FOURTH ECONOMY
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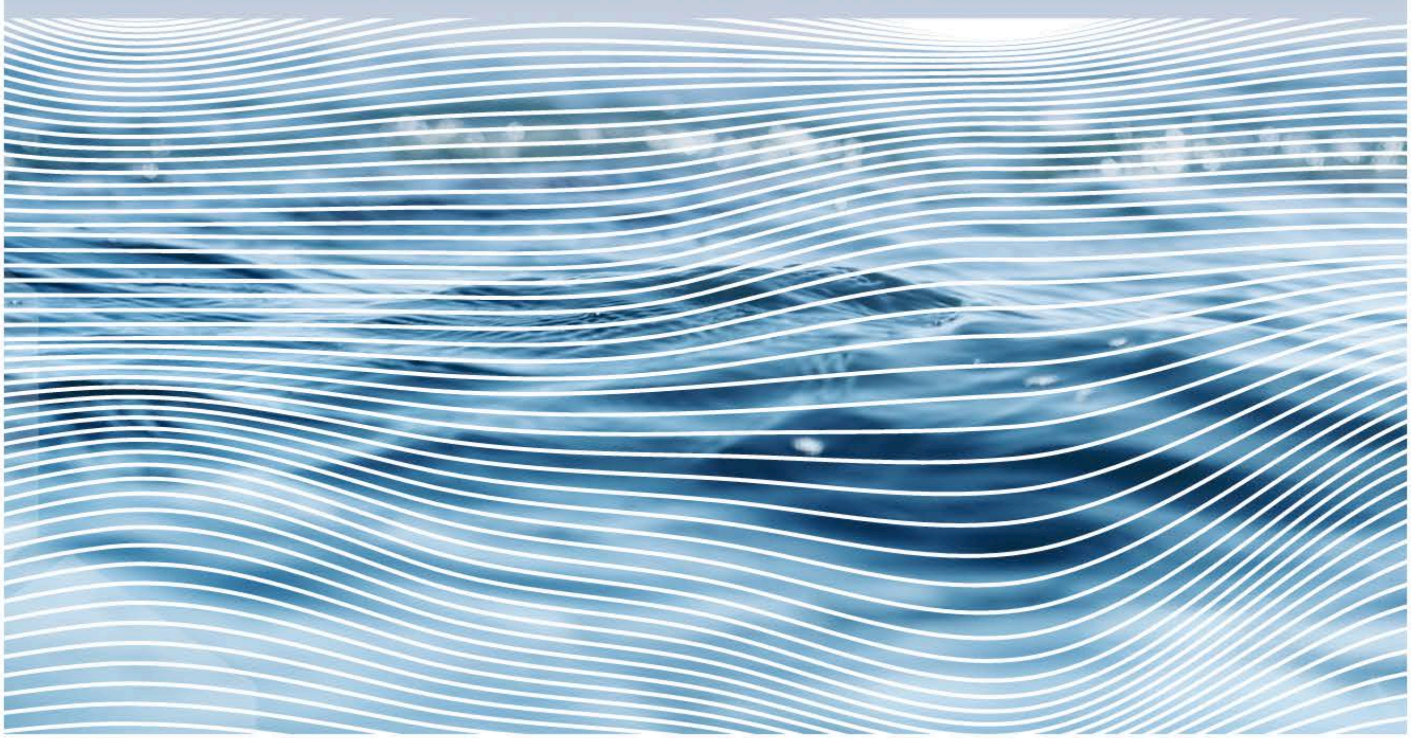
Ocean Tech Market Analysis

Commissioned by the Rhode Island Commerce Corporation and Prepared for the Ocean Tech Hub of Southeastern New England

July 2024



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Project Initiation

The **Ocean Tech Hub of Southeastern New England (OTH)** was announced in October 2023 as one of thirty-one Tech Hubs designated by the **US Economic Development Administration (EDA)**. This designation recognizes the long history and deep assets in Rhode Island and the Southeastern Massachusetts region for developing undersea technologies that can withstand the ocean environment.

The OTH is a consortium-based initiative, led by the Rhode Island Commerce Corporation ("Corporation"), designed to accelerate the commercialization of ocean technology in Rhode Island and Southeastern Massachusetts. The Corporation is the lead convener of the OTH. OTH is focused on advancing economic prosperity, national security, and environmental sustainability through sparking the ocean technology ecosystem. OTH will harness the region's assets and burgeoning technology and create global-market-rich opportunities by accelerating commercialization of tech-ready innovation; scaling workforce programs to create new good-paying jobs; and ensuring the removal of barriers to technology development, including those related to policy.

In order to position OTH in the most advantageous way to capture this growing market, the Corporation sought a more targeted, deeper, and comprehensive analysis of market demand and global use cases around the confluence of ocean robotics, marine sensors, advanced materials, artificial intelligence, machine learning, and data mapping, as well as an assessment of how they relate to the region's capabilities and assets. This analysis will help OTH develop a targeted growth strategy.

Economic Development Administration

This analysis was funded, in part, through the EDA Statewide Planning Grant and EDA Tech Hubs Strategy Development Grant. The EDA did not, however, contribute to or review the content of this publication prior to release.

Advisory Committee

To guide the development of this market analysis, an advisory committee was formed, and we wish to thank the members for their time and the invaluable expertise they provided:

- Lisa Carnevale, Vice President of Innovation Initiatives, Rhode Island Commerce Corporation
- Daniela Fairchild, Chief Strategy Officer, Rhode Island Commerce Corporation
- Darya Blout, Founder, Deep Blue Composites
- Drew Carey, Vice President of Americas, Venterra Group (Retired)
- Jennifer Downing, Executive Director, New Bedford Ocean Cluster
- Ian Estaphan Owen, CEO and Cofounder, Jaia Robotics
- Mark Parsons, Founder and Executive Director, New Bedford Research and Robotics
- Pete Rumsey, Chief Business Development Officer, URI Research Foundation / URI Ventures

Executive Summary

Introduction

The **Ocean Tech Hub** "is a cutting-edge regional innovation center dedicated to marine science and technology. Its mission is to advance economic prosperity and environmental sustainability by fostering the ocean technology innovation ecosystem."[1] The blue economy is demonstrating significant growth, largely driven by the use of technology and the impact of technology on the expanded market.

This **Ocean Tech Hub Market Analysis** report provides a point-in-time analysis, as of July 2024, of the Ocean Tech sector, sector components, investment trends, research drivers, and growth opportunities. The report is a resource for the Ocean Tech Hub consortium and the startup and established businesses that it seeks to serve. This analysis will serve to identify near-term opportunities and inspire additional follow-on research to generate additional deeper analytic dives as market conditions change.

Ocean Technology is a subset of a larger regional and growing global focus on the blue economy, which includes a broader array of industry sectors that relate to water assets. For this market analysis, the research is focused on ocean technology that includes **ocean robotics, marine sensors, advanced materials, artificial intelligence, machine learning, and data mapping.**

Key Findings

1. The **Ocean Tech Hub** has the **opportunity to support the development of ocean technology and growth** of companies, researchers, and organizations that utilize it through networking, waterfront coordination, talent development and recruitment, and shared R&D platforms. Read more: Southeastern New England Opportunities

2. Southeastern New England's **existing specializations** in autonomous underwater vehicle development (10 percent of all global deals 2014–23) and advanced materials manufacturing (16 percent of global deal amount 2014–23), legacy of blue economy workers, and presence of strong academic and private research capacity **make the region competitive in a plethora of ocean technology subsectors**. Read more: Market Assessment

3. **Key market drivers** for ocean technologies include the demand of offshore **renewable energy facilities**, rising levels of **military spending worldwide**, an increasing volume of

[1] Ocean Tech Hub: https://www.oceantechnologyhub.com/

global maritime trade, and trends in **environmentalism, oceanography, and sustainable aquaculture**. Read more: Market Drivers and Use Cases

4. High startup and operational costs, strict regulatory environments surrounding ocean habitats, supply chain issues, harsh operating environments, and the general infancy of many ocean technology industries all **hinder cluster growth in the medium to long term**. Read more: Risks to Market Entry and Expansion

5. Southeastern New England's companies and universities are **nationally competitive for R&D funding**. Neighboring Boston's strengths in R&D amplify broader research capacity and provide critical workers for Southeastern New England. Read more: Investment Trends

6. Across the industries studied, around **one quarter of purchases (25 percent) come from within the region**, while three quarters (75 percent) come from outside the region. **The US military is the largest purchaser of Ocean Tech products for the Southeastern New England region**—with more than $240 million of sales from Ocean Tech industries within the region generated by the military annually. Read more: Supply Chain Analysis

7. **Ocean technology clusters throughout the world**, anchored by strong partnerships, organizations, and government authorities, are **redefining how geographies excel** in funding business creation, testing and developing products, accelerating commercial growth, and generating knowledge-sharing events and connections. Read more: Competitive Analysis of Global Ocean Tech Hubs

Ocean Tech Defined

Ocean Technology is a subset of a larger regional and growing global focus on the blue economy, which includes a broader array of industry sectors that relate to water assets.

For this market analysis, the research focused on a definition of Ocean Technology that includes the following subsectors:

- **Ocean Robotics:** For purposes of this analysis we have opted to define ocean robotics to include :
    - **Autonomous Underwater Vehicles (AUVs):** Vessels that are used to complete precise, efficient work related to ocean research and exploration, shipbuilding, infrastructure maintenance, and more without human controllers.
    - **Autonomous/Unmanned Surface Vehicles (ASVs/USVs):** "Unmanned vessel[s] that [operate] on the sea surface without real-time input or control from human operators."[2] These vehicles, typically used in ocean research or operations related to ports and offshore wind farms, are typically sensor equipped and mimic boats or other small flotation devices due to their need for buoyancy.

[2] ScienceDirect – Encyclopedia of Geology, Second Edition

- **Remotely Operated Vehicles (ROVs):** Defined as "remotely controlled and tethered submersible[s], typically equipped with cameras, echosounders, and manipulators," [3] and are commonly used vehicles in activities related to ocean research and exploration, underwater infrastructure maintenance, and military exercises that previously required the manual participation of humans.
- **Hybrid Ocean Robots:** Some ocean robotics can cross categories—for example, hybrid AUV/ASVs, or aquatic drones, that can autonomously collect aquatic data and deliver payloads in pods of one-to-many vehicles with user-defined spatial resolution and temporal synchronization. These vehicles can be multisensor configurable and used in the open ocean, with coastal, surf-zone, estuarine, and inland water applications. These systems are typically much lower cost and simpler to use than traditional AUVs and ASVs.[4]

- **Marine Sensors:** Marine sensors are electronic devices used to gather, process, and convey oceanographic data to various users. Sensors are typically attached to an existing asset, such a buoy, boat, or ocean robot, and gather data to capture information such as ocean conditions and the identification and classification of marine animals. The data captured from marine sensors is critical for general ocean research, the maintenance of physical assets at sea, offshore energy, aquaculture, and the advancement of AI in the blue economy, often through the creation of digital twins.[5] Marine sensors are also perceived as a key component in the fight against climate change, as they provide the most accurate data available on the marine environment.
- **Advanced Materials:** Advanced materials are typically composite materials used in the manufacturing of physical assets.
  - In the blue economy, advanced materials are key for the construction and maintenance of ships, offshore wind turbines, ocean robotics, and other vessels. The purpose of advanced materials, compared to materials traditionally used in the manufacturing process, is twofold:
    1. These newer advanced materials are incredibly energy and environmentally efficient, bringing sustainability to the blue economy.[6]
    2. Advanced materials are created to operate with enhanced durability, resistance to corrosion, and other characteristics that make them particularly useful in a maritime environment. Specific advanced materials used in the blue economy include polymers, coatings, advanced concrete, and other ceramics and adhesives.[7]
- **Artificial Intelligence, Machine Learning, and Data Mapping:** AI, machine learning (ML), machine vision, and data mapping encompass the use of new technologies to complete automated tasks using "human-like" learning.[8]

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[3] ScienceDirect – Encyclopedia of Geology, Second Edition
[4] PwC – Above and Below Water Drones Market
[5] IBM – What Is a Digital Twin?
[6] ScienceDirect – Advanced Material
[7] US Department of Energy – Workshop on Materials & Manufacturing for Marine Energy Technologies
[8] SAS Institute – Artificial Intelligence

- **AI and Machine Learning:** In the blue economy space, AI and other products have a variety of uses, including capturing data through oceanographic research, performing tasks related to manufacturing and shipbuilding, and operating aquaculture farms. Similarly, as in most industries, AI brings unprecedented productivity to data gathering, processing, and comprehension. In general, AI and ML are perceived to have massive implications for human productivity, efficiency, and research capabilities, with blue economy applications being no different.
- **Data Mapping:** A popular data mapping product early in the adoption of AI and its adjacent technologies is digital twins. The European Digital Twin of the Ocean is the largest of its kind, modeling the ocean's environments and trends to make predictions of future conditions and implications for commerce and livelihood.[9]

The Ocean Tech Opportunity

The overall blue economy is demonstrating significant growth. This is largely being driven by the use of ocean robotics, marine sensors, and advanced materials as well as the emerging space of artificial intelligence, machine learning, and data mapping technologies.

Subsector	Current Market	Growth Expectation	Drivers
Ocean Robotics			
Autonomous Underwater Vehicles (AUVs)	Market grew from $1.68 to $2.03 billion between 2022 and 2023, a growth rate of 20.4 percent.[10]	The industry is projected to reach $4.03 billion by 2027, representing a CAGR of 18.8 percent.	• Increase in Ocean Research • Reliance on Maritime Trade • Rising Military and Defense Expenditures • Rise of Artificial Intelligence • Marine Renewable Energy • Deep-Sea Mining
Autonomous / Unmanned Surface Vehicles (ASVs and USVs)	Existing market share of around $2 billion.[11]	CAGR of 4.4 percent is expected to grow the industry to $2.9 billion by 2030.	• Increase in Ocean Research • Reliance on Maritime Trade • Rising Military and Defense Expenditures • Rise of Artificial Intelligence • Marine Renewable Energy
Remotely Operated Vehicles (ROVs)	Estimated at $1.3 billion in 2022.[12]	Ten-year CAGR of 11.5 percent is expected to grow the industry to around $3.7 billion by 2032.	• Increase in Ocean Research • Rising Military and Defense Expenditures • Offshore Oil and Gas Exploration • Evolution of Aquaculture • Implementation of Underwater Infrastructure • Marine Renewable Energy • Deep-Sea Mining

[9] European Commission – European Digital Twin of the Ocean
[10] The Business Research Company – Autonomous Underwater Vehicles Global Market Report
[11] Fortune Business Insights – Unmanned Surface Vehicle Market Size
[12] Global Market Insights – Remote Operated Vehicle Market

Marine Sensors	The global market had an estimated value of $23.66 billion in 2023.[13]	An expected 2023–33 CAGR of 7.7 percent, bringing the market value to $43.68 billion.	• Increase in Ocean Research • Reliance on Maritime Trade • Rise of Artificial Intelligence • Evolution of Aquaculture • Implementation of Underwater Infrastructure • Marine Renewable Energy
Advanced Materials	The total of the marine-related advanced materials market was $9.55 billion at the end of 2023.[14] The marine composites market, which represents the majority of all marine advanced materials, is around a $5 billion total market.[15]	A 9.8 percent CAGR between 2024 and 2030 will bring the market to an $18.37 billion valuation by the end of the decade. Advanced materials CAGR is expected to be around 6 percent over the next ten years.	• Reliance on Maritime Trade • Rising Military and Defense Expenditures • Worldwide Environmentalism
Artificial Intelligence (AI), Machine Learning (ML), and Data Mapping	AI and machine learning (ML) compose one of the world's largest emerging technological markets. The AI market is worth $214 billion as of 2023.[16]	Globally, the AI market is expected to surpass $1.3 trillion by 2030, with a CAGR of 36 percent[17] from 2024 to 2030. This growth is primarily anchored by increasing activities related to generative AI and ML.[18] Maritime-related AI is typically clustered into the "AI Robotics" and "Autonomous & Sensor Technology" categories, which are smaller but still rapidly emerging at a global scale.	• Increase in Ocean Research • Reliance on Maritime Trade • Rising Military and Defense Expenditures • Offshore Oil and Gas Exploration • Evolution of Aquaculture

[13] Fact.MR – Marine Sensors Market
[14] Virtue Market Research – Global Marine Advanced Materials Market Research Report
[15] Research Nester – Marine Composites Market Size and Share
[16] Statista – Artificial Intelligence Worldwide
[17] Markets and Markets – Artificial Intelligence Market
[18] Bloomberg – Generative AI to Become a $1.3 Trillion Market by 2032, Research Finds

Southeastern New England Opportunities

The Ocean Tech Hub has the opportunity to support the development of ocean technology and the growth of companies, researchers, and organizations that utilize it through a number of possible efforts.

