acidify the ocean, improving the quality of shellfish living nearby. It can also provide an additional revenue source to income to fisheries threatened by climate change and overfishing.⁴³

Protecting Ocean and Coastal Resources

Climate change is an existential threat to business as usual, both on land and at sea. Marine-related climate change impacts that are affecting us today include changes in sea temperature, ocean acidity, sea-level rise, and storm surge, the effects of which will impact SENE at an accelerating pace. In our 2017 report on the Massachusetts

⁴¹ Day, J, A Hughes, L Greenhill and MS Stanley (2016), *Blue Biotechnology*. Commonwealth Blue Economy Report Series, No. 5. Commonwealth Secretariat: London. Page 14

⁴² Doyle, Alistair. “Ocean Algae Can Evolve Fast to Tackle Climate Change,” *Scientific American*.

⁴³ <https://www.nytimes.com/2019/04/30/dining/kelp-seaweed-recipes.html>

maritime economy, a survey of Blue Economy business owners revealed that “preserving and protecting our ocean resources” is the second most important policy area to the success of their businesses, preceded only by “reducing business costs related to taxes.”⁴⁴ The extent to which this set of problems presents a market opportunity is still an open question. However, the economic value of the harm that could be averted is immense, whether it is to maintain the idyllic nature of the seaside to maintain an ocean environment that is hospitable to valuable fish species such as scallops, or to prevent the catastrophic loss of property due to storm surge and sea level rise.

At least 10 percent of the 329 MST scientists in SENE state an interest in applying their expertise to issues of ocean and coastal health, and the region’s number one area of expertise—physical oceanography—makes it possible to predict climate change impacts under different adaptation scenarios. In addition, a majority of key informant interviews and stakeholder meetings revealed an interest in promoting science and technology that helps to improve the ocean and coastal environments. It is possible to build off of this regional specialization to inform activities related to mitigating and responding to climate change impacts and other threats to coastal economies. Companies likely to benefit include environmental engineering firms, marine construction firms, and others.

The range of scientific and technological solutions includes such things as bioremediation, through which naturally occurring organisms can be identified and bred to metabolize pollutants such as certain types of hydrocarbons, and solutions to ocean plastics, ocean acidification, and nitrogen loading. It also includes activities at the land-sea interface, such as wetland restoration and other innovative ways to adapt to a rising sea or more frequent storms, and social science in support of sound coastal zone management practices.

Spotlight

Advanced Ocean Modeling Is Making Forecasts More Accurate

The UMass Dartmouth’s School for Marine Science and Technology hosts the Marine Ecosystem Dynamics Modeling Laboratory (MEDML), currently headed by Dr. Changsheng Chen. MEDML uses a high-performance computing cluster to model ocean dynamics around the globe at a high degree of precision. Researchers in the lab work to develop mathematical models of coastal and estuarine circulation, ecosystem dynamics, biophysical interactions, frontal dynamics, and suspended sediment processes. Their Finite Volume Community Ocean Model is able to simulate ocean circulation and ecosystems in differing regions at various scales.

Value-Added Products

There are an array of value-added, specialty products that can be made from marine organisms. While fish oil is a common example, there are many other marine bioresources contributing to health food and cosmetic applications including processing macroalgae for essential fatty acids (omegas), deriving calcium or chitin from shellfish, and various sources of active compounds such as vitamins and antioxidants. Cosmetic ingredient suppliers are increasingly interested in non-petrochemical-derived ingredients so that products can be labelled ‘natural.’ Natural ingredients often have strong marketing power and can command a premium price. Research on the effects of these products is an often-neglected area, but has the potential to increase their market value and public acceptance.

⁴⁴ Borges et al. (2017), Navigating the Global Economy: A Comprehensive Analysis of the Massachusetts Maritime Economy, The Public Policy Center at UMass Dartmouth.

There are three main routes by which products enter the cosmeceutical and nutraceutical markets: as raw materials, as bulk extracts for formulation, and as specialized functional ingredients. To get to this point, commercialization of marine specialty products will require the development of a sustainable way to grow, capture, or harvest the targeted organisms, as well as appropriate extraction and preservation methods.⁴⁵

Spotlight

Using the Whole Fish

After processing fish to remove the meat, what is leftover—the skin, shells, bones, and other sordid parts—are either discarded or turned into low value products such as decorative paving material for driveways. There is now a movement underway, which began with Iceland's Ocean Cluster initiative and is now being explored by the New Bedford Ocean Cluster, to find ways to make use of the whole fish. The results in Iceland have been very promising, with the value of the products made from fish byproducts often selling for more than the fillets. For example, fish skin has been used to make wound dressings, leather, and collagen extracts. Likewise, lobster shells have shown promise as an input into making biodegradable plastic and implantable medical devices.

⁴⁵ OECD (2013). *Marine Biotechnology: Enabling Solutions for Ocean Productivity and Sustainability*, OECD Publishing.

Low Opportunity Areas

This category includes those opportunities that are not tied to any deep regional strengths or do not present substantial job growth prospects for the region. They include marine-inspired and marine-derived pharmaceuticals and medical devices, marine hydrokinetic energy, clean propulsion systems, and ports and shipping technology. While SENE companies and organizations have made discoveries or developed new products in many of these areas, companies in this category tend to leave the region when they grow to scale in order to be near their primary market or a cluster of related businesses and key resources.

Take for example marine hydrokinetic energy, which encompasses all technologies that harness the power of the various movements of the ocean. There are several business and organization in the region that focus on marine hydrokinetic energy, with a specific focus on tidal and wave energy. However, there is very little tidal energy available in nearby waters.⁴⁶ Therefore, while tidal companies sometimes get their early start in SENE, they tend to relocate to places with more tidal energy available. Wave energy is more abundant in the region, but the technology is still very immature and since the devices must be placed underwater, use conflicts and other siting concerns may pose a major impediment to wave energy deployment in SENE.

Spotlight

Electrifying the Water Transportation Sector

Boats and ships are becoming increasingly electrified as mariners demand features similar to those they have in their cars and homes: think voice automated controls, entertainment systems, and remote start. Furthermore, many of the trends affecting land transportation are slowly catching on in the water transportation sector. International agreements are forcing the adoption of clean propulsion systems and autonomous navigation systems are being developed for both underwater and surface vessels. As more electronically-powered devices are deployed, there will be a commensurate need for a combination of improved battery technology and ways to generate, store, and release electricity on-site in remote locations.

⁴⁶ See Georgia Tech Research Corporation, (2011). Assessment of Energy Production Potential from Tidal Streams in the United States. Technical Report.

8 NAVIGATING AROUND HAZARDS

In order for the MST sector to thrive, future initiatives and regional collaborations should be aware of and prepared to respond to a series of potential threats to the natural resources that enable the regional MST sector and the larger Blue Economy. Any future growth in the MST sector will depend on adopting strategies and policies that strike a balance between preserving ocean and coastal resources for future use and allowing for present-day economic activities. Furthermore, policies and programs designed to encourage the growth of the MST sector must avoid the common pitfalls that have resulted in the failure of previous cluster development efforts in SENE and beyond. Finally, addressing the obstacles facing entrepreneurs in this region, including the lack of access to venture capital, would support innovation and entrepreneurship, which is essential to growth all sectors of the economy.

8.1 ENVIRONMENTAL HAZARDS

Many industries in the Blue Economy, such as Tourism or Living Resources, depend on healthy, functioning, and accessible marine ecosystems. Human activities have a direct impact on nearby marine ecosystems, and many, such as coastal development; domestic, agricultural, and industrial waste; and bottom trawl fishing, are subject to our control. State and local governments must consider how to balance the needs of today's residents and businesses while also taking action to protect a shared natural resource for future enjoyment and as a means for creating economic opportunity.

Climate change and related phenomena also have a major impact. Rising seas, ocean acidification, temperature changes, and extreme weather events are all expected to change the marine habitats the Blue Economy depends upon. For example, ocean warming off the coast of Massachusetts and throughout the Gulf of Maine is causing the habitat for lobsters to shift north. These trends are a clear and present threat to traditional maritime industries, as well as to marine biodiversity. Yet, they also present opportunities to leverage and grow the regional MST sector if regional firms and institutions can organize themselves to respond and successfully adapt to a changing climate and the rising tides. Over the long-term, the success of the Blue Economy in SENE will depend on how well we respond to these emerging threats to our ocean and coastal resources.

Spotlight

Watershed Grants Help Protect and Preserve Important Coastal Resources

To help promote cleaner water and healthier coastal ecosystems in southeastern New England, the Environmental Protection Agency, in partnership with Restore America's Estuaries (RAE), awarded 13 organizations in Massachusetts and Rhode Island a total of \$2.3 million. The Southeast New England Program Watershed Grants were provided to organizations including the Association to Preserve Cape Cod, Buzzards Bay Coalition, and Woonasquatucket River Watershed Council. The Association to Preserve Cape Cod's Three Bays Stormwater Project is working to restore clean water to estuaries in the Town of Barnstable. The Buzzards Bay Coalition supports research to understand marsh loss in Buzzards Bay and restoration efforts. In Rhode Island, the Woonasquatucket River Watershed Council, along with other organizations, aims to reduce pollution in the Providence River and Narragansett Bay. These programs are designed to improve the health of coastal watersheds and protect clean water in the region.

8.2 POLICY HAZARDS

Policymakers can have an influence on the future growth trajectory of the MST sector in SENE by supporting evidence-based ocean planning and cluster development strategies that build on established regional strengths and assets, and avoid the pitfalls that have led to the failure of similar efforts both within and beyond SENE.

Ocean and Coastal Zones Must Be Carefully Managed

Ad hoc development was cited by The World Bank as one of the major threats to the growth in the Blue Economy. In their words, “unplanned and unregulated development in the narrow coastal interface and near shore areas have led to significant externalities between sectors.”⁴⁷ Regionally, the need to effectively manage competing uses of ocean resources has risen as a top issue as the fishing industry resists any disruption of their current fishing practices from offshore wind siting and construction. Other negative outcomes that could arise from ad hoc development include “suboptimal siting of infrastructure, overlapping uses of land and marine areas, marginalization of poor communities, and loss or degradation of critical habitats.”⁴⁸

Cluster Initiatives Must Be Well-Supported and Evidence-Based

Misdirected efforts in the implementation phase could stymie any well-intentioned efforts to grow SENE's MST sector. It is prudent to acknowledge that it is extremely difficult to do cluster initiatives well, and, despite their widespread appeal, few universities have the resources to support meaningful, large-scale research and economic development partnerships.⁴⁹ “Many regions only go as far as marketing their clusters to attract businesses, rather than building authentic and robust local ecosystems to support the needs of existing firms in the cluster.”⁵⁰ Sustainability is also difficult, as many organizations lack the fiscal and institutional capacity to sustain even well-designed efforts for more than a few years.

Finally, many cluster initiatives fail to identify the right clusters, often choosing unrealistic or generic targets. One business responding to the MST Business Survey noted that “the various efforts to promote the “Blue Economy” feel like a forced marriage. Everything from whale watching trips to WHOI's Alvin are lumped together under this “Blue Economy” umbrella. The reality is that the “Blue Economy” is very segmented; we have substantially different needs. Making an impact will require focusing on one or two segments rather than the current shotgun efforts.” Some of this criticism has to do with the various and disparate efforts in the region to grow the “Blue Economy” and the catchall nature of the term.

8.3 ENTREPRENEURIAL HAZARDS

A number of issues that present economic hazards are discussed elsewhere in the report, such as access to a skilled workforce and research funding. As discussed in detail earlier, serious consideration should be given to improving

⁴⁷ World Bank Group. (2016). *Oceans 2030: Financing the Blue Economy for Sustainable Development*. Retrieved at <http://pubdocs.worldbank.org/en/446441473349079068/AMCOECC-Blue-Economy-Development-Framework.pdf>

⁴⁸ Ibid.

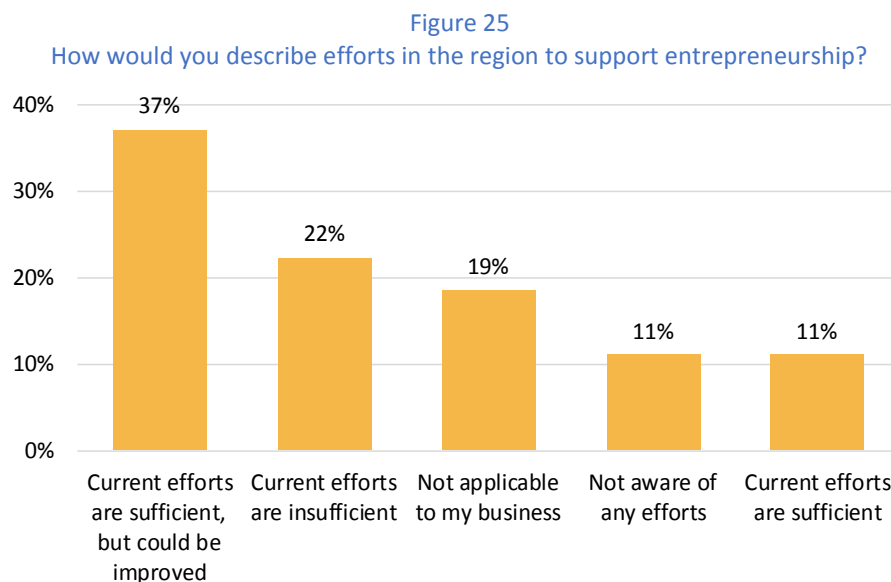
⁴⁹ Fairweather, J. S. (1988). *Entrepreneurship and Higher Education; Lessons for Colleges, Universities, and Industry*. ASHE-ERIC Higher Education Report No. 6, 1988. ASHE-ERIC Higher Education Reports, The Georgetown University, One Dupont Circle, Suite 630, Dept RC, Washington, DC 20036-1183.

⁵⁰ Donahue, R., Joseph, P., and McDearman, B. (2018). *Rethinking cluster initiatives*. The Brookings Institute.

and maintaining the workforce pipeline, and to sustaining the flow of extramural research funding. However, our research also revealed other potential hazards for the MST sector, which are primarily related to supporting and developing entrepreneurship in the region. The MST sector, like other technology sectors, is dependent on innovation and entrepreneurship and the transition from idea or prototype to product is seldom straightforward. SENE is undeniably a global leader in basic research in MST, but to date, very little of the cutting edge science being conducted in the region has found its way into the marketplace, in part due to inadequate entrepreneurial supports. Consequently, the regional economic development return on scientific research and development has historically been disappointing.

Improve Support Systems for Regional Entrepreneurs and Entrepreneurial Ventures

Fifty-nine percent of respondents to the MST Business Survey report that efforts to support entrepreneurship in the region are insufficient or could be improved. Interview and survey responses indicate that access to capital, infrastructure for new product development (such as prototype labs and proof-of-concept testing facilities), and business leadership and mentoring are three areas that deserve more attention.



Source: Public Policy Center (n=27)

Startup capital can take many forms, including loans, grants, and venture capital. In the 2016 PPC report *Navigating the Global Economy*,⁵¹ key informants in the MST sector noted that access to capital is an impediment to commercialization, since venture capitalists and large banks do not generally fund small projects that do not have a clear path to scale. This is especially challenging when competing for investment capital against larger, more developed industries such as information technology and biotechnology

Massachusetts is one of the leading states in the nation for access to venture capital funding, but the lion's share of this money goes to businesses in the healthcare industry, and venture capitalists are hesitant to work with businesses

⁵¹ Borges et al. (2017), *Navigating the Global Economy: A Comprehensive Analysis of the Massachusetts Maritime Economy*, The Public Policy Center at UMass Dartmouth.

outside of the Greater Boston region.⁵² In addition, investors often do not see the market potential for marine technology, which is generally viewed—sometimes correctly—as having a low return on investment.

We also find that the federal funding for research-oriented private enterprises is also limited in the MST space. The SBIR/STTR program, which funds research and innovation for small businesses, sets aside a small percentage of the extramural research budget of all federal agencies for investment into promising enterprises. As a practical matter, most of the dollars for technology development in new and emerging industries comes from the Department of Defense or the Department of Health and Human Services, the two agencies that have the largest research budgets. This leaves some regional firms without an obvious source of capital to support commercialization efforts and helps explain why the size and growth of smaller MST firms in SENE has been so modest.