1. Network Coordination and Global Connectivity
2. Real Estate Identification and Waterfront Coordination
3. Talent Development and Recruitment
4. Shared Research and Development Platform(s)

Network Coordination and Global Connectivity

Existing Environment

- There is a growing yet still informal regional, national, and global network with collaboration characterized as more ad hoc than strategic.
- Ocean Tech sector information is accessed by participants via decentralized channels—from industry associations, networking, and news.
- Federal spending is the most significant driver, with the US Navy and National Oceanic and Atmospheric Administration (NOAA) being significant regional customers with increasing collaboration around innovation.
- Investment-related activities are becoming more common as programs scale and partnerships form.

Future Opportunity

- Form structured collaborative opportunities with organizations such as the COVE (Halifax), ORE Catapult (UK), Plymouth Sound (UK), and TMA BlueTech (San Diego) as their technology focus aligns with the Southeastern New England region.
- Develop a membership/association model for larger companies interested in identifying company pipeline opportunities, smaller companies looking for “first” customer relationships, and investment showcase(s).
- Develop a resource that tracks global ocean tech trends, advances in tech, research needs, and so on, and create an inbound/outbound communications platform.
- Seek to fill local purchasing gaps by strengthening the supply chain to meet these gaps. A quarter of inputs come from in-region supply chain purchasing; as a result, there are large opportunities across all supplier industries.
- Explore the expansion of SupplyRI in the Ocean Tech space and across the region.
- Bring together lending and investing organizations in the region to identify improved opportunities for access to capital.

- Provide information to create more visibility to venture capital and other private investment opportunities. On the public side, support more SBIR/STTR proposals (Federal and State Technology [FAST] Partnership Program).
- Connect academic researchers to commercialization opportunities—a "C-suite for hire" network or experienced executives to help companies scale faster.

Real Estate Identification and Waterfront Coordination

Existing Environment

- Based on interviews with existing companies operating in the region, a regional draw is the relatively lower-cost real estate profile as compared to the Boston area.
- In addition, cost-of-living considerations are top of mind with many of the companies, for both leadership and the recruitment of talent.

Future Opportunity

- Work with real estate developers/brokers to identify a portfolio of real estate options for Ocean Tech companies based on core criteria such as light industrial, water access, researcher access, prototyping, and so on.
- Compare existing waterfront space (specifically open for testing and other R&D) to what it looks like in other clusters.
- Work to optimize existing waterfront space and explore what space is viable for development/redevelopment.
- Network with existing research centers / business parks in the region to understand their future needs.
- Develop an Ocean Tech–specific site selection application/portal for the region.

Talent Development and Recruitment

Existing Environment

- Ocean Tech companies are slowly scaling their employment base utilizing close connections to existing higher education and research organizations.
- There are traditional hiring opportunities such as career fairs that are complemented by networking-related hiring from the University of Rhode Island (URI), the Naval Undersea Warfare Center (NUWC) supply chain, UMass Dartmouth, Brown, and the Woods Hole Oceanographic Institution (WHOI).

Future Opportunity

- The current talent development process limits scaling due to the limits of the existing talent pool and aging demographics in the region. Out-of-region recruitment will be required while also building in-state awareness.

- Develop a joint recruitment campaign and job board that sells the Ocean Tech opportunity to midcareer workers and graduate students in other ocean tech hubs.
- Create a centralized career board for ocean tech companies.
- Create tools that allow workers to assess career progression opportunities in the region.
- Work with education institutions to develop ocean tech educational programs from apprenticeships to postgrad.
- Better market the Southeastern New England region's ocean tech assets in Boston; attract mid-level tech talent from Boston.
- Expand transportation options and link to site identification.

Shared Research and Development Platform(s)

Existing Environment

- The majority of space is located within college and university facilities, accessible but capped in terms of time available. Regional observers have noted the need for light-manufacturing and assembly space.
- New Bedford Research and Robotics (a not-for-profit organization) is establishing itself as an R&D asset in the region, connecting to companies and engaging talent in the pipeline. As the organization continues to scale, their research and robotics space and programming can fill a critical gap identified in the analysis.
- NUWC at Naval Station Newport has established a Cooperative Research and Development Agreement (CRADA) process to allow for streamlined engagement.
- MITRE and WHOI have established presence in the region.
- SBIR/STTR awards are concentrated among a few companies: two dozen companies in the region have multiple SBIR/STTR awards. Top funders include the Department of Defense, Department of Energy, National Science Foundation (NSF), and Department of Commerce.
- Federal spending in the Ocean Tech sector within the region largely stems from Department of Defense contracts.
- NSF awards are diverse in scope and include awards across sensors, ocean monitoring, and the development of unmanned vehicles at URI, WHOI, UMass Dartmouth, and other institutions.

Future Opportunities

- Develop a set of regional services that addresses the market barrier by reducing the time and cost to bring regional and global ocean robotics to market, including by providing access to:
    - Rapid prototyping, testing validation
    - Development simulation
- Create a "soft-landing" effort in the region for domestic and global companies looking for development support.

- Develop a process for shared ocean tech development problem identification (for in-region and out-of-region companies, and regional research capacity). This can include market growth opportunities resulting from ocean technology sector expansion such as:
    - Composites and fiber recycling / circular economy opportunities
    - Battery technology for use in harsh environments
    - Sensor recycling
    - Development of new coatings, retrofitting of infrastructure
    - Circular economy considerations for ocean tech materials; identification of recycled content feedstock opportunities
- Develop a focus onshore to support device communication technology; create a test bed.
- Support the collection and utilization of data developed by autonomous vehicles and devices to support digital twin development.
- Create shared test boats/vessels to allow ocean tech companies to test in real-world environments. Currently there is limited capacity to test components of propulsion, energy, sensors, and so forth, with URI having one boat and private charters.
- Support machine vision research and tech commercialization for Ocean Robotics.
- Create a test bed for unmanned underwater vehicle (UUV) and unmanned surface vehicle (USV) applications.
- Support materials research to develop more impact-resistant, longer-life-cycle sensors.
- Explore sensor management and deployment management as a “service”—develop a trained local workforce to serve the region and global environment.
- Support AI-enabled sensor networks and utilize data capture for predictive modeling.

Market Assessment

The following sections detail each of the Ocean Tech subsectors and provide:

- An overview of the sector
- Current market size estimates and expected growth
- Industry drivers, further detailed in the Market Drivers and Use Cases section of this report
- Emerging research and opportunities to consider

The purpose of this information is not only to gain a deeper understanding of these individual ocean technology sectors and their market segments but to begin to comprehend how these sectors connect to ongoing commercial activities and initiatives in the Southeastern New England region. These technologies all have a plethora of use cases for potential customers and end users. All products are undergoing constant improvements and expansions, too, driven by market forces that demand increased exploration of the ocean for a variety of purposes. While the information provided below provides data from a point in time, it is important to understand the evolutionary period many of these products are in. To truly comprehend these products and their direction, consistent research is needed on a semiannual basis.

Sector Overview

Ocean Robotics

Overview

Ocean robotics, which include remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), autonomous surface vehicles (ASVs), unmanned surface vehicles (USVs), aquatic drones, and other machines, are systems that operate in the marine environment to complete tasks typically deemed dangerous or impossible for humans to attempt. Presently used for ocean research and exploration, infrastructure implementation and maintenance, and activities related to aquaculture, these robots are key aspects of the blue economy's future. The primary aim of ocean robots is to fulfill specific tasks and functions that make maritime activities safer and more efficient for humans. Most robots are also "outfitted with numerous sensors and tools to collect extensive amounts of data from deep-sea environments."[19] This data collection allows humans to gain a deeper understanding of the ocean environment.

[19] NOAA Ocean Exploration – Education Theme: Underwater Robots

Market Size and Expected Growth

In general, undersea robotics (used as a proxy for the Ocean Robotics sector) had a global market of $4.49 billion in 2022, with an expected CAGR of 14.5 percent through 2030 expanding the market to over $13 billion by the end of the decade.[20]

Remotely Operated Vehicles (ROVs)

Overview

Remotely operated vehicles, defined as "remotely controlled and tethered submersible[s], typically equipped with cameras, echosounders, and manipulators,"[21] are commonly used vehicles in activities related to ocean research and exploration, underwater infrastructure maintenance, and military exercises. These vehicles differ from autonomously operated vehicles in that they require an aboveground, manual operator. Vehicles are operated with controllers of varying complexity—some mimic a controller used for a computer game, while others are more comparable to the cockpit of an airplane. ROVs have been in use since the 1980s and have evolved in their weight, battery life, ability to capture detailed photos of the underwater environment, and acumen for completing manual tasks that were formerly reserved for humans.[22]

Market Size and Expected Growth

ROVs have an existing market size of $1.3 billion globally as of 2022, with a ten-year CAGR of 11.5 percent expected to grow the industry to around $3.7 billion by 2032.[23]

Industry Drivers

- Increase in Ocean Research
- Rising Military and Defense Expenditures
- Offshore Oil and Gas Exploration
- Evolution of Aquaculture
- Implementation of Underwater Infrastructure
- Marine Renewable Energy
- Deep-Sea Mining

Emerging Research and Opportunities

Flotation Technologies

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[20] Grand View Research – Underwater Robotics Market Size
[21] ScienceDirect – Encyclopedia of Geology, Second Edition
[22] ScienceDirect – Encyclopedia of Ocean Sciences
[23] Global Market Insights – Remote Operated Vehicle Market

Ocean robots rely on floating devices and buoyancy systems to serve as a counterweight to vehicular weight and ocean pressure, keeping vehicles afloat and agile on their explorations. Researchers are consistently exploring new systems that make the most maneuverable, usable robots possible.[24]

Underwater Acoustic Communication

Communication between ROVs and their aboveground, human controllers is still a developing space. Communication is slow due to the reliance on electromagnetics, which cannot function properly in submerged conditions. Instead, acoustic waves are utilized.[25] Both researchers and the private sector are working to improve ROV communications.

Autonomous Underwater Vehicles (AUVs)

Overview

Autonomous underwater vehicles are vessels that are used throughout the blue economy industries to complete precise, efficient work related to ocean research and exploration, shipbuilding, infrastructure maintenance, and more. Unlike ROVs, AUVs operate with no human controller.[26] Vehicles are programmed using either code or forms of AI to complete specific tasks. In the context of ocean exploration, ROVs and AUVs also differ in that AUVs typically store data until they resurface while ROVs can provide live video and share data feeds in real time.

Market Size and Expected Growth

The AUV global market grew from $1.68 to $2.03 billion between 2022 and 2023, a growth rate of 20.4 percent. The industry is projected to reach $4.03 billion by 2027, representing a CAGR of 18.8 percent.[27] This AUV market is an individual segment of the ROV market.

Relevant Industry Drivers

- Increase in Ocean Research
- Rising Military and Defense Expenditures
- Offshore Oil and Gas Exploration
- Rise of Artificial Intelligence
- Evolution of Aquaculture
- Implementation of Underwater Infrastructure
- Marine Renewable Energy

[24] Intelligent Marine Technology and Systems – Review of Research and Control Technology of Underwater Bionic Robots
[25] Marine Technology News – Challenges of Underwater Acoustic Communication
[26] NOAA Ocean Exploration – What Is an AUV?
[27] The Business Research Company – Autonomous Underwater Vehicles Global Market Report

- Deep-Sea Mining

Emerging Research and Opportunities

Increased Endurance

A drawback of ocean robotics and vehicles to date is their endurance and operating ranges. Due to constraints related to power, communication systems, and pressure, most robots can only operate for certain amounts of time until they need to resurface.[28] R&D to reduce power consumption—exploring bio-inspired propulsion and hydrodynamics, for example—will expand the endurance and operating ranges of these vehicles, saving money and allowing for increased adoption and utilization of individual products over time.

Battery Power

Batteries are one of the heavier components in an AUV, yet their quality and duration determine the efficacy of the vehicle in its performance. As battery R&D continues for vehicles worldwide, researchers are striving to make lighter, longer-lasting batteries that can power ocean exploration and other underwater activities.[29]

Subsea Communications

The ability to transfer increasingly large amounts of data from the AUV to another subsurface or surface system will greatly increase operational efficiency and real-time decision-making in response to data collection. R&D in subsea communications can include acoustic, electromagnetic, and electro-optical methods.

Underwater Acoustic Communication

Communication between AUVs and above-ground users is still a developing space. Communication is slow due to the reliance on electromagnetics, which cannot function properly in submerged conditions. Instead, acoustic waves are utilized.[30] Both researchers and the private sector are working to improve AUV communications.

5G Underwater Cable Implementation

With the internet, telecommunications, and overall digital connectivity primed for expansion with 5G technologies, the laying, implementation, and maintenance of underwater cables is expected to increase dramatically.[31] This increase can be supported by AUVs equipped with the tools and

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[28] NOAA Ocean Exploration – How Robots Are Uncovering the Mysteries of the Deep
[29] US Department of Defense – Navy SBIR Leads to Resilient, Rechargeable Batteries Powering Autonomous Undersea Applications
[30] Marine Technology News – Challenges of Underwater Acoustic Communication
[31] Center for Strategic and International Studies – Undersea Cables and Transatlantic Security

functions necessary to essentially perform this underwater construction effort. Companies and governments are both already undertaking efforts to evolve the vehicles that can do this work.