Risk Aversion Prevents New Ideas from Being Adopted or Commercialized

Many of the scientific breakthroughs that could lead to new business creation in SENE are made by people who already have day jobs, whether in a research institution or a private business. In this situation, there are three possible options: (1) the current organization finds a way to directly profit off of the discovery (usually not an option at research institutions), (2) the discovery becomes intellectual property and is sold or licensed to an outside party, or (3) the employee who made the discovery starts a new business as a “spinoff” of the originating organization. Option two requires having the capacity to manage the intellectual property and promote it through “technology-transfer” and outreach activities designed to find organizations that could benefit from adopting or promoting the new technology. Done effectively, this can generate a significant revenue stream for the home organization, including universities and research institutions ever since the passage of the Bayh-Dole Act.

However, technology-transfer often runs up against the problem of risk aversion, in which businesses that could benefit from the new technology are not willing to take a chance on a new way of doing business or investing the capital required to make the change. Many technological improvements in the Blue Economy are capital intensive, making the financial barrier more significant than in other industries. For example, local fish processors could improve the efficiency of their operations by incorporating new technology but to date have resisted doing so, reportedly for both financial and non-financial reasons. Effectively encouraging the adoption of locally developed technologies would have the dual benefit of improving the competitiveness of traditional Blue Economy businesses and opening up local markets for the regional MST sector.

In option three, organizations run into the “lifestyle business” conundrum, in which the person who might spin out the business already has a day job and is otherwise settled in their life. In this situation, there is a significant downside to taking a risk, so the spinoff may never happen. Sometimes the employee may try to keep their day job while starting the business, resulting in neither being done well. Overcoming this obstacle will require meaningful changes in the incentive structure at local research institutions and an intentional effort to reward and support applied scientific ventures and activities.

⁵² Massachusetts Technology Collaborative. (2018). *2018 Index of the Massachusetts Innovation Economy*.

9 IMPLICATIONS FOR ACTION

The research presented in this report is designed to assist the project team in understanding the current state of the MST sector in Southeastern New England and informing the development of evidence-based strategies in Year 2 of the project. Up to this point, the report has provided a comprehensive analysis of the region's MST sector, including a general overview of the sector, a regional assessment that describes the MST landscape, and an analysis of key sub-clusters. The research also includes an assessment of research strengths and opportunities, a workforce analysis that identifies current and future high priority occupations, and an analysis of opportunity areas and challenges for the MST sector going forward. Several clear implications for action have emerged from this analysis.

1. Build on the MST sector's strengths by connecting traditional maritime industries to existing and emerging scientific developments and technological opportunities.

Connecting tradition with technology will help to preserve our maritime heritage and support longstanding regional industries that have been areas of comparative advantage for the region (e.g., living resources and water transportation). While efforts should be made to foster the development of emerging and promising marine technologies, aligning efforts with traditional strengths will help to ensure that we are supporting businesses that are well-positioned to grow to scale in the region, rather than elsewhere. Accordingly, approaches to supporting marine technology enterprises should be designed to identify and develop new opportunities, while at the same time meeting the needs of the traditional sectors that have made SENE a center of Blue Economy activities for centuries. Towards these ends, we identified the following opportunity areas for growing the MST sector:

- Connecting defense-related innovation to commercial market opportunities;
- Modernizing and expanding the living resources sector;
- Positioning the region to capitalize on offshore wind;
- Leveraging the region's expertise in marine science to address the challenges of climate adaptation.

2. Redouble efforts to advocate for federal funding.

The region's MST companies and public and nonprofit organizations are highly dependent on federal research funding for both applied and basic research. In 2017, both WHOI and URI ranked among the top ten largest recipients of oceanographic research funding in the nation. Furthermore, MST firms and research institutions in the region received over \$1 billion in federal contracts from the Department of Defense from 2014 to 2019. Continuous and effective advocacy for federal funds is necessary to maintain support for scientific research and defense-related technological innovation.

3. Organize and respond to the threats presented by climate change and other threats to the Blue Economy.

Our world is confronted with extreme threats to its ocean environment. Issues of food security and water availability, energy security, sea level rise, and ocean pollution require us to think critically about how we relate to, depend upon, and derive value from the ocean. While many of these threats present economic costs, they also present opportunities to the organizations and businesses that find innovative ways to address them. The future success of the MST sector and the prospects for the regional Blue Economy as a whole will depend in important ways on the degree to which we are successful in predicting, adapting, and responding to these challenges.

4. Focus educational and workforce development efforts on both emerging and long-standing gaps in the regional labor force

MST employers indicated concerns about labor supply in two essential fields. MST employers responding to the business survey emphasized the importance of degrees in engineering disciplines over other credentials. Specifically, employers reported they have difficulty hiring in subfields such as systems and software engineering, acoustics, artificial intelligence, and ocean engineering. Overall, these responses reflect the increasing prevalence of autonomous robotics, IoT, and instrumentation in the MST sector. Given ongoing and expected developments in new technology, the demand for software engineers and other computing-related engineers is expected to grow both within and well beyond the MST sector. Increasing demand for this kind of talent is not unique to SENE and therefore a sustained effort to both “grow our own” engineering talent and to make the region attractive in ways that serve to both attract and retain these workers and their families will be required if this gap is to be filled.

Our analysis also reveals that the workforce needs of the MST sector in SENE extend well beyond the engineering disciplines. The demand for production workers was at the forefront of workforce issues raised by MST employers in key informant interviews. While much of the MST sector’s output is grounded in scientific research and technological innovation, a very significant portion of the employment in the sector and in the businesses that support the sector involves production and manufacturing oriented occupations. Consequently, supporting and developing sustainable workforce pipelines from regional vocational schools, community colleges, and universities to regional MST employers will be essential if the MST sector is to continue to grow and thrive SENE. Significantly, meeting this challenge would help increase and support much needed and well-paying job opportunities for SENE workers, many of whom remain unemployed or underemployed as a result of the dearth of well-paying regional job opportunities for workers without a college degree or advanced technical skill.

5. Reduce barriers that inhibit collaboration between regional research institutions and private industry.

MST companies in SENE report a strong desire to improve collaboration with the region’s universities. Key informants noted that past efforts to work with the region’s universities have been frustrating because the university bureaucracy makes collaboration difficult and time consuming, and key institutions simply lack an ethos that encourages and rewards industry-university partnerships. More flexibility and openness to collaboration from academic research institutions as well as practical solutions to bureaucratic obstacles will be needed if these collaborations are to be more effective and regionally impactful. This is not a new problem and addressing it will require a sustained and intentional effort to encourage a more entrepreneurial and collaborative culture within and between the region’s major research institutions as well as fundamental changes to the ways in which these institutions relate to each other and to industry.

Left unaddressed, it is hard to see how SENE will be able to extract much more economic value from its sizable and highly relevant research enterprise than it does today.

6. Yield more economic value from the regional MST research enterprise.

The region's marine science research institutions and firms are focused primarily on basic science, which historically has seldom been translated into meaningful commercial opportunities in SENE. Going forward, the region's universities and other research institutions will need to focus more on applied research and improve the capacity and performance of institutional technology transfer operations if university-industry spin-offs are to develop and translate into meaningful job growth for the region. This is not a new challenge and will also require meaningful cultural and institutional change if SENE is to meaningfully increase the local economic development impacts of the regional research activity.

7. Reimagine and transform the regional support systems designed to promote entrepreneurship.

The transition from idea or prototype to product is not straightforward and many commercially valuable technical innovations can result from research carried out without commercial application in mind. Evidence from key informant interviews suggests that regional entrepreneurs and companies need more and better support to assist them in scaling their ideas and bringing their products to market. For instance, 41 percent of survey respondents report that legal services such as IP protection and licensing would make it possible for more MST firms to thrive in the region. In addition, many regional MST businesses are best described as "lifestyle businesses," which are typically led by scientists and engineers working full-time elsewhere and who tend to lack the time, resources, or know-how to move an idea or product from concept to reality.

8. Educate the investor community.

Regional MST stakeholders report that access to capital is an impediment to commercialization, since venture capitalists and large banks do not generally fund small projects that do not have a clear path to scale. This is especially challenging when competing for investment capital against larger, more developed industries such as Information Technology and Biotechnology. Also, while Massachusetts is one of the leading states in the nation for access to venture capital funding, in practice most of this investment finds its way to other sectors such as life sciences, and venture capitalists are hesitant to work with businesses outside of the Greater Boston region. Notably, investors often do not see the market potential for marine technology, which is generally viewed—sometimes correctly—as having a low return on investment. Consequently, there is a need for strategies that connect entrepreneurs and developing businesses to the investor community and those that educate investors about the commercial prospects of marine science and technology. These educational efforts will only be successful to the extent that they are able to present commercially meaningful business opportunities to a community of skeptical investors that remains largely unpersuaded that such opportunities exist in SENE.