Machine Vision

The ocean is vastly unexplored, meaning many observations captured by an AUV are not previously seen or noted in existing data. Considering AUVs operate on machine learning models that rely on existing data and images, AUVs can struggle to identify new objects and environments that have never been identified in their training. MIT and other researchers are trying to better understand how to improve this area of machine vision, so that AUVs are able to see and interpret more information correctly.[32]

Marine Datasets

AUVs operate by learning from existing datasets and then recognizing familiar patterns on their explorations. Industry leaders believe that AUVs can improve in their precision and performance only with larger, more coordinated marine datasets that inform these machines of what they may observe in the marine environment.[33]

Charging Systems

Researchers are exploring AUVs that autonomously dock mid-mission to recharge and transfer data. Due to AUVs' lack of human operators, getting the vessels to surface and dock is a complex task. However, researchers believe that streamlining this task can lead to more charging power and data transfers, leading to longer, more informative underwater missions.[34]

Autonomous / Unmanned Surface Vehicles (ASVs and USVs)

Overview

Autonomous surface vehicles and unmanned surface vehicles are "unmanned vessel[s] that [operate] on the sea surface without real-time input or control from human operators."[35] These vehicles, typically used in ocean research or operations related to ports and offshore wind farms, rely on the programming of a human but then operate autonomously, without human intervention other than maintenance and reprogramming. ASVs and USVs are typically sensor equipped, similar to AUVs. ASVs and USVs typically mimic boats or other small flotation devices due to their need for buoyancy.

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[32] MIT Sea Grant – The Autonomous Underwater Vehicles Lab
[33] Scientific Reports – FathomNet: A Global Image Database for Enabling AI in the Ocean
[34] Purdue University – What If Underwater Robots Could Autonomously Dock Mid-Mission?
[35] ScienceDirect – Encyclopedia of Geology, Second Edition

Market Size and Expected Growth

As of 2023, ASVs and USVs have a global market of around $2 billion, with a small CAGR of 4.4 percent expected to grow the industry to $2.9 billion by 2030.[36]

Industry Drivers

- Increase in Ocean Research
- Reliance on Maritime Trade
- Rising Military and Defense Expenditures
- Rise of Artificial Intelligence
- Marine Renewable Energy

Emerging Research and Opportunities

Naval Applications

The US Navy has prioritized the development and implementation of USVs as a mechanism of mapping the positioning of maritime assets, both friendly and enemy.[37] This military expenditure has led to an increase in USV production and utilization, and will be increasingly important in future maritime conflicts.

Use of Solar and Wind Power

Because they remain above the surface of the water, USVs are almost exclusively powered by wind, wave, and solar power.[38] These multiple power sources create numerous opportunities for continued innovation around the size of these power sources, their efficacy, and how USVs will be powered in the future.

Water Quality Monitoring

Using USVs for monitoring water quality and testing other environmental conditions can be a simpler, lower-cost option than more complex AUVs and ROVs.[39] USVs are easier to build than AUVs, as they are often just component parts attached to an existing flotation device.

Testing for Aquaculture

[36] Fortune Business Insights – Unmanned Surface Vehicle Market Size
[37] Congressional Research Service – Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress
[38] NOAA Ocean Exploration – Uncrewed Surface Vessels
[39] ScienceDirect – A Low-Cost and Small USV Platform for Water Quality Monitoring

USVs are increasingly being used in aquaculture operations to support site planning, operations and maintenance, and data tracking on fish populations and environmental conditions. These use cases often pair a USV with AUVs to monitor conditions.[40]

Docking for Other Systems

USVs can serve as convenient offshore docking stations for other AUVs and ROVs that need to be charged or transfer their data to a centralized location. This interconnectivity with other vehicles amplifies the importance of USVs, which can become the data hubs of fleets of more limited AUVs.[41]

Marine Sensors

Overview

Marine sensors are electronic devices used to gather, process, and convey aquatic data to various users. Sensors are typically attached to assets, such a buoy, boat, or underwater robot, and gather data to capture information such as ocean conditions, the patterns of currents, and the movement of specific underwater species. The data captured from marine sensors is critical for general ocean research, the maintenance of physical assets at sea, aquaculture, and the advancement of AI in the blue economy, often through the creation of digital twins.[42] Marine sensors are also perceived as a key component in the fight against climate change, as they provide the most accurate data available on the marine environment.

Market Size and Expected Growth

The global marine sensor market is worth $23.66 billion as of 2023, with an expected 2023–33 CAGR of 7.7 percent bringing the market to $43.68 billion.[43]

Industry Drivers

- Increase in Ocean Research
- Reliance on Maritime Trade
- Rise of Artificial Intelligence
- Evolution of Aquaculture
- Implementation of Underwater Infrastructure
- Marine Renewable Energy

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[40] North Carolina State Extension – The Use of Uncrewed Vehicles in Coastal Aquaculture
[41] NOAA Ocean Exploration – Uncrewed Surface Vessels
[42] IBM – What Is a Digital Twin?
[43] Fact.MR – Marine Sensors Market

Emerging Research and Opportunities

IoT Integrations at Scale

As pilot projects come online for fully integrated "smart ports" and shipping systems, more use cases are needed to understand what a fully fleshed out, connected marine sensor and fleet system looks like. Specifically, a complete system running at least partially on AI is also still an emerging space in terms of vetted case studies and best practices.[44]

Testing for Sensor Calibration

Due to the cost-intensive nature of sensor maintenance and calibration, researchers are exploring mechanisms for automated testing that yield a better system of predictive and real-time maintenance needs. Improving maintenance and calibration directly yields better data quality and control. To date, automated testing systems are showing promise as a cost-effective way to keep sensor systems consistently online.[45]

Integrations with Defense Research

The US Office of Naval Research is consistently conducting industry-leading research into marine sensors, their durability and efficacy, and their use in capturing data and intelligence for multiple purposes. Research areas include exploration of autonomous sensor systems, acoustic sensors, energy storage technology for sensors, and the development of computationally intelligent multisensor systems.[46]

Deep-Sea Research

Marine scientists are frequently collaborating to utilize sensors in deeper parts of the ocean to explore areas that have long been inaccessible to humans. New technologies are being developed to go deeper into the ocean and capture data relevant to not only the blue economy but marine biology, climate change, geology, and more. The Maka Niu is a new example of a marine sensor product meant to survive under the immense pressure of the ocean's depths, and included collaboration from scientists throughout Rhode Island and Massachusetts.[47]

Low-Power Underwater Data Transmission

Scientists recently made a massive leap forward in systems related to underwater signal transmission between receivers. Using a system based on backscatter communication, this

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[44] Journal of Marine Science and Engineering – Innovations in Smart Ports
[45] JPI Oceans – Martine Metrology in Europe
[46] Office of Naval Research – Maritime Sensing
[47] Frontiers in Marine Research – Maka Niu: A Low-Cost, Modular Imaging and Sensor Platform

system has lower power needs and can successfully track acoustic communications at longer ranges than ever before.[48]

Advanced Materials

Overview

Advanced materials are typically composite materials used in the manufacturing of physical assets. In the blue economy, advanced materials are key for the construction and maintenance of ships, offshore wind turbines, ocean robotics, and other vessels. The purpose of advanced materials, compared to materials traditionally used in the manufacturing process, is twofold. First, these newer advanced materials are incredibly energy and environmentally efficient, bringing sustainability to the blue economy.[49] Second, advanced materials are created to operate with enhanced durability, resistance to corrosion, and other characteristics that make them particularly useful in a maritime environment."[50] Specific advanced materials used in the blue economy include polymers, coatings, advanced concrete, and other ceramics and adhesives.[51]

Market Size and Expected Growth

The total of the global marine-related advanced materials market was $9.55 billion at the end of 2023. A 9.8 percent CAGR between 2024 and 2030 will bring the market to an $18.37 billion valuation by the end of the decade.[52] The global marine composites market, which represents the majority of all marine advanced materials, is around a $5 billion total market as of 2023. The market's CAGR is expected to be around 6 percent over the next ten years.[53]

Industry Drivers

1. Reliance on Maritime Trade
2. Rising Military and Defense Expenditures
3. Worldwide Environmentalism

Emerging Research and Opportunities

Increased Corrosion Resistance

While some advanced materials, such as carbon fiber polymers, exhibit exceptional corrosion resistance, other new and emerging materials struggle to survive in the ocean environment. More

[48] MIT Technology Review – Low-Power Underwater Communication
[49] ScienceDirect – Advanced Material
[50] Medium – Marine Composite Materials Market Size, Growth, Forecast 2023–2030
[51] US Department of Energy – Workshop on Materials & Manufacturing for Marine Energy Technologies
[52] Virtue Market Research – Global Marine Advanced Materials Market Research Report
[53] Research Nester – Marine Composites Market Size and Share

research and testing is needed to improve the performance of materials in the long term, ensuring they can withstand frequent wear and tear from the ocean.[54, 55]

Recyclable and Organic Materials

With environmental considerations being a primary driver of the market, there is more demand for materials that are both sustainably sourced from recycled materials and recyclable after their use. Exploring the utilization of recyclable materials is an emerging research space.[56]

Intersections with Renewable Energy

As advanced materials come into use for more maritime-related activities, there are emerging concepts on how materials can be used in the development, installation, and maintenance of offshore wind farms and other forms of renewable energy. The National Renewable Energy Laboratory (NREL) hosts a "collaborative research environment [that] enables scientists to push wind energy industry frontiers in advanced manufacturing and materials" via partnerships and funding opportunities.[57, 58]

Artificial Intelligence, Machine Learning, and Data Mapping

Overview

AI, machine learning (ML), and data mapping encompass the use of new technologies to complete automated tasks using "human-like" learning.[59] In the blue economy space, AI and other products have a variety of uses, including capturing data through oceanographic research, performing tasks related to manufacturing and shipbuilding, and operating aquaculture farms. In general, AI and ML are perceived to have massive implications for human productivity, efficiency, and research capabilities, with blue economy applications being no different. A popular data mapping product early in the adoption of AI and its adjacent technologies is digital twins. The European Digital Twin of the Ocean is the largest of its kind, modeling the ocean's environments and trends to make predictions of future conditions and implications for commerce and livelihood.[60]

Market Size and Expected Growth

AI and ML compose one of the world's largest emerging technological markets. Globally, the AI market is worth $214 billion as of 2023 and is expected to surpass $1.3 trillion by 2030, with a

[54] Texas A&M Engineering – Researchers Fight Underwater Deformation with Enhanced Metals
[55] National Renewable Energy Laboratory – New Study Breaks Materials Down
[56] ScienceDirect – Advanced Materials from Recycled Waste
[57] National Renewable Energy Laboratory – Advanced Manufacturing and Materials
[58] US Office of Energy Efficiency & Renewable Energy – Exploring New Materials and Manufacturing Processes to Help Marine Energy Achieve Commercial Success
[59] SAS Institute – Artificial Intelligence
[60] European Commission – European Digital Twin of the Ocean

CAGR of 36 percent from 2024 to 2030.[61] This growth is primarily anchored by growth in activities related to generative AI and ML.[62] Maritime-related AI is typically clustered into the "AI Robotics" and "Autonomous & Sensor Technology" categories, which are smaller but still rapidly emerging at a global scale.[63]

Industry Drivers

1. Increase in Ocean Research
2. Reliance on Maritime Trade
3. Rising Military and Defense Expenditures
4. Offshore Oil and Gas Exploration
5. Evolution of Aquaculture

Emerging Research and Opportunities

Navigation Systems

AI and ML tactics are increasingly being used to navigate underwater robots, submarines, and other vessels through the marine environment.[64] Using tactics that teach robots and machines to wayfind on their own has helped increase the viability and demand for uncrewed vehicles and AUVs, which contribute to ocean research, defense, and more.[65]

Ocean Research

Oceanography and ocean-exploration-related activities are relying on AI to capture key images and data that can be autonomously interpreted using ML and neural networks. These AI systems can be taught to recognize and comprehend complex images and data patterns related to ocean climate, salinity, patterns in fish movement, and other key avenues of ocean research.[66]

Data Interpretation and Processing

AI and ML systems provide unprecedented speed in processing and comprehending data, drawing insights out of datasets composed of images, numbers, and other variables in seconds. These systems allow for deeper insights related to ocean health, machine functionality, and more.

Fishing and Aquaculture

Tech-enabled commercial fishermen and aquaculture specialists are using AI in both research and production, transforming some of the world's oldest industries to dually prioritize efficient fishing systems and the sustainability of marine life. AI applications in this space include

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[61] Markets and Markets – Artificial Intelligence Market
[62] Bloomberg – Generative AI to Become a $1.3 Trillion Market by 2032, Research Finds
[63] Statista – Artificial Intelligence Worldwide
[64] Caltech – Engineers Teach AI to Navigate Ocean with Minimal Energy
[65] IEEE Spectrum – Autonomous Subs Use AI to Wayfind without GPS
[66] University of Washington School of Oceanography – Applying AI to Oceanography

identifying fish species underwater, tracking the health and volume of specific species, and driving systems that can fully operate aquaculture farms.[67]

Port Digitization

"Smart ports," defined as "modern and technologically advanced port[s] that [leverage] innovative technologies and data-driven solutions to enhance [their] operational efficiency, safety, and sustainability,"[68] are increasingly an industry standard in new construction and the retrofitting of existing ports. These ports are equipped with AI that is key in port operations, maintenance, and efficiency.[69] A variety of startups have followed this trend and are taking to market new AI technologies that are sold directly to ports and other waterfront operations.[70]

Intersections with Offshore Wind

AI applications in the field of offshore wind construction, implementation, operations, and maintenance are numerous. AI systems can detect when critical maintenance is needed, which turbines outperform others, and the optimal positioning of turbines in the implementation process to maximize energy production and capture. As wind farm installation increases, demand for new technologies is expected to increase.[71, 72]

[67] The Fish Site – The Rise of AI in Aquaculture
[68] Port Technology International – What Is a Smart Port?
[69] Management and Economics Review – Smartening Up Ports Digitalization with AI
[70] Scale AI – Smart Port Lab
[71] The Alan Turing Institute – Using ML to Design More Efficient Offshore Wind Farms
[72] Energy and AI – Challenges and Opportunity for AI and Robotics in the Offshore Wind Sector

Market Drivers and Use Cases

While there are specific market needs that are compelling growth in the Ocean Tech subsectors, there are also cross-cutting macro trends that must be considered. This section provides a deeper dive into a handful of key market drivers identified through this project's research.

Ocean Energy

Offshore Oil and Gas Exploration

Intro: The continued pursuit of oil and liquefied natural gas to power commerce, transportation, and more is a key market driver for ocean technology. The global offshore drilling market, the segment of the oil and gas market related to maritime activities, is a $36.5 billion market with expected growth up to $75 billion by 2032.[73] This market is part of the broader oil and gas industry, a $6.5 trillion market projected to grow up to $8.6 trillion by 2030.[74] In the United States, around 14.6 percent of oil and 2.3 percent of gas was produced from offshore wells and other sources in 2022.[75] The continued demand for oil and gas sources calls for the consistent exploration of potential offshore drilling sites, which increasingly utilize ocean technologies for efficiency, optimization, and safety. And, with modern regulations, the growth of these industries catalyzes continued demand for research and environmentalism.