9. Align the region's research capacity with emerging Marine Science and Technology opportunities.

SENE has deep and meaningful research expertise in a number of MST fields including scientific instrumentation, ocean & coastal health, and underwater communications. However, seizing emerging MST opportunities will require building expertise in additional areas, such as marine microbiology, offshore engineering and construction, and aquaculture. If individual institutions elected to grow strategically in one

or more of these areas through, for example, strategic “cluster hiring” designed to capitalize on those opportunities, it would benefit both the individual institutions and increase the potential economic development benefits for the larger region.

Aligning the region’s research agenda with emerging MST opportunities will also require the deliberate exploration of industry-sponsored research activities. For instance, improving communication and facilitating more substantive interactions between research institutions and industry would benefit all parties and help to maximize more commercially relevant research and regional entrepreneurial activity. Facilitating these connections will require a significant change in the culture and practices of the region’s major research institutions.

10. Learn from the mistakes of other industry cluster initiatives.

Misdirected efforts in the implementation phase of this project could thwart efforts to significantly grow SENE’s MST sector. Cluster initiatives can go awry for a variety of reasons, including emphasizing attracting new businesses over supporting existing firms and startups, where most new job growth will likely occur. Cluster initiatives also frequently fail to identify the correct clusters, or see the sector as a monolith rather than acknowledging that it contains several distinct types of firms that have unique needs, interests, and goals. Acknowledging these issues and building evidence-based strategies for overcoming them will be a key to sustaining this initiative and achieving the goal of a more competitive and prosperous regional economy.

APPENDIX A: SURVEY METHODOLOGY & QUESTIONNAIRE

An online survey of the region's MST businesses was conducted to identify the strengths, challenges, and opportunities for these companies, as well as to gain basic company background information such as the number of employees and the number of years the company has been in business. The survey includes field-tested questions utilized in similar projects conducted by the PPC, questions adapted from similar surveys used by other organizations, and questions developed from lessons learned in our key informant interviews. The survey was administered online using Qualtrics.

While a total of 115 MST companies were identified for this study, 25 of these companies reported that they did not want to be included in the study. Consequently, a total of 90 survey invitations were emailed at the outset. Three of these emails were not deliverable and a deliverable contact email could not be obtained, thus the total sample size is 87. A follow-up email reminder was sent a week after the first email to companies that did not respond. A week later, a PPC staff member called as a reminder to complete the survey. Companies that still did not complete the survey were called again two weeks later, with an option this time to complete the survey on the telephone with a PPC staff member.

Overall, 28 companies completed a survey, for a response rate of 32 percent. Total employment for these companies is 2,484, which accounts for 26.2 percent of total employment all the region's MST companies and 47.3 percent of all companies who received an email invitation. Eight companies are from Rhode Island (1,896 employees) and twenty are from Massachusetts (588 employees).

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Survey Questionnaire

Hello!

As you may be aware, UMass Dartmouth is leading a three-year initiative funded by the U.S. Economic Development Administration to grow the regional Blue Economy, with a special focus on marine science and technology. Year one of this initiative is dedicated to a comprehensive study of the regional landscape for blue innovation, which is being conducted by UMass Dartmouth's Public Policy Center (PPC). The Year 1 goal is to identify the strengths, challenges, and opportunities for companies operating in marine science and technology industries and other firms that rely on access to the ocean and its resources.

This survey is an important component of our study and we are very interested in obtaining your input. The survey will take about ten minutes to complete and your responses will remain confidential. Data will be reported in the aggregate only - no individual responses will be reported. If you have any specific questions about the survey, you can contact David Borges, PPC's Director of Research, at dborges@umassd.edu.

Please note that for the purposes of this survey, we are interested in the Southeastern New England region, which comprises Southeastern Massachusetts, the Cape & Islands, and Rhode Island (see map below). Each time we refer to your business or location, we mean the business establishment(s) located in this region.



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Background Information

The following questions will allow us to develop an overall profile of the region's blue-tech landscape and to determine if responses vary by different types of companies. As noted, data will be reported in the aggregate only - no individual responses will be reported.

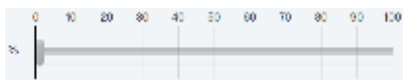
1. Which of the following best describes your role at this business location?

- Owner
- President/CEO
- Vice President
- Department Head or Supervisor
- HR Director
- Mid-level Manager
- Other (please specify)

2. How many years has your business been open?

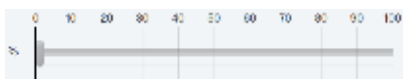
- Less than 1 year
- Between 1 and 5 years
- Between 6 and 10 years
- More than 10 years
- Not sure

3. What percent of your business's annual operations do you consider to be part of, or support, the marine science and technology industry?



4. Approximately how many full- and part-time employees, excluding contractors, are currently employed at all your locations in Southeastern New England? ____

5. What percentage of these employees are full-time, with full-time being defined as 30 or more hours per week?



6. Which of the following activities take place at this business location? (please select all that apply)

- Manufacturing
- Research and Development
- Services for other businesses (e.g. engineering, design, consulting, and other technical services)
- Sales, Marketing, Administration, etc.
- Other (please describe) _____

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7. Who are the primary customers for your products or services? (please select all that apply)
- U.S. Department of Defense
 - Other U.S. government agencies
 - Foreign defense agencies
 - Commercial businesses
 - Academic and research institutions
 - Retail customers
 - Other (please specify) _____
8. Which of the following best describes the status of your business?
- Development/Seed: Business idea is still being developed
 - Startup: Your business is a legal entity and is securing investment capital
 - Growth Stage: Your business is consistently generating revenue, adding new customers, and there is room to grow in your primary market
 - Expansion Stage: Your business is thriving, but in order to increase revenue you are looking to expand into new markets
 - Mature: Your business is established in the market and could still be growing, but not at the rate previously experienced
 - Some other term to describe your business (please specify)

Research, Development, and Innovation

R&D Activities

9. How does your business meet its R&D needs? (please select all that apply)
- We do not have any R&D needs
 - We develop new or improved products or services internally
 - We develop new or improved products or services for hire through contract or grant funded research
 - Our R&D needs are met externally through outsourcing or collaborative agreements
 - Other (please specify) _____
10. [If choices 2-4 in Q9] What are your sources for funding research and development? (please select all that apply)
- Internal funding (e.g., reinvesting profits)
 - Small Business Innovation Research or Small Business Technology Transfer Research (SBIR/STTR)
 - Defense industry contract
 - Other state or federal government funding
 - Industry sponsored
 - Venture capital or other private financing
 - Other (please specify) _____
11. [If Yes to R&D in Q6] Over the past five years, have the R&D activities at your business location increased, decreased, or stayed the same?
- Increased
 - Decreased
 - Stayed the same
 - Not sure
12. Over the past five years, has your business ... (please select all that apply)

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- Applied for intellectual property (IP) protection (patent, copyright, etc.)
- Transferred IP to other businesses, organizations, or persons through licensing agreements
- Received IP from other businesses, organizations, or persons through licensing agreements
- Transferred IP to a spin-off of your business
- None of the above
- Not sure

Role of Academic and Research Institutions

13. How would you describe your business's relationship with universities, colleges, and research institutions in the Southeastern New England region? (please select all that apply)

- I don't interact with universities, colleges, or research institutions in the region
- I don't interact with universities, colleges, or research institutions in the region, but would like to
- Their graduates are a source of skilled labor for my business
- We collaborate with researchers at these institutions to help solve problems
- We have a formalized partnership with a university, college, or research institution, such as a memorandum of understanding, academic partnership agreement, or other formal affiliation
- They provide access to research equipment and infrastructure
- We license technology from one or more of these institutions
- They act as convener of regional businesses and/or organizations (e.g. conferences and symposiums)
- My business is a university, college, or research institution spin-off
- Other (please describe) _____

13a. [If Yes to choice #4, #5, #6, or #7 above] With which institutions have you collaborated or are you currently collaborating? (Note that this list is not comprehensive and includes only the major institutions and organizations. We have included an "other category" at the end of the list).

- Brown University
- CINAR (Cooperative Institute for the North Atlantic Region)
- Marine Biological Laboratory
- Massachusetts Division of Marine Fisheries
- Massachusetts Maritime Academy
- NOAA Narragansett Laboratory
- North East Fisheries Science Center
- NUWC (Naval Undersea Warfare Center)
- Rhode Island DEM Marine Fisheries Section
- Roger Williams Aquatic Diagnostic Laboratory
- SMAST UMass Dartmouth (School for Marine Science and Technology)
- U.S. Naval War College
- UMass Dartmouth
- University of Rhode Island
- URI Coastal Resources Center
- Woods Hole Oceanographic Institution
- Other (please specify)

Work Force

14. In the next 3 years, do you expect the number of people working for your business to increase, decrease, or stay the same?

- Increase

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- Decrease
- Stay the same
- Not sure

15. Please rate the following items in terms of the importance of the qualifications your business values when considering new employees.

	Not Important	Moderately Important	Very Important
A college degree in a math, computer, or data science discipline	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A college degree in a natural science discipline	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A college degree in an engineering discipline	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A degree or certificate in advanced manufacturing or precision machining	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training or certification on a specific technology or machine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Professional license in a trade, e.g., electrician, plumber, engine repair, welding, captain's license	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Experience in the marine trades, but not necessarily a professional license (e.g. boat manufacturing & repair, engine repair, rigging, welding, fabrication, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quality control experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Entrepreneurial experience or expertise	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lab or field experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. Of the degrees that you selected as moderately or very important in the previous question, do you require 2-year degrees, 4-year degrees, or graduate/advanced? You can select more than one choice for each discipline.

- 2-Year
- 4-year
- Advanced/Graduate

17. For which positions do you have difficulty hiring, if any? Make box larger.

18. Which of the following workforce-related issues present constraints for your business' growth?

- There are not any workforce-related issues that would constrain business growth
- Difficulty in finding employees with the requisite **educational credentials**
- Difficulty in finding employees with the requisite **technical skills**
- Potential employees are not willing to move to the area from their current area
- Other

19. Are there any specific technical skills that are difficult to find in the workforce?

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Business Environment

Regional Strengths and Weaknesses

20. Please indicate how critical each of the following policy actions is to your business on a scale of 1 to 5, with 1 being not critical and 5 being critical. [RANDOMIZE]

	1 - Not Critical	2	3	4	5 - Critical	Not Sure
Reducing business costs related to taxes, such as corporate taxes, unemployment insurance, and workers compensation	0	0	0	0	0	0
Improving information infrastructure such as broadband, wireless access, and connectivity	0	0	0	0	0	0
Streamlining the regulatory climate in terms of fees, permitting, and zoning	0	0	0	0	0	0
Advocating for your industry in Washington, DC	0	0	0	0	0	0
Advocating for your industry at the state level	0	0	0	0	0	0
Improving physical infrastructure such as roads, airports, and commuter rail	0	0	0	0	0	0
Improving the infrastructure of the region's ports and waterways	0	0	0	0	0	0
Offering specialized education and training for jobs in your industry	0	0	0	0	0	0
Preserving and protecting our ocean resources	0	0	0	0	0	0
Developing export opportunities	0	0	0	0	0	0
Offering tax incentives designed to attract new marine science & technology businesses	0	0	0	0	0	0
Offering tax incentives designed to expand existing businesses	0	0	0	0	0	0
Improving the pipeline of science, technology, engineering, and math workers	0	0	0	0	0	0
Developing more effective public/private/government collaborations	0	0	0	0	0	0
Creating more workforce housing	0	0	0	0	0	0

Entrepreneurial and Innovation Ecosystem

21. How would you describe efforts in the region to support entrepreneurship?

- Not aware of any efforts
- Current efforts are insufficient
- Current efforts are sufficient
- Current efforts are sufficient, but could be improved
- Not applicable to my business

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22. Please rate the extent to which you agree with the following statement: "There is a high degree of collaboration among marine science and technology firms in the region."
- Strongly agree
 - Agree
 - Disagree
 - Strongly disagree
 - Not sure
23. Thinking of the marine science and technology sector as a whole and not just your business, which of the following would make it possible for more marine science and technology firms to thrive in the region? (please check all that apply)
- Business incubators or accelerators
 - Business mentoring
 - Start-up capital
 - Capital for growing or mature businesses
 - Prototype labs
 - Testing and proof-of-concept facilities [please specify]
 - Shared equipment or infrastructure [please specify]
 - Legal services such as for intellectual property protection and licensing
 - A new industry association to advocate for the region's blue-tech sector
 - A cohesive marketing and branding strategy for the regional blue-tech sector
 - Increased engagement with traditional maritime economy businesses, such as fishing and boat building
 - Increased engagement with universities and research institutes
 - Improved access to the ocean
 - Research partnerships between academic & research institutions and businesses
 - Stronger regional supply chain relationships
 - Other (please specify) _____

Supply Chain and Inter-firm Linkages

24. Who are some of your major suppliers located in the region? Larger box
25. Please provide some examples of items that you cannot purchase locally, but would purchase if they were available?

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Exports

26. In which of the following markets does your business sell its products or services? (please check all that apply)

- Southeastern New England (Southeastern Massachusetts, Cape Cod and the Islands, and Rhode Island)
- Nationally
- Internationally

[If Internationally] To what region(s) of the world do you export your products?

- North America
- Northern Asia & Pacific Rim (China/Japan/Taiwan)
- South America
- Western Europe
- Southern Asia (India/Indonesia/Malaysia)
- Middle East
- Central America
- South Africa
- Eastern Europe
- Other

27. [If No to Internationally] Would you like to sell your goods or services outside the United States?

- Yes
- No
- Not sure

28. [If Internationally or Would like to sell internationally] What do you consider the main barriers and challenges to selling your goods and/or services to foreign customers? (please check all that apply)

- I don't have goods and/or services that are exportable
- Don't know much about it and not sure where to start
- I'd worry too much about getting paid
- Regulatory barriers/complexities
- Unaware how to utilize free/foreign trade agreements
- Can't get financing to offer foreign customers
- It would take too much time away from my regular, domestic sales
- Insufficient protection of intellectual property rights (patents, copyrights, trademarks)
- Too costly
- Obtaining visas and work permits
- Restrictions on forming partnerships or joint ventures, or the requirement to have partnerships with local businesses
- Unfair trade practices
- Other (please specify)

29. Do you have any additional comments?

APPENDIX B: SBIR & STTR METHODOLOGY

Metadata on all SBIR/STTR awards by state were collected from the U.S. Small Business Administration for the time period 2011 through 2015. For Massachusetts, awards involving maritime-related technologies were identified by hand. In order to facilitate identification, all SBIR/STTR awards for Massachusetts were divided into two groups: (1) those awarded by the U.S. Navy and (2) all other. All Navy awards were included, with the exception of those that were clearly aerospace-related. For all other awards, PPC kept only those that are clearly maritime-related. The first group is likely to slightly overstate the true number of maritime awards, while the second group is likely to slightly understate the true number of maritime awards. Thus, the number and dollar amounts of maritime-related SBIR/STTR awards should be treated as estimates.

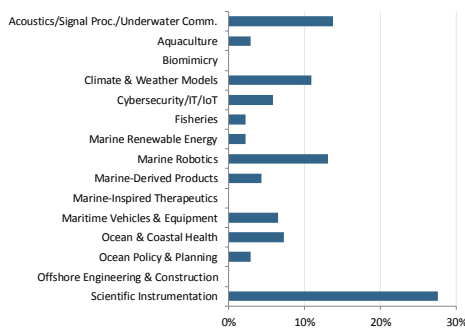
APPENDIX C: R&D AT ACADEMIC RESEARCH INSTITUTIONS

Applied Research Interests

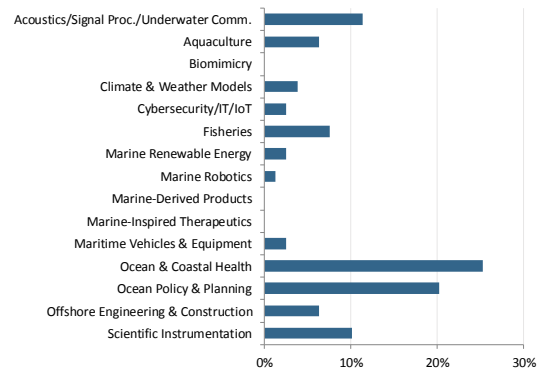
To characterize the research activity at area institutions, we categorized all full-time, permanent position faculty and researchers at area research institutions based on their self-reported basic and applied research interests and/or activities. This analysis was based on staff profiles, curriculum vitae, and media appearances. The following provides an overview of the applied research interests of MST faculty and staff engineers by research institution.