Tech: Oil and gas companies, specifically those involved in underwater extraction, are increasingly utilizing ocean robotics and sensor systems to provide key services that previously lacked efficiency and safety for humans. Exploration of potential fuel sources is the largest activity now done partially, if not entirely, by robotic vehicles. Pipeline and rig construction and maintenance can now also be handled by remotely operated and autonomous underwater vehicles.

Investment: Investment in offshore oil and gas exploration is driven by institutional investors, private equity and hedge fund actors, and energy companies themselves, who buy up startups and further consolidate. A 2023 report highlighted an influx of new investment in the space, with $200 billion in new industry investment signaling a comeback as an energy source.[76] Few federal investments in Southeastern New England support companies working in the oil and gas industry. The few ongoing projects in the region are related to robotics that explore the seafloor for specific minerals and sensors that track water composition and quality to mitigate against environmental disasters.

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73 Offshore Drilling Market Size, Growth | Industry Outlook [2032]
74 Oil and Gas Market Size, Share & Trends | Outlook [2030]
75 Stop Offshore Drilling
76 Offshore Oil And Gas Is Back with More than $200 Billion in New Investment

Existing Assets and Businesses: The offshore oil and gas industry is dominated by big energy companies, including Halliburton, Schlumberger, Baker Hughes, Gazprom, and ExxonMobil. Oil and gas is a heavily consolidated industry, with the major companies dominating drilling typically having robust, stable supply chains, leaving little room for startup activity in the space. Still, ocean technology businesses manage to work with oil and gas companies through the creation of ocean robotics, advanced materials, and marine sensor systems. Still, this industry is not well developed in Southeastern New England compared to clusters along the Gulf Coast, California, and Alaska.

Risks and Regulation: The oil and gas industry is heavily regulated worldwide, even more so in current years due to trends in environmental sustainability to curb pollution and, in general, the use of oil and gas. Rig and pipeline development is an incredibly political process, with new facilities taking years, and even decades, to come to fruition. While the industry continues to grow currently, there remain questions over the long-term viability of fossil fuels as the primary energy source for the world.

Market Intelligence: Resources that can be referenced include:

- **National Ocean Industries Association:** The leading national trade association for offshore oil and gas companies.
- **Oil & Gas Journal:** An online industry journal on happenings across the world in the oil and gas industry.
- **Offshore Magazine:** A publication highlighting work across the offshore energy sector.
- **Offshore Technology:** An online publication specifically highlighting trends and innovations related to offshore energy technologies.
- **Offshore Energy Magazine:** A global news outlet for happenings in the offshore energy space.

Use Case – Limiting Oil Spills with Surface Vessels

Tech: Ocean Robotics and Marine Sensors

Oil spills are an ocean travesty: they kill marine animals, fish, and plants through pollution and habitat degradation, and are one of many reasons for public outcry against oil and gas companies. Liquid Robotics, a Boeing Company, helps offshore rigs limit oil spills and mitigate against ongoing ones, through their Wave Gliders. Wave Gliders are unmanned surface vessels (USVs) that rove the waters near offshore oil rigs and pipelines. Using marine sensors to capture immense troves of data from the ocean, the Gliders can not only detect when conditions might yield an oil spill or other environmentally harmful event but also monitor water quality to detect when hydrocarbons are at the water's surface. This dual purpose allows oil and gas companies to maintain environmental standards in their operations and keeps marine flora and fauna healthy in the long term.

Offshore and Marine Renewable Energy

Intro: Offshore renewable energy is increasingly perceived as a critical component of the globe's future energy grid. Wind, tidal energy, and thermal conversions are all growing at different rates and scales to become actively used methods of energy development.[77] Projections suggest that the offshore wind market is worth up to $36 billion on its own, with a CAGR of 8 percent through 2030.[78] The smaller marine renewable energy market, which includes energy from waves, tides, and thermal sources, is a $1 billion market with a 22.8 percent CAGR in the next ten years, with an expected market size of $8 billion by 2032.[79] These markets are driven primarily by the globe's shift away from fossil fuels as a primary energy source. Renewable energy is perceived as the most scalable, sustainable form of future energy, and marine-based activities are a key component of the scalability of these products.

Tech: Offshore wind farms and other forms of marine renewable energy products require innovative technologies from installation through maintenance and even teardown. AI systems help to optimize turbine performance. Advanced materials account for most of the source product for physical renewable energy products, specifically including advanced composites. Marine sensor systems help to predict operations and maintenance needs, which are then often performed by autonomous underwater vehicles (AUVs) to limit the need for undersea human labor.

Investment: The marine energy space is increasingly dominated by private equity investors due to the immense market opportunity seen in the space. Major investors include groups such as Global Infrastructure Management LLC, Morgan Stanley Infrastructure Partners, and Stonepeak Partners LP.[80] Marine energy investors are typically smaller firms, such as Clean Energy Ventures, AC Ventures, and One Equity Partners. Regional investments into R&D in this space include focuses on underwater robots that can perform critical industry functions in tight areas, more optimized advanced materials for wind energy output, marine sensors to help increase the efficacy of marine energy systems, and advancements in systems that can capture wave energy.

Existing Assets and Businesses: The offshore wind market is dominated by major companies worldwide, with only a few companies producing, developing, and operating offshore wind farms. These companies include General Electric, Siemens, Orsted, and Goldwind. Marine energy companies operate in a more nascent market. Key players include Carnegie Clean Energy, Ocean Power Technologies, CorPower Ocean, and OceanEnergy.

Risks and Regulation: Both offshore and marine energy sources present ample challenges and regulations for full-scale operations. Offshore wind development is incredibly cost intensive and must meet strict regulations and guidelines in any country. Furthermore, the industry's supply chain is still not fully caught up to demand. Marine energy requires durable, consistent equipment

[77] International Renewable Energy Agency – Offshore Renewables
[78] Offshore Wind Market Size, Share & Trends Report, 2030
[79] Marine Energy Market Size, Share & Trends Report, 2032
[80] Private Equity Wades Deeper into US Offshore Wind Investments | S&P Global Market Intelligence

that is not yet fully developed. Both industries must also navigate regulations surrounding environmental review, infrastructure deployment, community impacts, and more.

Market Intelligence: Resources that can be referenced include:

- **National Hydropower Association:** A trade association supporting the growth of renewable hydropower and marine energy types.
- **Oceantic Network:** A member-based organization growing the offshore wind energy and its vast supply chain.
- **Offshorewind.biz:** A leading worldwide publication on offshore wind innovations and happenings.
- **International Marine Energy Journal:** The world's leading academic journal for research and innovation related to marine energy sources and products.

Use Case – Reusing Offshore Wind Turbines

Tech: Advanced Materials and Marine Sensors

A compelling use case for ocean technologies related to offshore and marine energy occurs at the end of a wind turbine's life cycle. It is estimated that offshore wind turbine blades have a life cycle of twenty to twenty-five years before they need to be replaced.[81] Using a blend of advanced composites, the source material for about 80 to 90 percent of offshore wind turbine mass, turbines can be recycled for future uses.[82] These advanced materials lend themselves to cement, steelworks, molding compounds, and more. Veolia North America, an energy and waste company, partners with General Electric to use the materials found in their offshore wind turbine blades to produce concrete. Advanced materials create a circular economy in this application, creating renewable energy for twenty to twenty-five years before being recycled into productive forms of infrastructure.

Rising Military and Defense Expenditures

Intro: In general, military spending has grown steadily, up to $2.24 trillion worldwide in 2022.[83] This defense spending is due to a variety of causes, including ongoing war and necessary aid; the increased militarization of the United States, China, and Russia as global powers; rising tensions between these countries; and the efforts of many countries to limit the powers of terrorist groups and other forms of organized crime. This increase in military spending has specifically occurred on the water, where large nations are investing heavily in ocean technologies to gain supremacy.

[81] Wind Turbine Blades Don't Have to End Up in Landfills – Union of Concerned Scientists
[82] How Can Companies Recycle Wind Turbine Blades?
[83] Statista – Military Spending Worldwide

Tech: As defense spending grows, individual countries have upped their expenditures on ships, aircraft carriers, amphibious docks, cruisers, submarines, and various forms of autonomous underwater vehicles (AUVs). Growth in these forms of vessels has simultaneously grown the markets for marine sensors, advanced materials, and ocean-related AI.

Investment: Much of the capital infused into large defense companies stems from institutional investors and the general stock market. Smaller startups are supported by defense-specific VC, such as the ones laid out in Business Insider's recent highlight of top firms. Many of the NSF and SBIR/STTR investments made into the Southeastern New England region's ocean technology entities focus on defense, including research and product development related to unmanned undersea vehicles, enhanced sensors for advanced radar systems, and the use of marine energy for weapons.

Existing Assets and Businesses: Southeastern New England has a strong military presence, anchored by the US Naval Undersea Warfare Center in Middletown and the presence of many defense primes in the region, such as Lockheed Martin, Raytheon, Huntington Ingalls, and BAE Systems. These defense primes rely on local supply chains for their R&D and products, ranging across different technology types. These agreements are often privatized by nondisclosure agreements.

Risks and Regulation: Ocean technologies built for military applications must be hyperspecific to the standards and regulations of the federal government. Technologies are often procured through RFP processes, ensuring that companies meet the specific needs of military-funded projects and use cases.

Market Intelligence: Resources that can be referenced include:

- **Ocean Science and Technology:** An online publication dedicated to news on ocean technology, with a specific section focusing on defense and military applications.
- **Sea-Air-Space:** An annual conference connecting defense companies and startups to the navy, hosted by the Navy League of the United States.
- **DefenseScoop:** An online news outlet covering the latest news in defense technologies across multiple disciplines.
- **DefenseNews:** An online news outlet that takes a specific focus on naval technologies.

Use Case – Defense Capabilities for Contested Oceans

Tech: Ocean Robotics, Advanced Materials, and Marine Sensors

The US Naval Undersea Warfare Center (NUWC) in Middletown is the primary driver of defense activities in Southeastern New England, acting as a national leader in naval activity and innovation. Companies throughout the region service NUWC with R&D and product development, helping the navy achieve a plethora of goals related to research and defense exercises. Two examples of ongoing work in the region, with company names excluded for the sake of privacy, include the development of unmanned underwater vehicles (UUVs), built from advanced carbon fiber materials, for use in deepwater ocean research, and the creation of towed underwater vehicles, equipped with marine sensors, to ensure naval exercises avoid the habitats of at-risk forms of marine life. In a world of escalating conflicts on the water, these capabilities, and a plethora of others, help the US maintain its military supremacy over countries such as China and Russia.

Reliance on Maritime Trade

Intro: The maritime trade market has fully bounced back from COVID-19, continuing to be an essential aspect of the modern global economy. Around 80 percent of global goods are moved on ships,[84] including eleven billion tons of goods such as food, other commodities, pieces of infrastructure, and raw materials that run the world.[85] While the importance of this economy is inarguable, the United Nations projects that growth will plateau, suggesting saturation in the market. Still, marine vessels and the technologies that support them, including ports, continue to implement new technologies that make them "smarter" and more sustainable.[86]

Tech: The global reliance on water-related transport has brought newfound technological innovation to make shipping more efficient, cheaper in production, and more environmentally friendly. Technologies such as AI, digital twins, and ocean robotics and vehicles are all being used to increase industry-wide productivity and efficiency. Specifically, AI and ocean robotics are being used to redefine the operations and efficiency in "smart ports," or "modern and technologically advanced port[s] that [leverage] innovative technologies and data-driven solutions to enhance [their] operational efficiency, safety, and sustainability."[87]

Investment: To date, investment in smart port technologies is primarily driven by VC firms due to the stage of the industry and its technologies. Examples of investors include VC4A's Smart Port Challenge and Pier71, Singapore's maritime innovation investment entity. Regional investments supporting technologies related to smart ports and shipping include new gravimeters for ships, technologies that detect underwater sounds to ensure safe passage for ships and marine animals alike, and AI that helps ports recognize different ships and their parameters for increased optimization in docking.

Existing Assets and Businesses: Technologies related to smart ports and maritime shipping are in demand at the moment, with ample room for innovation in the market. Globally, Thetius recently published a high-level overview of the top technology companies contributing to new

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[84] Statista – Ocean Shipping Worldwide
[85] Review of Maritime Transport 2022 | UNCTAD
[86] Marine Vessel Market Size, Growth, Industry Forecast, 2028
[87] Port Technology International – What Is a Smart Port?

innovations in the space. Locally, Quonset Business Park and the New Bedford Ocean Terminal lead the way in port modernization, specifically built out to support offshore wind.

Risks and Regulation: While large ships and barges must maintain certain standards and documentation to travel at sea and dock at specific ports, there is continued room to innovate on the technologies found on both ships and port facilities. Risks in this market include susceptibility to macroeconomic trends (i.e., financial and natural disasters), the continued use of ports for smuggling illegal supplies and substances, and the often slow, bureaucratic nature of ports in adopting new technologies.

Market Intelligence: Resources that can be referenced include:

- **Ship Technology:** An international news outlet covering evolutions and innovations in maritime shipping.
- **Port Technology International:** A publication highlighting current events in port technologies.
- **North American Shippers Association:** A trade association of shipping companies and relevant supply chains.
- **Seatrade Maritime News:** An international publication highlighting news in the maritime shipping space.

Use Case – Smart Ports and Dockside Charging

Tech: AI and Ocean Robotics

Smart ports are equipped with numerous technologies, from AI systems to drones to facilities that allow for electric ships to dock and recharge. These technologies allow for ports to optimize their operations, reducing congestion and the potential for disastrous wrecks. Valenciaport in Spain partnered with NextPort to create a predictive AI software for monitoring the flow of trucks in and out of the port, creating the optimal flow of traffic for the port to maximize its import and export activities. This technology, applicable on both the land and sea sides of the port, helps the port forecast demand and make individual calculations that make each day run smoother. An example of a technology local to Southeastern New England with smart port applications is PowerDocks, an offshoot of E2SOL. These smart docks use state-of-the-art technology that charge autonomous vehicles on floating docks using solar energy. While currently used primarily for undersea and surface-level autonomous vehicles, along with electric recreational boats, these docks have potential to scale into a product that charges electric ships and barges.

Rise of Artificial Intelligence (AI)

Intro: AI, machine learning (ML), and data mapping encompass the use of new technologies to complete automated tasks using "human-like" learning.[88] AI and ML compose one of the world's largest emerging technological markets. Globally, the AI market is expected to surpass $1.3 trillion by 2030 with a CAGR of 36 percent from 2024 to 2030.[89] In general, AI and ML are perceived to have massive implications for human productivity, efficiency, and research capabilities, with blue economy applications being no different. The exploration of these new technologies, along with their promised impacts, is the primary driver behind AI and ML continuing to dominate the world's technology market in the coming years.