Distribution of applied research interests by research institution, 2019

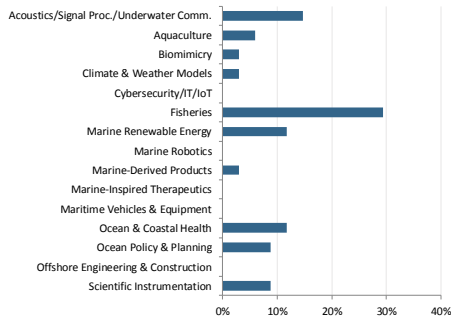
Woods Hole Oceanographic Institution



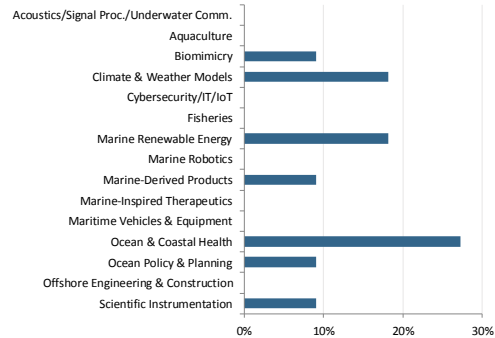
University of Rhode Island



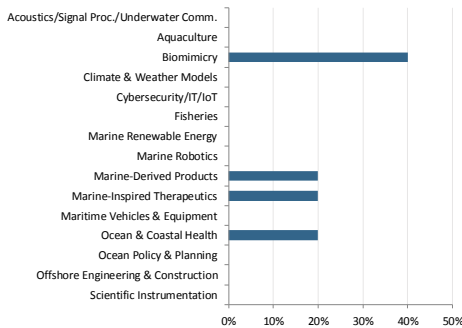
University of Massachusetts Dartmouth



Brown University



Marine Biological Laboratory



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Journal Articles

The Web of Science classifies all journal articles published in peer-reviewed journals into the journal's main topic area. The following provides the top fields in which faculty publish by area research institution.

Journal articles by institution and field, top 10 fields, 2014–2019



APPENDIX D: MST SURVEY FREQUENCY TABLES

Q1 - WHICH OF THE FOLLOWING POSITIONS BEST DESCRIBES YOUR ROLE IN YOUR FIRM AT THIS BUSINESS LOCATION?

Answer	%	Count
Owner	37.1%	13
President/CEO	22.9%	8
Vice President	2.9%	1
Department Head or Supervisor	5.7%	2
HR Director	0.0%	0
Mid-level Manager	8.6%	3
Other	22.9%	8
Total	100%	32

Other (open response):

Executive Assistant

Lead

Sales

Outside Director

Q2 - HOW MANY YEARS HAS YOUR BUSINESS BEEN OPEN?

Answer	%	Count
Less than 1 year	0.0%	0
Between 1 and 5 years	12.5%	4
Between 6 and 10 years	12.5%	4
More than 10 years	75.0%	24
Not sure	0.0%	0
Total	100.0%	32

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Q3 - WHAT PERCENT OF YOUR BUSINESS’S ANNUAL OPERATIONS DO YOU CONSIDER TO BE PART OF, OR SUPPORT, THE MARINE SCIENCE AND TECHNOLOGY INDUSTRY?

Answer	%	Count
10	3.1%	1
30	6.3%	2
34	3.1%	1
40	3.1%	1
46	3.1%	1
50	3.1%	1
51	6.3%	2
66	3.1%	1
75	6.3%	2
90	3.1%	1
95	3.1%	1
99	3.1%	1
100	53.1%	17
Total	100.0%	32

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Q4 - APPROXIMATELY HOW MANY FULL- AND PART-TIME EMPLOYEES, EXCLUDING CONTRACTORS, ARE CURRENTLY EMPLOYED AT ALL YOUR LOCATIONS IN SOUTHEASTERN NEW ENGLAND?

Answer	%	Count
0	3.3%	1
1	6.7%	2
2	13.3%	4
3	3.3%	1
5	10.0%	3
6	6.7%	2
9	3.3%	1
10	10.0%	3
13	3.3%	1
15	10.0%	3
16	3.3%	1
20	3.3%	1
25	3.3%	1
47	3.3%	1
100	3.3%	1
150	3.3%	1
400	3.3%	1
420	3.3%	1
800	3.3%	1
Total	100.0%	30

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Q5 - WHAT PERCENTAGE OF THESE EMPLOYEES ARE FULL-TIME, WITH FULL-TIME BEING DEFINED AS 30 OR MORE HOURS PER WEEK?

Answer	%	Count
2	3.45%	1
5	3.45%	1
10	3.45%	1
30	3.45%	1
33	3.45%	1
38	3.45%	1
40	3.45%	1
41	3.45%	1
47	3.45%	1
50	3.45%	1
80	6.90%	2
81	3.45%	1
85	3.45%	1
88	3.45%	1
90	3.45%	1
92	3.45%	1
95	3.45%	1
97	3.45%	1
98	3.45%	1
100	31.03%	9
Total	100.0%	29

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Q6 - WHICH OF THE FOLLOWING ACTIVITIES TAKE PLACE AT THIS BUSINESS LOCATION? (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
Manufacturing	48.4%	15
Research and Development	64.5%	20
Services for other businesses (e.g. engineering, design, consulting, and other technical services)	64.5%	20
Sales, Marketing, Administration, etc.	64.5%	20
Other	3.2%	1
Total	N/A	76

Other (open response):

Scientific data collection and compliance monitoring for government and the marine construction industry

Q7 - WHO ARE THE PRIMARY CUSTOMERS FOR YOUR PRODUCTS OR SERVICES? (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
U.S. Department of Defense	58.1%	18
Retail customers	32.3%	10
Other	6.5%	2
Other U.S. government agencies	58.1%	18
Foreign defense agencies	22.6%	7
Commercial businesses	64.5%	20
Academic and research institutions	64.5%	20
Total	N/A	95

Other (open response):

Industrial

Utilities

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Q8 - WHICH OF THE FOLLOWING BEST DESCRIBES THE STATUS OF YOUR BUSINESS?

Answer	%	Count
Development/Seed: Business idea is still being developed.	0.0%	0
Startup: Your business is a legal entity and is securing investment capital.	6.5%	2
Growth Stage: Your business is consistently generating revenue, adding new customers, and there is room to grow in your primary market.	29.0%	9
Expansion Stage: Your business is thriving, but in order to increase revenue you are looking to expand into new markets.	19.4%	6
Mature: Your business is established in the market and could still be growing, but not at the rate previously experienced.	32.3%	10
Some other term to describe your business	12.9%	4
Total	100.0%	31

Other (open response):

Just acquired by large DOD prime

Stable consultancy

Still recovering from 2008

Q9 - HOW DOES YOUR BUSINESS MEET ITS R&D NEEDS? (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
We do not have any R&D needs	12.5%	4
We develop new or improved products or services internally	71.9%	23
We develop new or improved products or services for hire through contract or grant funded research	43.8%	14
Our R&D needs are met externally through outsourcing or collaborative agreements	21.9%	7
Other	3.1%	1
Total	N/A	49

Other (open response):

Student internships

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Q10 - WHAT ARE YOUR SOURCES FOR FUNDING RESEARCH AND DEVELOPMENT? (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
Internal funding (e.g., reinvesting profits)	73.1%	19
Small Business Innovation Research or Small Business Technology Transfer Research (SBIR/STTR)	34.6%	9
Defense industry contract	30.8%	8
Other state or federal government funding	30.8%	8
Industry sponsored	19.2%	5
Venture capital or other private financing	7.7%	2
Other (please specify)	11.5%	3
Total	N/A	54

Other (open response):

Loans

Self

Q11 - OVER THE PAST FIVE YEARS, HAVE THE R&D ACTIVITIES AT YOUR BUSINESS LOCATION INCREASED, DECREASED, OR STAYED THE SAME?

Answer	%	Count
Increased	68.4%	13
Decreased	10.5%	2
Stayed the same	21.1%	4
Not sure	0.0%	0
Total	100.0%	19

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Q12 - OVER THE PAST FIVE YEARS, HAS YOUR BUSINESS ... (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
Applied for intellectual property (IP) protection (patent, copyright, etc.)	46.4%	13
Transferred IP to other businesses, organizations, or persons through licensing agreements	14.3%	4
Received IP from other businesses, organizations, or persons through licensing agreements	10.7%	3
Transferred IP to a spin-off of your business	10.7%	3
None of the above	35.7%	10
Not sure	0.0%	0
Total	N/A	33

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Q13 - HOW WOULD YOU DESCRIBE YOUR BUSINESS’S RELATIONSHIP WITH UNIVERSITIES, COLLEGES, AND RESEARCH INSTITUTIONS IN THE SOUTHEASTERN NEW ENGLAND REGION? (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
I don’t interact with universities, colleges, or research institutions in the region	6.7%	2
I don’t interact with universities, colleges or research institutions in the region, but would like to	13.3%	4
They are a source of skilled labor for my business	40.0%	12
We collaborate with researchers at these institutions to help solve problems	43.3%	13
We have a formalized partnership with a university, college, or research institution, such as a memorandum of understanding, academic partnership agreement, or other formal affiliation	30.0%	9
They provide access to research equipment and infrastructure	20.0%	6
We license technology from one or more of these institutions	10.0%	3
They act as a convener of regional businesses and/or organizations (e.g. conferences and symposiums)	23.3%	7
My business is a university, college, or research institution spin-off	6.7%	2
Other (please describe)	30.0%	9
Total	N/A	67

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Q14 - WITH WHICH INSTITUTIONS HAVE YOU COLLABORATED OR ARE YOU CURRENTLY COLLABORATING? (NOTE THAT THIS LIST IS NOT COMPREHENSIVE AND INCLUDES ONLY THE MAJOR INSTITUTIONS AND ORGANIZATIONS. WE HAVE INCLUDED AN “OTHER CATEGORY” AT THE END OF THE LIST)

Answer	%	Count
Brown University	10.5%	2
CINAR (Cooperative Institute for the North Atlantic Region)	5.3%	1
Marine Biological Laboratory	15.8%	3
Massachusetts Division of Marine Fisheries	15.8%	3
Massachusetts Maritime Academy	15.8%	3
NOAA Narragansett Laboratory	0.0%	0
North East Fisheries Science Center	15.8%	3
NUWC (Naval Undersea Warfare Center)	31.6%	6
Rhode Island DEM Marine Fisheries Section	0.0%	0
Roger Williams Aquatic Diagnostic Laboratory	0.0%	0
SMAST UMass Dartmouth (School for Marine Science and Technology)	31.6%	6
U.S. Naval War College	5.3%	1
UMass Dartmouth	15.8%	3
University of Rhode Island	31.6%	6
URI Coastal Resources Center	0.0%	0
Woods Hole Oceanographic Institution	52.6%	10
Other	36.8%	7
Total	N/A	54

Other (open response):

New England Institute of Technology and possibly Woods Hole

NOAA Endangered Species

Several France academic institutions and Malta institutions

UCONN

UCONN and UNH

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Q15 - IN THE NEXT 3 YEARS, DO YOU EXPECT THE NUMBER OF PEOPLE WORKING FOR YOUR BUSINESS TO INCREASE, DECREASE, OR STAY THE SAME?

Answer	%	Count
Increase	64.3%	18
Decrease	3.6%	1
Stay the same	25.0%	7
Not sure	7.1%	2
Total	100.0%	28

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Q16 - PLEASE RATE THE FOLLOWING ITEMS IN TERMS OF THE IMPORTANCE OF THE QUALIFICATIONS YOUR BUSINESS VALUES WHEN CONSIDERING NEW EMPLOYEES.

	Not Important		Moderately Important		Very Important		Total	
	%	#	%	#	%	#	%	#
A college degree in a math, computer, or data science discipline	23.1%	6	46.2%	12	30.8%	8	100.0%	26
A college degree in a natural science discipline	37.5%	9	41.7%	10	20.8%	5	100.0%	24
A college degree in an engineering discipline	7.4%	2	29.6%	8	63.0%	17	100.0%	27
A degree or certificate in advanced manufacturing or precision machining	29.2%	7	50.0%	12	20.8%	5	100.0%	24
Training or certification on a specific technology or machine	44.0%	11	48.0%	12	8.0%	2	100.0%	25
Professional license in a trade, e.g., electrician, plumber, engine repair, welding, captain's license	75.0%	18	12.5%	3	12.5%	3	100.0%	24
Experience in the marine trades, but not necessarily a professional license (e.g. boat manufacturing & repair, engine repair, rigging, welding, fabrication, etc.)	34.6%	9	53.9%	14	11.5%	3	100.0%	26
Quality control experience	8.3%	2	83.3%	20	8.3%	2	100.0%	24
Entrepreneurial experience or expertise	40.0%	10	52.0%	13	8.0%	2	100.0%	25
Lab or field experience	20.8%	5	41.7%	10	37.5%	9	100.0%	24
Other	25.0%	2	25.0%	2	50.0%	4	100.0%	8

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Q17 - FOR WHICH POSITIONS DO YOU HAVE DIFFICULTY HIRING, IF ANY?

Open Responses:

Laborers

Software Development

Software engineers with experience

Software engineers, especially with embedded systems and MS experience

Q18 - WHICH OF THE FOLLOWING WORKFORCE-RELATED ISSUES WOULD PRESENT CONSTRAINTS FOR YOUR BUSINESS' GROWTH? (PLEASE SELECT ALL THAT APPLY)

Answer	%	Count
There are not any workforce-related issues that would constrain business growth	24.0%	6
Difficulty in finding employees with the requisite educational credentials	28.0%	7
Difficulty in finding employees with the requisite technical skills	48.0%	12
Potential employees are not willing to move to the area from their current area	20.0%	5
Other	12.0%	3
Total	N/A	33

Other (open response):

Heroin addiction – overdoses

Health care and other fringe benefit costs

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Q19 - ARE THERE ANY SPECIFIC TECHNICAL SKILLS THAT ARE DIFFICULT TO FIND IN THE WORKFORCE?

Responses:

Experienced software engineers. Most kids nowadays go into the gaming fields for software development so we have to rely on the seasoned people to come aboard which is getting harder to find.

Design and manufacturing of marine products

Electrical engineers

Entry-level machinists

Ideational electrical, control, and ocean engineers, specifically dealing with novel electrical generators, variable buoyancy, and their control

N/A

RF experience

Small business relies on a team approach to problem solving. Team members must be able and willing to take on challenges for which they have little to no training. Effective and efficient employees are self-motivated problem solvers who demonstrate dedication to the business and the company mission. Teach a multidisciplinary approach to problem solving.

Software development

Software engineers

Software in general, robotics and machine learning. These skills are more available in Boston and closer to suburbs.

Technical sales

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Q20 - PLEASE INDICATE HOW CRITICAL EACH OF THE FOLLOWING POLICY ACTIONS IS TO YOUR BUSINESS ON A SCALE OF 1 TO 5, WITH 1 BEING NOT CRITICAL AND 5 BEING CRITICAL.