Tech: In the blue economy space, AI and other products have a variety of uses, including capturing data through oceanographic research, performing tasks related to manufacturing and shipbuilding, and operating aquaculture farms. A popular data mapping product early in the adoption of AI and its adjacent technologies is digital twins. The European Digital Twin of the Ocean is the largest of its kind, modeling the ocean's environments and trends to make predictions of future conditions and implications for commerce and livelihood.[90]

Investment: Companies in the AI space are currently primed for investment as the market sees exponential growth. Investment is driven by large technology companies, hedge funds, and private equity actors looking to capitalize on current opportunities for cornering market share. Smaller local companies in Southeastern New England have also seen venture investments into their operations to drive innovation and business growth. Federal investments, such as NSF programming and SBIR/STTR, are yet to catch up to the trend of AI in the region.

Existing Assets and Businesses: IBM and other advanced computing companies have emerged as leaders in ocean-related AI, helping companies build systems to use AI in ocean research, exploration, conservation, and commercialization efforts. Smaller companies are also driving new uses of AI within the blue economy. In Southeastern New England, companies like HavocAI, Spear AI, Infused Innovations, and BLUEiQ are redefining the use cases of AI in the ocean sector.

Risks and Regulation: AI is currently a nascent, vastly unregulated market, with the US and other major countries still figuring out exactly how to monitor and regulate advances in AI and their implications. The White House recently published its Blueprint for an AI Bill of Rights, but is yet to see anything formal passed into law. The upcoming 2024 presidential election may shift how the US goes about regulating the use of AI moving forward.

Market Intelligence: Resources that can be referenced include:

- **AI Magazine:** The online leader in discussing current events in the fast-paced environment of AI research.

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[88] SAS Institute – Artificial Intelligence
[89] Markets and Markets – Artificial Intelligence Market
[90] European Commission – European Digital Twin of the Ocean

- **The MIT Press Reader:** A leader in thought leadership at the intersection of the environment and modern technologies, including AI.
- **High Level Panel for a Sustainable Ocean Economy:** This NGO has taken a leading role in discussing how AI will be involved in the fight for ocean conservation and climate resilience.

Use Case – Digitally Twinning the Ocean

Tech: AI and Marine Sensors

Using a complex array of marine sensors across the oceans and seas of Europe, the European Union (EU) led the creation of the Digital Twin Ocean, a data-driven AI replica of the ocean with real-time updates and conditions. This digital twin, powered by Mercator Ocean International, gives the EU unprecedented access to key research and innovation that can wholeheartedly change the way ocean exploration occurs. Through the merger of many datasets, the EU's Digital Twin Ocean is the largest digital twin of a body of water and puts Europe ahead in the international game of ocean research and discovery. The open-source data tool, funded through multiple nations, is expected to be operational in late 2024.

Worldwide Environmentalism

Intro: Ocean conservation is considered a core piece of global environmentalism, aimed at preserving natural habitats across the world that yield human, animal, and plant health. The ocean covers the majority of the earth's surface and is a crucial piece of atmospheric health, global trade, food, medicine, and more. Its health is paramount to the blue economy.[91] The industry behind ocean conservation, dubbed the Ocean-Based Climate Solutions Market, is worth $10 billion worldwide as of 2022, and may grow up to $30 billion by 2029, a CAGR of 16.5 percent.[92] This market focuses on technology and other solutions that prioritize ocean health and preservation.

Tech: Various technologies are used in monitoring ocean health and intervening to ensure ocean health. For example, marine sensors can be used to help ships better understand where to release treated waste based on water composition and habitats. AI can be used to predict harmful maritime events, such as oil spills and red tides. Undersea robotics can dive to unprecedented depths to capture information on the ocean. These technologies, and more, continue to innovate on how humans both monitor and ensure overall ocean health.

Investment: Investors in ocean-related climate technologies include Katapult, Ocean 14 Capital, Capricorn Investment Group, and subsidiaries of major companies, such as BP Ventures. These

[91] Why Should We Care about the Ocean?
[92] Ocean-Based Climate Solutions Market

investors seek to fund nascent, innovative solutions to complex climate problems. Emerging ideas include focuses on carbon extraction, the health of biodiversity, and the capture of wave energy to drive ocean-related industry. The federal government is also an investor in ocean climate solutions. Regional investments into R&D include employing AI and marine sensors to better track ocean circulation and environmental shifts, using robotics to investigate the ocean's depths for potential solutions to preserving biological environments, and improving on acoustic communication for vehicles taking environmental measurements.

Existing Assets and Businesses: Ocean protection is a shared public and private responsibility, with many governments and NGOs working alongside private actors to prioritize maritime health. For example, the US prioritizes ocean health through its Office of Marine Conservation, housed in the Department of State, and programs through the Environmental Protection Agency. NGOs such as Oceana and the Ocean Conservancy help lead the fight for this work. Private industry actors, including companies such as ORPC and Ocean Infinity, drive innovation in ocean-based climate solutions.

Risks and Regulation: One potential risk in the space of ocean-related climate solutions is the speed at which progress is occurring. Ocean health is deemed a top priority for overall ocean health, with companies and governments pouring billions of dollars into solutions. At this scale, it can be difficult to assess which solutions are truly effective and which may even detrimentally affect the ocean moving forward.[93] More research is needed into efficacy and the potential harm of solutions as they are tested.

Market Intelligence: Resources that can be referenced include:

- **High Level Panel for a Sustainable Ocean Economy:** A global initiative serving world leaders in building momentum for a sustainable ocean economy.
- **Ocean Conservancy:** An NGO publishing industry-leading research and insights into ocean-related climate solutions.
- **Ocean Visions:** An environmental nonprofit providing valued thought leadership into solutions for ocean-related climate change.
- **UN Global Compact, Ocean Stewardship Coalition:** A global entity publishing reports on needs for smart ocean technologies.

Use Case – Exploring the Ocean's Depths for CO_2 Solutions

Tech: Ocean Robotics and Marine Sensors

To better understand how species at the depths of the ocean help move carbon dioxide (CO_2) from the ocean's surface to its deeper water, the Woods Hole Oceanographic

[93] Assessing the Potential Risks of Ocean-Based Climate Intervention Technologies on Deep-Sea Ecosystems

Institution (WHOI) developed a state-of-the-art undersea robot to assess water and species over one thousand meters below the surface.[94] The 2,500-pound unmanned underwater vehicle, dubbed *Deep-See*, is equipped with marine sensors and a camera system that allow for enhanced measurement of oxygen, currents, water properties, and even water sampling at depth.[95] The vehicle can transmit data in real time to onboard scientists, allowing for optimized ocean research and discovery. *Deep-See* is an example of R&D, driven by academia for both private and public uses, that helps Southeastern New England stay at the forefront of ocean technologies, research, and environmentalism. This use case also exhibits how multiple forms of ocean technology—in this case, both robotics and sensors—are combined to create innovative products.

Increase in Ocean Research

Intro: Ocean research is arguably the largest market driver of all ocean technology activities. A primary activity of the military, private companies, academics, and more, the pursuit for further knowledge on the ocean helps the world better utilize the ocean for everything from national defense to increased sustainability. Ocean-related research is clustered around a few core topics: the study of biodiversity via marine ecology; geosciences and their implications for oil, gas, and mineral extraction; oceanography; and climate-related studies.[96]

Tech: Various forms of modern technologies are used in exploring the ocean and capturing critical research. New AI systems are utilized to map the ocean and better understand its conditions and trends over time. Ocean robotics and their advanced materials can travel to previously unattainable depths to discover new species, rock formations, and other facts regarding the ocean floor. And modern marine sensors allow for reliable data capture in the harshest marine environments, gathering information in areas humans could not previously explore.

Investment: The federal government and private interests are the primary drivers of ocean research. The government, through NOAA and programs like SBIR/STTR, funds academic and business research into the ocean. Private companies, such as telecommunications entities and oil and gas miners, survey the ocean to better understand how they can deploy underwater infrastructure and facilities to capture profits. An emerging investment space within the private sector is ocean-related climate technology, which relies on ocean research to both innovate on existing climate solutions and mitigate negative impacts.[97]

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94 5 Essential Ocean-Climate Technologies
95 The Deep-See Towed Vehicle
96 Ocean Research Report: Emerging Topics and Opportunities
97 Oceans: A Vast Opportunity in Climate and Biodiversity Investing

Existing Assets and Businesses: Ocean research is driven by a mix of academic institutions, public-private partnerships, government entities, and private companies. NOAA maintains a list of "Ocean Enterprise" companies across the country that help lead the way in ocean research within the private sector. Major domestic academic and nonprofit players in the space include the Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, the Gulf Coast Research Laboratory, and the Bigelow Laboratory for Ocean Sciences.

Risks and Regulation: The ocean research market is rather unregulated, with the open waters available for research as long as domestic regulations are met surrounding where boats can go and when. Biodiversity and the surrounding environment must also be respected. The inherent risks in ocean technology lie in rough conditions, specifically for untested products. Deep-sea research is inherently dangerous for both humans and technology, as underwater pressure and above-water conditions can cause chaos. The now infamous explosion of the *Titan* sub is a prime example of how a lack of regulation and untested technology can lead to calamity in the ocean environment.

Market Intelligence: Resources that can be referenced include:

- **The Oceanography Society:** The world's leading trade association for ocean research and sciences.
- **Association for the Sciences of Limnology and Oceanography:** A publication-driven association focused on new research and innovation in ocean sciences.
- **Oceanographic Magazine:** A monthly print and digital outlet for news related to ocean exploration.
- **Applied Ocean Research:** A leading industry journal on discoveries related to the ocean.
- **Ocean and Coastal Research:** A free peer-reviewed ocean research journal.

Use Case – Sensors for Ocean Exploration and Knowledge

Tech: Advanced Materials and Marine Sensors

Ocean exploration is a cost-intensive process, typically requiring large-scale funding from a private entity or the federal government for R&D and access to necessary deep-sea technologies. Rhode Island–based Juice Robotics is working to shift this paradigm. Their small-scale marine sensor system can be attached to any ocean vessel, from a Jet Ski to a deep-sea underwater vehicle, and capture various forms of customizable marine data. These sensor systems can fit in carry-on luggage, are cost-effective, and ultimately democratize the process of researching the ocean. Their state-of-the art packaging, which incorporates advanced materials into a pressure-resistant pod of sensors, allows the product to consistently capture high-quality data for a fraction of the normal cost. Juice Robotics also works with Massachusetts-based EdgeTech to continue innovation on the sensor system's acoustic communication capabilities.

Evolution of Aquaculture

Intro: Aquaculture is a massive $220 billion global industry, with projected growth up to $332 billion by 2032.[98] Over 50 percent of human consumption of seafood stems from aquaculture, a percentage that is anticipated to continue rising.[99] The aquaculture market includes the nonfishing production of seafood and aquatic plants for consumption and other uses. Aquaculture is particularly prevalent in the US and Asia Pacific regions. Key sectors in the aquaculture space include fish, shellfish, and aquatic plants, such as kelp. Key market drivers include the increasing importance of seafood as a sustainable source of food, the growing population of Earth, and niche demand from the pharmaceutical industry for undersea plants and animals.

Tech: Modern technologies are increasingly prevalent in the cultivation and management of aquaculture systems. For example, aquaculture farms are relying on AI systems, marine sensors, and other forms of robotics to do everything from feed fish to track their behavior and survival. Increasingly, across all activities, technology is becoming embedded into ocean-related processes and activities. These technologies will continue to see increased utilization in this industry to limit cost-intensive underwater manual labor.

Investment: Investment in these technologies has grown in recent years. With $2.2 billion in new funding for aquaculture in 2023, including Indonesia's eFishery becoming the first unicorn in the aquaculture space, the industry is supported by broad private investment.[100] Key private players include Aqua-Spark, S2G Ventures, CREO Syndicate, and many others, according to the Aquatic Network.[101] Regional investment from the federal government includes research into renewable energy to fund aquaculture activities, innovative forms of marine infrastructure, and spending on marine sensors that optimize aquaculture processes and fish populations.

Existing Assets and Businesses: Though Rhode Island's existing value of aquaculture products is low ($82 million in 2022), 11 percent growth from 2021 suggests momentum in the space.[102] The recent breaking of ground on the Matunuck Shellfish Hatchery and Research Center in South Kingstown, RI, further positions the Southeastern New England Ocean Tech Hub to pursue forms of R&D relevant to AI and marine sensor use in local aquaculture. Companies such as SeaDeep

98 Aquaculture Market Size to Hit USD 332.28 Billion by 2032
99 NOAA – Aquaculture
100 Where Has the Most Venture Capital Been Invested in Aquaculture? | The Fish Site
101 Aquaculture & Aquaponics Funding and Investments
102 Aquaculture in Rhode Island 2022

can play a key role in product creation to develop a localized supply chain for these technological uses.

Risks and Regulation: Risks to consider related to aquaculture technologies center around the quality, maintenance, and consistency of marine sensor systems. These high-technology sensors must survive various underwater conditions and continue to produce results, with a high cost of labor associated with maintenance.

Market Intelligence: Resources that can be referenced include:

- **National Aquaculture Association:** The national trade association for the aquaculture industry.
- **The Fish Site:** A knowledge-sharing platform for aquaculture industry leaders and innovators.
- **Aquaculture Magazine:** The leading aquaculture magazine in the world.
- **Aquaculture North America:** A trade publication for aquaculture industry professionals.
- **Aquatic Network:** A resource for businesses and allied organizations to use in connecting with customers and supporters.

Use Case – Tracking Fish Populations with AI and Marine Sensors

Tech: AI and Marine Sensors

An emerging use of AI and marine sensors in the process of aquaculture management is to track fish volume, health, and individual needs. Cermaq Global, an international salmon farming company based in Norway, utilized Norway-based startup BioSort to develop the iFarm, a system that relies on marine sensors and machine learning to assess the number of fish, fish size, number of sea lice, and possible signs of the disease within an individual fish farm. This system ensures fish health over time, optimizes feeding, and limits staffing needs, solving multiple market inefficiencies for aquaculture farmers. The iFarm is supported by Seafood from Norway's robust approach to innovating the country's aquaculture industry.

Implementation of Underwater Infrastructure

Intro: The global underwater infrastructure construction industry is a massive $70 billion market, with projected growth up to $107.4 billion by 2030—a CAGR of 8.2 percent in the coming seven years.[103] The underwater infrastructure is propped up by increasing demand for at-sea facilities and communication technologies. Underwater infrastructure is needed for energy-creating activities such as offshore oil rigs, wind farms, and other forms of marine energy capture. Infrastructure is also needed to support massive communications companies with deploying

[103] Water Infrastructure Construction Market Size, Share and Growth [2030]

necessary cables for technologies such as 5G and other forms of faster connectivity via the internet.[104] As the global population increases, both of these market drivers are amplified.

Tech: The deployment, operation, and maintenance of underwater infrastructure still requires a mix of human labor and technology products. Key forms of technology include advanced materials and composites for creating pipelines and other marine facilities, ocean robotics for implementing assets and maintaining them throughout their lifespans, and marine sensors for understanding the health and efficacy of individual assets as part of larger systems.

Investment: Underwater infrastructure projects are incredibly capital intensive, typically funded by a high-earning, multinational company with the funds to deploy new infrastructure. These companies, such as wind, oil, and gas and telecommunications giants, typically rely on a blend of their own capital, bank financing, and private investment from private equity players to fund infrastructure deployment. Local investments into the technology that drives infrastructure deployment includes VR and AI systems that help ships and AUVs navigate wind farms, research into materials that make pipeline development and implementation more sustainable, and the continued development of undersea robots that can assist in infrastructure implementation and maintenance.

Existing Assets and Businesses: Major companies known for their work in underwater infrastructure deployment include Cemex, Siemens, Conmix, and Underwater Construction Corporation. Companies in the Southeastern New England region that support underwater infrastructure development include Composite Energy Technologies, Riptide Autonomous Solutions, and E2SOL.

Risks and Regulation: The implementation of underwater infrastructure is a capital-intensive, risk-ridden effort that comes with a plethora of regulations from national and international laws. Robust environmental impact statements, surveying efforts, and years of permitting and public politics go into the implementation of underwater cables, pipelines, and other facilities. These projects are heavily monitored by watchdogs due to the history of negative externalities stemming from these projects: oil spills, environmental degradation, and loss of marine biodiversity.

Market Intelligence: Resources that can be referenced include:

- **WaterWorld:** An online publication with a focus on underwater asset and utility management.
- **Water Online:** A news outlet covering current events in water-based developments, from commercial to industrial projects.
- **Construction Journal:** The leading trade publication for construction-related innovations and current events.

[104] The Rise of 5G Continues to Drive the Proliferation of Subsea Cables

- **Underground Infrastructure:** An online news outlet dedicated to covering projects with underground infrastructure components.

Use Case – Maintenance of Key Pipelines and Cables

Tech: Ocean Robotics

Offshore wind is an increasingly large driver of demand for underwater infrastructure, from the implementation of cables to their ongoing maintenance, required by federal regulations. Woods Hole Oceanographic Institution, in partnership with the Massachusetts Clean Energy Center, is aiming to help offshore wind companies optimize their operations and maintenance activities with new autonomous undersea vehicles (AUVs) that can detect cable health and irregularities using magnetometers and a side-scan sonar system. This AUV, dubbed REMUS, can limit the need for the human and ship capacity typically responsible for such operations and maintenance, saving wind companies dollars immediately in their ongoing efforts to preserve and optimize their existing infrastructure assets.

Deep-Sea Mining

Intro: Marine mining is a swiftly growing global maritime market, with a projected growth of 33.8 percent per year from 2023 to 2032, growing the market from $2.3 to $41.3 billion.[105] Deep-sea mining presents an economic opportunity, driven by the increasing demand for metals and minerals crucial for modern technologies, especially those related to renewable energy and electric vehicles. The ocean floor contains vast deposits of valuable resources like cobalt, nickel, copper, and rare earth elements, which are essential for batteries, electronics, and other high-tech applications. The deep-sea mining industry is incredibly controversial on a global scale, with only a few countries supporting these activities to date while many oppose these operations.[106]

Tech: Ocean robotics are the primary technology used for modern deep-sea mining. Specifically, remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) can reach new depths in the ocean and complete mining-related tasks. These tasks may include surveying, drilling, collecting minerals, and more. Deep-sea mining is a prime example of how ocean technologies can change the makeup of a global industry—the development of new high-tech robots allows deep-sea mining to occur efficiently and precisely in a manner human workers cannot replicate. Marine sensors are also utilized in surveying the seafloor.

Investment: The ROI of deep-sea mining is subject to debate. Through a series of reports in 2023–24, Planet Tracker, a leading ESG investment think tank, portrayed the deep-sea mining market as not only environmentally harmful but a massive financial risk for institutional investors.

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[105] Marine Mining Market Size – Global Industry, Share, Analysis, Trends and Forecast 2023–2032
[106] The Main Players in the Push towards Deep-Sea Mining | Reuters

[107] Still, regional investments are occurring into activities related to deep-sea mining, including new robotics technologies for seafloor surveying, better understanding the recycling potential of ocean minerals used in batteries and other energy sources, and marine sensors that assists with seabed research.

Existing Assets and Businesses: Deep-sea mining is an incredibly nascent industry, with few players currently having operating permits to conduct mining operations. As of April 2023, only thirty-one permits existed to mine in the ocean, with most of this work occurring in the Pacific Ocean. The Metals Company is a major international corporation driving deep-sea mining in the Pacific. Other companies to watch include Moana Minerals, Loke Marine Minerals, and Transocean.[108]

Risks and Regulation: The deep-sea mining opportunity is mitigated by the potential risks associated with the destruction of underwater ecosystems, biodiversity, and many other potential impacts of an area where much is still undiscovered. The International Seabed Authority is charged with advancing policy and regulations to govern future exploration, taking a cautious approach to date by calling for more research before it grants approvals for mining operations. This action is pitting countries against one another as some look to fast-track deep-sea mining licenses, while others support a more drawn-out and research-driven decision-making process.

Market Intelligence: Resources that can be referenced include:

- **National Mining Association:** The leading trade association for the national mining industry.
- **Marine Geology:** A journal on innovative findings related to geological processes in the ocean.
- **Engineering and Mining Journal:** The leading publication for global news related to the mining industry.

Use Case – ROVs for Seafloor Surveying

Tech: Ocean Robotics

To assess potential locations for mining activities, corporations have enlisted remotely operated vehicles (ROVs) to survey the conditions of the seafloor, looking for traces of specific minerals. This surveying is also meeting the UN's requirement for ocean floor surveying to occur before deep-sea mining happens at scale. EDDY Pump, an ocean robotics company in California specializing in technologies related to dredging, mining, and pumping, developed two tethered ROVs that can assist deep-sea mining efforts with both surveying and dredging the ocean floor. Their ROVs, attached to a surface vessel, can reach the seafloor and gather samples of the bedrock of potential sites, allowing humans on the

[107] How to Lose Half a Trillion
[108] 10 Deep Sea Mining Companies to Watch in 2024

aboveground vessel to search for desired minerals. If a site is deemed promising, another, larger ROV can be used for dredging the ocean floor due to pump attachments. This ROV is controlled by an aboveground operator and can begin to gather minerals en masse before they are transported back to the surface. These ROVs allow ocean mining to occur in places previously inaccessible to humans.

Risks to Market Entry and Expansion

In the following section, we profile a variety of risks that may impact the market entry and expansion of ocean technologies. These findings can be a limiting factor to the region's Ocean Technology sector, or they can serve as opportunities for companies to identify and develop solutions to create positive economic opportunity.

Ocean Robotics: Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), and Autonomous/Unmanned Surface Vehicles (ASVs and USVs)

Operational Costs: The startup and operational costs of developing ocean robotics are incredibly high, hindering startups and other smaller companies from entering this market. Due to their highly technical nature, vehicles cost anywhere from $500,000 to $12 million, with additional costs associated with exploration and surveying activities, maintenance, and storage.[109] These costs can limit the adoption of these ocean robotics, but are still typically less than keeping a vessel at sea for comparable work.

Testing and Evaluation: Access to instrumented test and evaluation facilities are limited, including in-water ranges that are needed as part of the product development process. The provision of local ranges accessible to AUV companies would significantly de-risk future product development, testing, and evaluation of AUVs.

Communication Systems and Other Hazards: Consistency with communication and navigation systems is a difficulty for operating and maintaining different forms of ocean robotics. The increased pressure and hazards of underwater habitats, varying temperature gradients, and other ambient noises all hinder the reliability of these robotics when in use.

Semiconductor Shortage: With the world in a semiconductor shortage from 2020 to 2023, and the shortage still not fully solved for, undersea vehicle manufacturing and operations have been limited. While this stunted growth

[109] Markets and Markets – Autonomous Underwater Vehicle Market

will stabilize in the medium term, vehicular development at scale has missed a few years of expected advancement.

Safety for Marine Life: Ample concerns and standards exist surrounding the use of ocean robotics in proximity to different marine species and geological structures.[110] The line between safe research activities and habitat disruption and destruction is a fine one. Larger robotic vehicles have the potential to leave lasting damages to habitats if the controller and programming are not sufficiently sensitive to environmental conditions.

Battery Size: Currently, a limiting factor in the utilization of AUVs is their battery size. These high-energy mechanisms can operate anywhere from five hours to multiple weeks, depending on battery size.[111] Larger batteries, which are required for longer missions, are cost intensive and harder to build. This hindrance does not allow for longer-term research missions or deeper dives toward the ocean floor. Larger batteries that offer longer-term missions are also heavier, limiting maneuverability of the AUV.

Lithium Shortages: As demand for electric vehicles (EVs) rises, economists and corporations are predicting a lithium shortage.[112] Lithium is the key element needed to produce modern batteries for EVs, including ROVs. With the lithium shortage coming as soon as 2025, more innovation is needed to both extract lithium and assess other mechanisms for powering ROVs.

Harsh Conditions and Hazards: Ocean conditions and weather hazards often make the utilization of AUVs difficult. Depth, salt water, strong currents, large waves, choppy water, and other weather-related happenings all put AUVs at risk of disruption and damage especially during launch and recovery. The technical complexities and consistent wear and tear on vehicles can put them at risk of becoming dysfunctional. This effect limits the use of these products and their benefits.

[110] Deep Ocean Education Project – Marine Technology
[111] Blueye Robotics – The New High Capacity Battery
[112] McKinsey & Company – How Battery Makers Can Respond to Surging Demand from EVs

Geopolitical Considerations: All three of the largest militaries in the world—US, China, and Russia—are all invested in both AUV technologies and broader maritime safety for their nations and relevant trade activities. As countries take on global stances in the ocean, such as China's aggressive defense of the South and East China Sea, AUVs are increasingly central.

Marine Sensors

Machine Maintenance: Maintenance of marine sensor networks is incredibly cost and time intensive. Sensors often need care on a monthly basis. Issues related to biofouling and other harsh ocean conditions only increase the likelihood of needed maintenance and repairs.

Sensor Calibration: Consistent calibration is needed for sensors to work in tandem to gather information on a variety of aspects of oceanographic conditions. With the harsh conditions of the ocean comes consistent issues with this calibration and connectivity. While systems can operate without 100 percent of sensors fully functioning, more resistant sensor networks are still needed for sensor implementation to remain a worthwhile investment.

Sensor Standards and Accuracy: The marine sensor industry lacks standardized forms of testing, accuracy, and data transparency. While individual companies produce their own sensors for a variety of uses, increased standards could help ensure data quality and improve the capabilities of smaller companies to succeed in the current market.

Advanced Materials

Rising Manufacturing Costs: The sourcing and manufacturing of advanced materials are still often cost intensive compared to more established materials and processes. Costs will likely dip over time, making increased utilization of these materials more feasible. But for now, adoption is still somewhat low due to higher costs.

Supply Chain Disruptions: Supply chain disruptions felt throughout the COVID-19 pandemic slowed the rates of both advanced material manufacturing and adoption. As supply chains return to their normal efficiency, it is anticipated that manufacturing and adoption will ramp up.

Artificial Intelligence, Machine Learning, and Data Mapping

High Startup and Compliance Costs: Purchasing, implementing, operating, and maintaining AI systems comes with a high cost compared to existing operations, creating a barrier to entry for many companies across industries. While experts and economists argue that AI systems often yield an increased profit margin in the mid to long term, this is an investment that many cannot afford to make. Furthermore, many blue economy companies utilizing AI have to meet high levels of compliance and regulation with their systems and use for environmental reasons. These additional costs further hinder adoption.

Lack of Education, Awareness, Concerns: Many companies, individual vessel operators, and other components of the blue economy ecosystem are slow to adopt AI and other modern technologies for a plethora of reasons. As nations push for adoption due to increased efficiency and productivity, it will remain a challenge to gain buy-in from these often small and midsize companies who are not forward thinking.

Lack of System Integrators and Other Experts: Individual startups, more established companies, and other research bodies working with AI and its applications need experienced workers and systems integrators to successfully adopt, implement, and utilize new technologies. As the AI industry develops, this workforce remains somewhat limited on all fronts.

Deep-Sea Representation: As digital twins are developed for specific regions of the ocean and even the ocean as a whole, there is an inherent flaw in design: digital twins rely on available data, and data does not exist on many of the ocean's unexplored depths. Therefore, digital twins of the ocean remain incomplete to date.

Investment Trends: Research and Development Pathways

Ocean Tech Research, Development, and Federal Contracts

This section highlights an understanding of R&D activities and federal awards around ocean technology focus areas, and includes the following data sources:

- SBIR/STTR
- Patents
- National Science Foundation Awards
- USA Spending Custom Awards Data

To supplement understanding of the ocean technologies of Undersea Robotics; Autonomous Underwater Vehicles; Marine Sensors; Advanced Materials; and Artificial Intelligence, Machine Learning, and Data Mapping, the following search terms were used:

Environment Search Terms

- Undersea
- Ocean
- Marine
- Estuary
- Coastal
- Water
- Underwater
- Hydro
- Hydrological
- Offshore
- Blue Economy

Science & Technology Search Terms

- Marine Science
- Hydrography
- Oceanography
- Autonomous
- Sensors
- Advanced Materials
- Robotics
- Unmanned Systems
- Engineering
- Energy
- Aquaculture
- Exploration
- Composites
- Battery/Batteries

The following section presents information about federal awards (e.g., from NOAA, DoD, EDA)—both research and contract awards and National Science Foundation awards made over the past five years (FY 2018–23).

Summary Findings

SBIR/STTR Awards

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are highly competitive programs that encourage domestic small businesses to engage in federal research and R&D with the potential for commercialization. This analysis identified SBIR and STTR awards across ocean technology firms located in Rhode Island and Massachusetts.