	1-Not Critical		2		3		4		5-Critical		Not Sure		Total	
	%	#	%	#	%	#	%	#	%	#	%	#	%	#
Reducing business costs related to taxes, such as corporate taxes, unemployment insurance, and workers compensation	8.0%	2	8.0%	2	12.0%	3	20.0%	5	40.0%	10	12.0%	3	100.0%	25
Improving information infrastructure such as broadband, wireless access, and connectivity	16.0%	4	4.0%	1	36.0%	9	8.0%	2	24.0%	6	12.0%	3	100.0%	25
Streamlining the regulatory climate in terms of fees, permitting, and zoning	23.1%	6	11.5%	3	7.7%	2	15.4%	4	26.9%	7	15.4%	4	100.0%	26
Advocating for your industry in Washington, DC	8.0%	2	8.0%	2	36.0%	9	12.0%	3	24.0%	6	12.0%	3	100.0%	25
Advocating for your industry at the state level	4.0%	1	8.0%	2	36.0%	9	16.0%	4	16.0%	4	20.0%	5	100.0%	25
Improving physical infrastructure such as roads, airports, and commuter rail	24.0%	6	20.0%	5	20.0%	5	16.0%	4	4.0%	1	16.0%	4	100.0%	25
Improving the infrastructure of the region's ports and waterways	32.0%	8	8.0%	2	20.0%	5	12.0%	3	12.0%	3	16.0%	4	100.0%	25
Preserving and protecting our ocean resources	12.0%	3	4.0%	1	4.0%	1	12.0%	3	60.0%	15	8.0%	2	100.0%	25
Offering specialized education and training for jobs in your industry	8.0%	2	16.0%	4	28.0%	7	20.0%	5	24.0%	6	4.0%	1	100.0%	25
Developing export opportunities	16.0%	4	12.0%	3	20.0%	5	28.0%	7	16.0%	4	8.0%	2	100.0%	25
Offering tax incentives designed to attract new marine science & technology businesses	12.5%	3	12.5%	3	25.0%	6	12.5%	3	25.0%	6	12.5%	3	100.0%	24
Offering tax incentives designed to expand existing businesses	20.0%	5	4.0%	1	20.0%	5	16.0%	4	32.0%	8	8.0%	2	100.0%	25
Improving the pipeline of science, technology, engineering, and math workers	0.0%	0	0.0%	0	12.0%	3	48.0%	12	28.0%	7	12.0%	3	100.0%	25
Developing more effective public/private/government collaborations	0.0%	0	0.0%	0	28.0%	7	32.0%	8	28.0%	7	12.0%	3	100.0%	25
Creating more workforce housing	19.2%	5	19.2%	5	19.2%	5	3.9%	1	26.9%	7	11.5%	3	100.0%	26

Q21 - HOW WOULD YOU DESCRIBE EFFORTS IN THE REGION TO SUPPORT ENTREPRENEURSHIP?

Answer	%	Count
Not aware of any efforts	14.8%	4
Current efforts are insufficient	22.2%	6
Current efforts are sufficient	11.1%	3
Current efforts are sufficient, but could be improved	33.3%	9
Not applicable to my business	18.5%	5
Total	100.0%	27

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Q22 - PLEASE RATE THE EXTENT TO WHICH YOU AGREE WITH THE FOLLOWING STATEMENT: "THERE IS A HIGH DEGREE OF COLLABORATION AMONG MARINE TECH FIRMS IN THE REGION."

Answer	%	Count
Strongly agree	15.4%	4
Agree	38.5%	10
Disagree	34.6%	9
Strongly disagree	3.9%	1
Not sure	7.7%	2
Total	100.0%	26

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Q23 - THINKING OF THE REGION'S MARINE SCIENCE AND TECHNOLOGY SECTOR AS A WHOLE AND NOT JUST YOUR BUSINESS, WHICH OF THE FOLLOWING WOULD MAKE IT POSSIBLE FOR EXISTING AND NEW MARINE SCIENCE AND TECHNOLOGY FIRMS TO THRIVE IN THE REGION? (PLEASE CHECK ALL THAT APPLY)

Answer	%	Count
Business incubators or accelerators	36.0%	9
Business mentoring	44.0%	11
Start-up capital	40.0%	10
Capital for growing or mature businesses	32.0%	8
Prototype labs	36.0%	9
Testing and proof-of-concept facilities [please specify]	24.0%	6
Shared equipment or infrastructure [please specify]	32.0%	8
Legal services such as for intellectual property protection and licensing	40.0%	10
A new industry association to advocate for the region's blue-tech sector	28.0%	7
A cohesive marketing and branding strategy for the regional blue-tech sector	32.0%	8
Increased engagement with traditional maritime economy businesses, such as fishing and boat building	32.0%	8
Increased engagement of universities and research institutes	60.0%	15
Improved access to the ocean	28.0%	7
Research partnerships between academic & research institutions and businesses	72.0%	18
Stronger regional supply chain relationships	24.0%	6
Other [please specify]	0.0%	0
Total	N/A	140

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Q24 - WHO ARE SOME OF YOUR MAJOR SUPPLIERS LOCATED IN THE REGION? (PLEASE SEPARATE EACH ENTRY WITH A COMMA)

Open Responses:

Case, Tempo, VR Industries

Celerity EDS, del Research LLC, Cotter Machine Co Inc, Dimark Precision Machining, RAM Machine, E-Paint

Edgetech, IxBlue, Teledyne, UMass CIE Fall River, YSI, Cotter Machine,

Local machinists, sensor manufacturers

Luzo's, Hercules, West Marine

Majority of our components come from local fabricators: carbon fiber, machining, molding, etc.

McMaster-Carr, Digi-Key, ImpulseBrantner, Subconn

Not sure but we buy nationwide

Teledyne Benthos, Mooring Systems, Inc., Oceanographic and Geophysical Instruments, Inc., McLane Research Labs

Various, from machinists to products to manufacturing

Q25 - PLEASE PROVIDE SOME EXAMPLES OF ITEMS THAT YOU CANNOT PURCHASE LOCALLY, BUT WOULD PURCHASE IF THEY WERE AVAILABLE? (PLEASE SEPARATE EACH ENTRY WITH A COMMA)

Open Responses:

Custom-made alkaline and lithium battery packs for geophysical instruments such as ADCPs

Manufacturing of our stretch hoses

Optics

Overrunning clutch, permanent magnet, rack (gear), bladder

SE Massachusetts has a great base of manufacturers for mechanical parts, fabrication services, sensors, etc. We buy some items from out of the area, but these are low value specialized items that we could probably get made in MA, but aren't worth the effort or risk to change sources.

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Q26 - IN WHICH OF THE FOLLOWING MARKETS DOES YOUR BUSINESS SELL ITS PRODUCTS OR SERVICES? (PLEASE CHECK ALL THAT APPLY)

Answer	%	Count
Southeastern New England (Southeastern Massachusetts, Cape Cod and the Islands, and Rhode Island)	70.4%	19
Nationally	81.5%	22
Internationally	70.4%	19
Total	N/A	60

Q27 - IN WHICH OF THE FOLLOWING MARKETS DOES YOUR BUSINESS SELL ITS PRODUCTS OR SERVICES? (PLEASE CHECK ALL THAT APPLY)

Answer	%	Count
North America	77.8%	14
Northern Asia & Pacific Rim (China/Japan/Taiwan)	50.0%	9
South America	38.9%	7
Western Europe	72.2%	13
Southern Asia (India/Indonesia/Malaysia)	50.0%	9
Middle East	27.8%	5
Central America	27.8%	5
South Africa	22.2%	4
Eastern Europe	38.9%	7
Other	16.7%	3
Total	N/A	76

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Q28 - WOULD YOU LIKE TO SELL YOUR GOODS OR SERVICES OUTSIDE THE UNITED STATES?

Answer	%	Count
Yes	55.6%	5
No	0.0%	0
Not sure	44.4%	4
Total	100.0%	9

Q29 - WOULD YOU LIKE TO SELL YOUR GOODS OR SERVICES OUTSIDE THE UNITED STATES?

Answer	%	Count
I don't have goods and/or services that are exportable	0.0%	0
Don't know much about it and not sure where to start	40.0%	2
I'd worry too much about getting paid	20.0%	1
Regulatory barriers/complexities	60.0%	3
Unaware how to utilize free/foreign trade agreements	60.0%	3
Can't get financing to offer foreign customers	20.0%	1
It would take too much time away from my regular, domestic sales	20.0%	1
Insufficient protection of intellectual property rights (patents, copyrights, trademarks)	40.0%	2
Too costly	0.0%	0
Obtaining visas and work permits	0.0%	0
Restrictions on forming partnerships or joint ventures, or the requirement to have partnerships with local businesses	40.0%	2
Unfair trade practices	0.0%	0
Other (please specify)	0.0%	0
Total	N/A	15

Q30 - DO YOU HAVE ANY ADDITIONAL COMMENTS? (PLEASE SEPARATE EACH ENTRY WITH A COMMA)

Open Responses:

The RI State Gov't Industry outreach for economic development is light years ahead of Massachusetts. And the support from the RI Congressional Delegation in making useful connections to US Gov't procurement agencies (DOD, USGS, NOAA, ACoE, etc) are double light years ahead of the MA delegation. The tax situation in MA has gotten consistently worse for the 20 years I have been following it (LT Cap Gains rates, ect). The misc. tax burdens disadvantage MA against other regions of the country, and the trend continues (Family Leave tax at .063% of salary starts now). The various initiatives (MEP, SouthCoast Development, UMass CIE, etc) are well meaning and occasionally valuable, but to most small business owners/managers, these State initiatives are an overall net-negative.

Need help in classifying product to make sure ITAR and EAR compliant.



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