Topics: Autonomous underwater vehicles (AUVs) and unmanned underwater vehicles (UUVs), energy, marine sensors, batteries, propulsion, aquaculture, monitoring and analytics, communications—at least 112 SBIR/STTR awards totaling more than $60 million since 2019 for Ocean Tech

SBIR/STTR Awards in Rhode Island and Massachusetts: Twenty-three companies with multiple awards: Triton Systems, Inc., Charles River Analytics, Inc., Giner Inc, Physical Sciences Inc., Boston Engineering Corporation, Radiation Monitoring Devices, Inc., **Littoral Power Systems, Inc.,** JPAnalytics LLC, Scientific Systems Co Inc, Resolute Marine Energy, Inc., **Mikel Inc**, EOM Offshore LLC, Triton Anchor LLC, TelAztec, Spectral Sciences, Inc., Seacorp LLC, **Ocean Acoustical Services and Instrumentation Systems, Inc., High Rez Consulting, Inc., Jaia Robotics, Inc.,** FTL Labs Corp, BioNet Sonar, Armada Marine Robotics, Inc., Aptima, Inc. ***Companies listed in bold are located in the Southeastern New England region.**

Activity In: Twenty-one cities with multiple awards: Chelmsford, Cambridge, Newton, Boston, Woburn, Middletown, Waltham, Andover, Watertown, Lexington, Burlington, Pocasset, New Bedford, Falmouth, East Falmouth, Bristol, North Falmouth, Littleton, Jamestown, Bedford, Amherst

Agency Funders: Department of Defense, Department of Energy, National Science Foundation, Department of Commerce, Department of Agriculture, NOAA

US Patents

Topics: Remote sensing, robotics, aquaculture, underwater autonomous vehicle (UAV), advanced materials, sensors, forecasting, wastewater treatment, coastal resilience, energy, hydrokinetic energy, fisheries, autonomous materials moving, communications—at least twenty-three awarded patents since 2019 for Ocean Tech

Patent Assignees:

- **Private:** Raytheon Company, Autonomous Marine Systems, Inc., Siren Marine LLC, The Tomorrow Companies Inc., Green NanoTech Labs, LLC, Zero Discharge, LLC, The Emerald Tutu Inc., Innovasea Systems, Inc., Littoral Power Systems, Inc., Textron Innovations Inc., Clearview, Inc., Gradiant Corporation, Giner Inc.—starting to see patterns emerge, with highlighted companies also receiving SBIR/STTR awards

  - **Public:** Northeastern University, Woods Hole Oceanographic Institution, Massachusetts Institute of Technology

Activity In: Waltham, Newport, Providence, New Bedford, Somerville, Woods Hole, Boston, Cambridge, Woburn, Newton Center, Brookline, Newton

National Science Foundation

Topics: Sensors, ocean monitoring, unmanned vehicles, oceanography, sample collection, communication, fisheries—**at least fifty NSF awards totaling $16 million since 2019 for Ocean Tech**

Recipients:
- Woods Hole Oceanographic Institution
- Brown University
- University of Rhode Island
- University of Massachusetts, Dartmouth
- Tufts University
- Trustees of Boston University
- Gordon Research Conferences
- Harvard University
- University of Massachusetts, Amherst
- Northeastern University

NSF Award Abstract Examples

- **PIRE: Multidomain, Multiscale, Policy-Aware Digital Twin for Offshore Wind Energy Infrastructure** – Most offshore wind turbines are typically designed for a service life of twenty-five to thirty-five years. In a few decades, the industry will face a consequential decision-making challenge as to whether to decommission, rebuild, or retrofit these assets. Here, the team develops a joint modeling framework for decision-making about offshore wind turbine safety, operation and maintenance, life extension, and design. (Babak Moaveni at Tufts)

- **Planning and Control of Heterogeneous Robot Teams for Ocean Monitoring** – This project realizes an integrated, heterogeneous robotic approach toward large-scale ocean monitoring for environmental mitigation and search and rescue operations. It enables data-driven tracking and mapping of various physical, chemical, and/or biological processes of interest in marine environments, such as tracking contaminant dispersion or missing aircraft. This project significantly improves the state of the art in ocean search and monitoring technology, helping us understand and harness ocean currents and improve the health of the world's oceans. (Nora Ayanian at Brown)

- **Advancing Underwater Robots in Complex Environments** – The health of underwater infrastructure is extremely important for reliable energy and the blue economy. While these complex environments are challenging and risky for human divers to perform repeated surveys, underwater robots must be considered as viable candidates. This award supports fundamental research in robot design, control, and perception to overcome the challenges faced in complex underwater environments. (Mingxi Zhou at URI)

DARPA

There are limits to what is revealed about DoD spending, especially DARPA.

- Most of DARPA spending is not revealed, but they have overviews of current research here: https://www.darpa.mil/our-research
- Archived projects are here: https://www.darpa.mil/archive/our-research

Of Interest to the Ocean Tech Project: Ocean Tech–related DARPA projects

- No Manning Required Ship (NOMARS) program seeks to design a ship that can operate autonomously for long durations at sea
- The Persistent Aquatic Living Sensors (PALS) program aims to leverage biology to augment the Department of Defense's existing hardware-based maritime monitoring capabilities
- Manta Ray is an effort involving unmanned undersea vehicles (UUVs) that operate for extended durations without the need for human-present logistic support or maintenance, offering the potential for persistent operations in forward environments
- Reefense seeks to develop self-healing, hybrid biological and engineered reef-mimicking structures to mitigate the coastal flooding, erosion, and storm damage that increasingly threaten civilian and DoD infrastructure and personnel

USA Spending – Ocean Tech Data

566 Federal Contracts Totaling $1.3 Billion

- Matching at least one Environment Search Term *and* one Science & Tech Search Term. FY 2019 to FY 2023 with primary place of performance in Rhode Island or Bristol, Plymouth, Norfolk, and Worcester Counties, Mass.
- Award agencies include Department of Defense, Federal Acquisition Service, Natural Resources Conservation Service, National Oceanic And Atmospheric Administration, Veterans Affairs, Environmental Protection Agency, Bureau of Ocean Energy Management, US Coast Guard, National Park Service, Public Buildings Service, National Institutes of Health
- In RI, primarily Department of Defense related

Private Investment and Venture Capital

A core component of understanding the market for ocean-related technologies is taking a close look at the various components of the investment ecosystem. Venture capital firms, private equity groups, and other financial institutions are investing capital that is driving the creation of startup companies and setting the stage for the future of ocean technology. The goal of this investment analysis is to help clarify and outline key stable and emerging trends, as well as identify key investors, companies and potential partners within the region, and areas of concentration in a dynamically evolving space.

In What Spaces Are Investors Investing?

Startup companies have received investor attention for their efforts in developing technologies, including:

- Autonomous undersea vehicles
- High-performing and low-carbon electric boat motors
- Generation of power underwater from aluminum seawater fuel cells
- Collection of ocean data and leveraging of artificial intelligence and machine learning capabilities to predict weather patterns

Barriers to Ocean Tech Investment

- Pathways to commercialization remain nascent
- Market demand for ocean tech technology is unclear besides a few key sectors
- Investors are still learning about ocean economy
- There could be barriers to entry for newer startups as the market consolidates and begins to define itself

Who Are the Key Investors?

Investment capital has flowed from well-established accelerators/incubators in the Ocean Tech space, such as MassChallenge, Techstars, Y Combinator, and BlueSwell, along with regional university-affiliated investment funds, including Brown University, Tufts University, and UMass Dartmouth, and venture-backed firms such as Toyota Ventures, Thiel Capital, NextGen Venture Partners, and Dudley Fund (based in Vermont).

Our data analysis and online research has uncovered a list of Ocean Technology investors that are somewhat applicable to this opportunity. Four of these private investor funds are detailed below; additional funders of interest include Faber, Lux Capital, AiiM Partners, and Katapult Ocean.

- **Ocean 14 Capital (O14C)** – Ocean 14 Capital (O14C) is a leading private equity growth firm in the blue economy. It focuses on achieving market returns with impactful investments by supporting late-stage ocean businesses to introduce data-driven, tech-enabled, circular platforms. The Capital fund is backed by founders with more than sixty-five years of finance and impact experience, and advised by top investors and marine experts, O14C's Fund 1. It is based in London and targets European (two-thirds of investments) and US (one-third of investments) companies in sustainable fishing, aquaculture, alternative proteins, and ocean conservation. With a surpassed €150 million fund target (US$162 million), it aimed for a €200 million (US$216 million) total by the end of 2023.

- **Capricorn Investment Group** – Capricorn, a leader in sustainable investing for over twenty years, aims to provide enhanced risk-adjusted returns while addressing environmental and social issues. Serving various clients, including families and institutions, through impact investment products, Capricorn manages over $9 billion in assets with thirty-three employees across New York City and Palo Alto. Their mission is to showcase the investment potential in breakthrough solutions to global challenges. With a diverse team focused on stewarding assets sustainably, Capricorn emphasizes strategic and creative thinking. One such project example includes Saildrone.
- **BP Ventures** – Focused on advancing BP's net-zero ambition, BP Ventures invests in new energy businesses, particularly in key areas like production, low-carbon energy, and innovation. BP Ventures invests in companies across the globe, but does have a dedicated focus on emerging markets like China and India. They have invested $1 billion in seventy companies, actively managing thirty of those. Their investments span various sectors, from AI to desalination technology, aiming to reduce carbon emissions and enhance operational efficiency globally. A notable investment includes Blue Ocean Seismic Services.
- **Tribe Capital** – Tribe Capital, established in 2018 in Menlo Park, California, manages over $1.6 billion in assets, employing product and data science to craft personalized solutions in ventures and crypto. Their portfolio spans global regions with notable investments including Carta, Relativity Space, and Kraken. They focus on frontier technologies like 3D printing rockets and sustainable farming. Despite market challenges, they navigate the venture capital landscape with innovative strategies. Their diverse investments range from enterprise software to healthcare, aiming for impactful outcomes globally.
- **Slater Technology Fund** – Founded in 1997, the Rhode Island–based Slater Technology Fund is a nonprofit seed fund working to invest in new venture development throughout the state. To date, the fund has helped companies raise $690 million, investing $35.7 million of its own capital. While its main focuses are on software, energy, and life sciences, the fund has explored investment into ocean technology companies with overlaps in these spaces. Investment recipients include Flux Marine, FarSounder, and Arctura.

These four spotlights provide a flavor of the types of private investment opportunities that exist for current and future Rhode Island–based maritime businesses, as well as highlight which key funders could be sighted on current public investment activity into Rhode Island.

PitchBook Data Analysis

Data from PitchBook, the leading resource for comprehensive data, research, and insights spanning the global capital markets, was used to understand the blue economy investment ecosystem in the last decade. The analysis tracked nearly 1,100 ocean tech–related deals globally. The analysis identifies notable geographic hubs, key investors and startups, and areas of concentration within the ocean tech space.

Funding by Ocean Tech Subsector

Within the blue economy, the strongest emphasis of investment funding broadly focused on the desire to better understand the ocean ecosystem because such a huge swath of the ocean environment remains undiscovered and commercially untapped. While there is considerable momentum, particularly in markets that focus on developing advanced materials for clean energy generation, or providing support for ocean shipping, there is inherent market risk because, historically, finding investment-grade projects in the ocean space is difficult, which makes some investors hesitate. Public investors such as the US Environmental Protection Agency and the US Department of Defense have invested in ocean mapping technology, which has been critical to de-risking the ocean tech market and creating proof of concepts of investable opportunities for private investors. Many of the current slate of investors are now seeking to capitalize on this momentum by creating ocean-focused teams and investment funds that will set the course of the ocean tech investment ecosystem over the next half decade.

Rhode Island and Massachusetts Private Investment by Subsector

Subsector	Deals RI & MA Region	Companies RI & MA Region	Total Deal Amount RI & MA Region
AI, Machine Learning, and Data Mapping	29	6	$134,390,000
Autonomous Underwater Vehicles	29	5	$110,880,000
Ocean Robotics	24	6	$113,430,000
Advanced Materials	20	3	$110,420,000
Marine Sensors	15	6	$53,900,000

Source: Fourth Economy analysis of PitchBook Data, 2014–23

Companies in the region received private investment across all ocean tech subsectors. These investment trends capture technologies applied in the ocean, sea, or underwater context. In terms of deal volume, the highest number of deals went to companies focused on Autonomous Underwater Vehicles; Ocean Robotics; and AI, Machine Learning, and Data Mapping. In terms of dollar amount, the companies within Ocean Robotics; AI, Machine Learning, and Data Mapping; Autonomous Underwater Vehicles; and Advanced Materials received large amounts of private investment.

Regional Share of Global Private Investment by Subsector

Subsector	Deals Region % Share of Global Total	Companies Region % Share of Global Total	Total Deal Amount Region % Share of Global Total
AI, Machine Learning, and Data Mapping	6%	5%	9%
Autonomous Underwater Vehicles	10%	7%	3%
Ocean Robotics	7%	6%	3%
Advanced Materials	7%	4%	16%
Marine Sensors	4%	5%	1%

Source: Fourth Economy analysis of PitchBook Data, 2014–23

From 2014 to 2023, companies in the region represented a large share of global investment activity within the Ocean Tech space. Autonomous Underwater Vehicles (AUVs) are a regional strength. Companies within the AUV subsector in the region represent 10 percent of the global private investment deals for AUVs and 7 percent of the AUV companies receiving private investment globally. AI, Machine Learning, and Data Mapping is another strength, with companies in the region receiving 9 percent of the private investment dollars for such firms globally. Advanced Materials is an emerging industry. Although companies in the region focused on Advanced Materials represented 4 percent of companies receiving private investment, they represented 7 percent of deals and 16 percent of investment dollars.

Regional Companies Receiving Private Investment

An analysis of PitchBook data identified sixteen ocean tech companies in Rhode Island and Massachusetts that received private investment. These companies work across ocean tech subsectors, including in businesses related to unmanned vehicles, computer hardware, electrical equipment, commercial and marine transportation, clean technology, energy, artificial intelligence, Internet of Things, and aquaculture.

Company	Ocean Robotics	Autonomous Underwater Vehicles	Marine Sensors	Advanced Materials	AI, Machine Learning, and Data Mapping
Greensea IQ (was Armach Robotics)*	✔				
Blue Water Metrics			✔		
CoastalOceanVision			✔		
Current Lab					✔
Fleet Robotics	✔				
Flux Marine				✔	
Jaia Robotics	✔	✔	✔		
Juice Robotics	✔	✔	✔		✔
Open Water Power (acquired by L3 Harris)				✔	
REGENT				✔	
Riptide Autonomous Solutions (acquired by BAE)		✔			
Salient Predictions					✔
Sea Machines Robotics	✔	✔			✔
SeaDeep			✔		✔
SeaTrac	✔	✔			✔
VerAI Discoveries					✔

Source: Fourth Economy analysis of PitchBook Data, 2014–23

***Note: Bolded companies in the table above are located in the Southeastern New England region.**

- **Armach Robotics** – Developer of ship husbandry robots designed to help in ship maintenance. The company's product offers proactive in-water cleaning service operated on industry-level navigation and operational platform, to deliver accurate, repeatable inspections that enable actionable hull intelligence, enabling customers to decrease carbon emissions and save on fuel costs.
- **Blue Water Metrics** – Developer of a global ocean monitoring system designed to fight climate change. The company's system is a unified cloud database that can extract data

from around the world, partnering with research institutions and volunteer organizations that gather data from specific industries or regions and deploy new sensors on oceangoing vessels to gather ground-truth data, enabling scientists and maritime industries to tackle environmental challenges.

- **CoastalOceanVision** – Developer of underwater measurement and observation systems designed to offer plankton imaging systems and cabled seafloor observatories to clients. The company's systems use stereo-imaging vehicles with a fully customizable sensor package for high-data fisheries and habitat monitoring, enabling clients to help people analyze aquatic attributes accurately and rapidly.
- **Current Lab** – Developer of ocean forecast platform designed to offer accurate forecasts of ocean conditions. The company's platform utilizes 3D sound speed models to offer hyperlocal coastal current forecasts in real time, enabling maritime industry to avail oceanographic insight to optimize their decision-making.
- **Fleet Robotics** – Manufacturer of a robotics system intended to provide underwater robotics. The company provides offshore procedures like routine inspection and maintenance of ocean-dwelling products, enabling businesses that operate underwater with enhanced workflow.
- **Flux Marine** – Developer of electric boat motors intended to provide power and reliability while reducing pollution. The company's motors leverage solid-state components to facilitate zero emissions with increased performance parameters as well as minimize carbon footprint and are virtually maintenance-free, enabling marine industries with increased transport efficiency and reduced noise, air, and water pollution.
- **Jaia Robotics** – Developer of microsized aquatic drones designed to change the paradigm in aquatic data collection. The company's technology is multisensor configurable requiring minimal user training with wide-ranging capabilities compared to traditional crewed or uncrewed data collection systems, enabling clients with affordable aquatic data collection.
- **Juice Robotics** – Developer of underwater robots designed to reframe view into the underwater world. The company offers small depth-tolerant lighting and camera systems to allow underwater filming.
- **Open Water Power** – Developer of an aluminum seawater fuel cell technology designed to generate power undersea. The company's aluminum seawater fuel cell platform technology develops an aluminum water platform with electrochemical system to provide safe, scalable, and nontoxic energy storage with extremely high energy density, promising a tenfold improvement in the endurance of unmanned underwater vehicles (UUVs) and sensors, enabling power companies to generate power undersea.
- **Regent** – Manufacturer of an electric boat-flying machine designed to offer fast, safe, and low-cost coastal transportation. The company's machine flies a few meters above the water and replaces ferries and short-haul aircraft on coastal routes and couples the high speed of an airplane with the low operating cost of a boat, enabling aerospace and maritime engineers to improve regional transportation between coastal cities.
- **Salient (Media and Information Services [B2B])** – Developer of weather prediction software designed to use ocean data and machine learning to predict precipitation and

temperature. The company's software provides accurate long-range weather forecasts and predicts heat and cold waves, floods, and droughts, enabling businesses to forecast weather for diverse applications across agriculture, energy and utilities, insurance, finance, and commodities.

- **Sea Machines** – Developer of autonomous control and dynamic vessel management systems designed to control boats and sea vessels remotely. The company's systems consist of self-driven control and navigation technology to feature real-time sea data, remote payload control, obstacle avoidance, remote communications, and machinery condition monitoring, enabling businesses to remotely drive their workboats and other commercial surface vessels with improved productivity and efficiency as well as safe operations in hazardous environments.
- **SeaDeep** – Developer of an environmental sensing platform designed to enhance hyperspectral imaging, data analysis, and 3D visualization of the ocean. The company's product is an underwater vision that can provide the data required for efficient, cost-effective, and sustainable ocean research and development with the help of artificial intelligence, providing clients with AI tools for sustainable subsea operation.
- **SeaTrac** – Manufacturer of solar-powered autonomous surface vessels designed to help with fish tracking, climate monitoring, and military missions. The company's vessels are solar powered and are deployable for missions ranging from several months to a year, and can operate in the open ocean or as little as two and a half feet of water without the need for need or waves for propulsion, enabling defense, environment, and energy companies to get a surface vehicle that is autonomous and can also be remotely controlled.
- **VerAI Discoveries** – Developer of an artificial intelligence platform designed to accelerate the global zero-carbon transformation. The company's platform detects concealed mineral deposits in the underexplored blue ocean of covered terrain, enabling the mineral exploration industry to trace unique signatures of existing deposits in complex datasets.

Supply Chain Analysis

The supply chain analysis includes detailed buying and production trends for Ocean Tech industries. Gross regional product and SBIR data were used to identify Ocean Tech industries that drive regional productivity and exhibit high potential for R&D and commercialization activity to include with the supply chain analysis. For each of these specific industries, industry sales are examined to understand the largest purchasers and inputs/purchases data to understand supply chain inputs. A more detailed analysis of the region's Ocean Tech supply chain is included in Appendix B.

Specific industries we included in the detailed supply chain analysis include industries supplying **Finished Ocean Tech Products and Services** and those that serve as **Inputs to Ocean Tech Products**.

Finished Ocean Tech Products and Services

- Engineering Services | NAICS 541330
- Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology) | 541715
- Ship and Boat Building | 3366
- Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing | 334511

Examples of Companies within Ocean Tech Products and Services

- Engineering Services
    - Marine Acoustics
    - Mikel
    - Boston Engineering
    - FTL Labs Corp
    - Metis Design Corporation
- Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)
    - Giner Inc
    - JPAnalytics
- Ship and Boat Building
    - Senesco Marine
    - Gladding-Hearn Shipbuilding, Duclos Corp
    - Marshall Marine Corp

- Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
    - General Dynamics Mission Systems
    - BAE Systems
    - Raytheon Technologies

Inputs to Ocean Tech Products

- Semiconductor and Other Electronic Component Manufacturing | 3344
- Other Electrical Equipment and Component Manufacturing | 3359
- Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing | 3252
- Coating, Engraving, Heat Treating, and Allied Activities | 3328
- Special Die and Tool, Die Set, Jig, and Fixture Manufacturing | 333514

Examples of Companies within Inputs to Ocean Tech Products

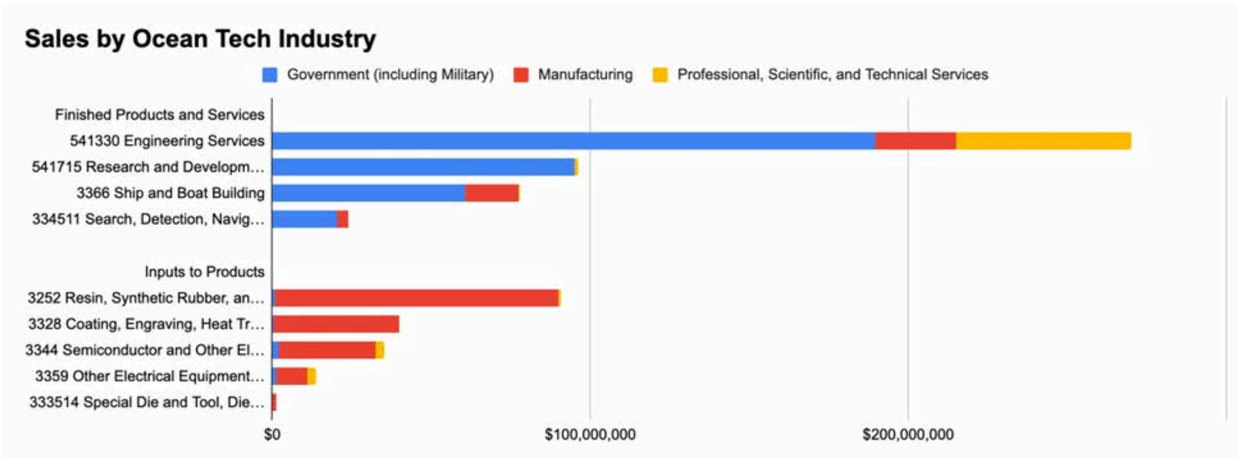
- Semiconductor and Other Electronic Component Manufacturing
    - CPS Technologies
- Other Electrical Equipment and Component Manufacturing
    - Materials Systems, Inc. / MSI Transducers
- Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing
    - Soluol Inc
    - Conneaut Industries Inc
- Coating, Engraving, Heat Treating, and Allied Activities
    - Teknicote Inc
- Special Die and Tool, Die Set, Jig, and Fixture Manufacturing
    - Composite Energy Technologies

Leading Businesses, Products, and Services

A listing of companies to watch in the ocean technology industry, including leading product developers and researchers, is included in Appendix A.

Top Ocean Tech Sales/Customers

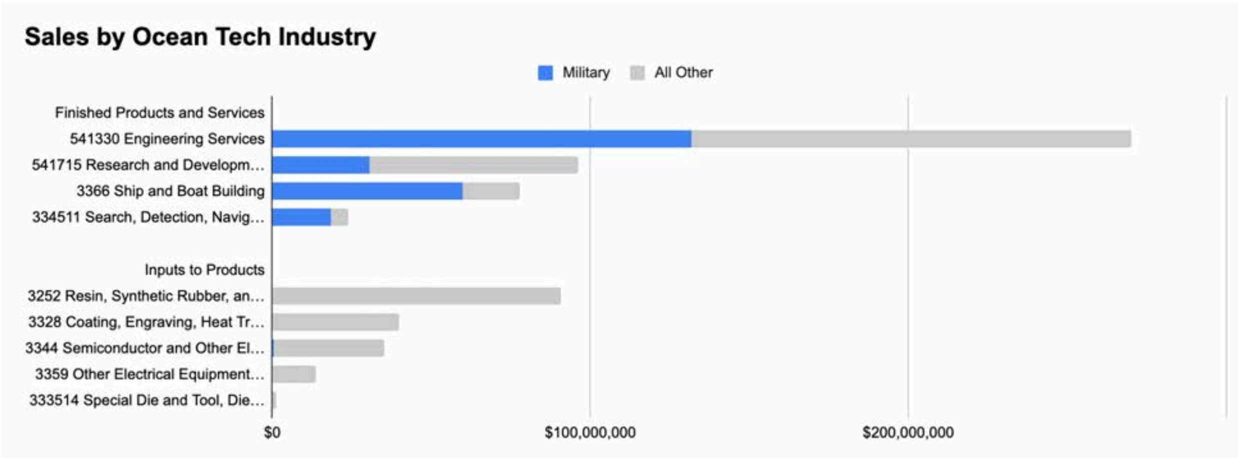
Industry sales data is indicative of the largest purchasers of ocean tech products and services. Within the Ocean Tech industry, sales include the end consumer for finished products and services (e.g., the military) and intermediate purchasers along the supply chain (e.g., other manufacturers).



Source: Fourth Economy Analysis of Lightcast™

The top purchasers of the Ocean Tech industry are Government (including Military); Manufacturing; and Professional, Scientific, and Technical Services. **Finished Products and Services are largely purchased by the Government (including Military)**, and **Inputs to Products are largely purchased by Manufacturing firms**.

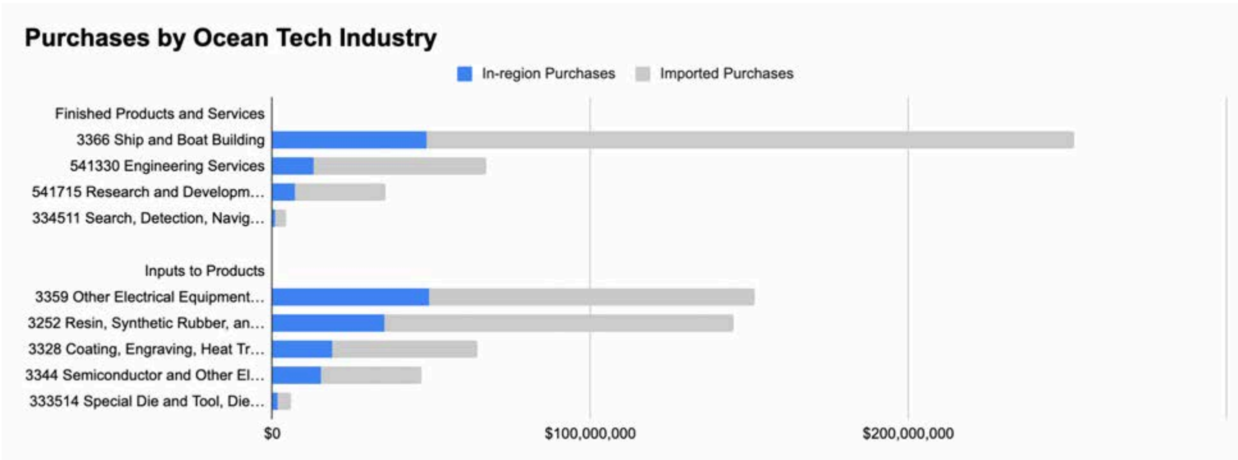
Military Sales



Source: Fourth Economy Analysis of Lightcast™

The military is the largest purchaser of Ocean Tech products—with more than $240 million of sales from Ocean Tech industries within the region generated by the military annually. This represents 37 percent of purchasing across the ocean tech industries examined and 51 percent of the purchasing across ocean tech industries that produce finished products and services. The industries with the highest sales volume to the military include Engineering Services; Ship and Boat Building; Research and Development in the Physical, Engineering, and Life Sciences; and Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing.

Top Ocean Tech Inputs/Purchases



Source: Fourth Economy Analysis of Lightcast™

Many inputs for Ocean Tech industries are purchased as imports from out of region, rather than in-region purchases, with many manufactured goods components for the industry coming from suppliers located outside the region. Our analysis indicates that **across the industries studied, around one quarter of purchases (25 percent) come from within the region, while three quarters (75 percent) come from outside the region.**

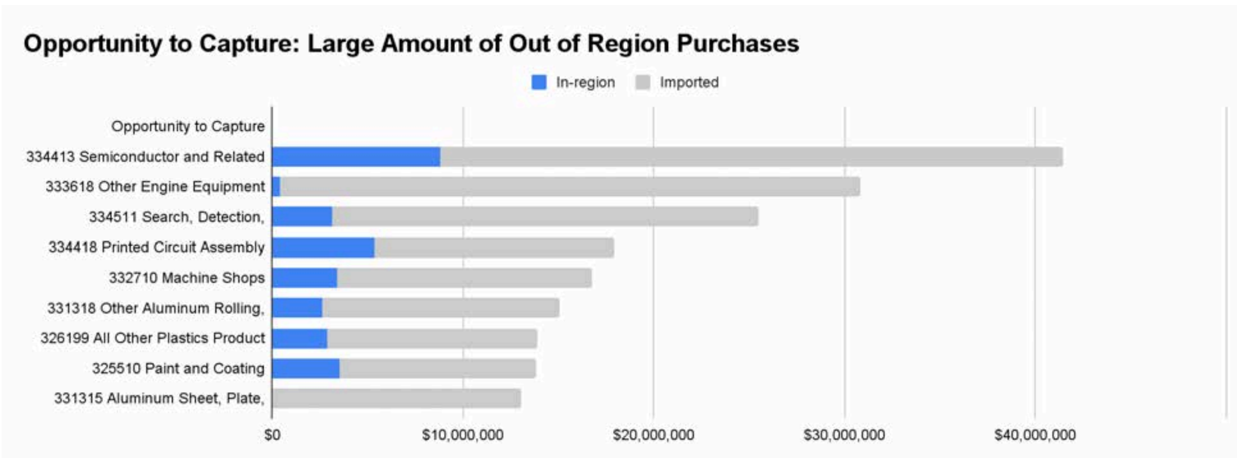
Ship and Boat Building has the largest volume of purchases, but the smallest percentage of manufacturing purchases that come from within the region (19 percent). All other industries within Finished Products and Services hover around one-fifth of purchases coming from the region: Engineering Services (19 percent); Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology) (20 percent); Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing (22 percent).

Inputs to Products fair relatively better, with more purchases of manufactured goods from within the region: Other Electrical Equipment and Component Manufacturing (33 percent); Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing (24 percent); Coating, Engraving, Heat Treating, and Allied Activities (29 percent); Semiconductor and Other Electronic Component Manufacturing (32 percent); and Special Die and Tool, Die Set, Jig, and Fixture Manufacturing (27 percent).

Across both finished products and services and inputs, there is an opportunity for the region to increase shares of in-region purchases. The next section discusses weaknesses in the supply chain due to out-of-region purchases and highlights some industry clusters that are relatively strong in the region.

Weakness in the Supply Chain Due to Out-of-Region Purchases

Some manufacturing industries that serve as inputs to ocean tech firms **highlight weaknesses in the supply chain due to out-of-region purchases**—these industries include those that represent at least $10 million of annual purchases and source at least two-thirds of all purchases from outside the region.



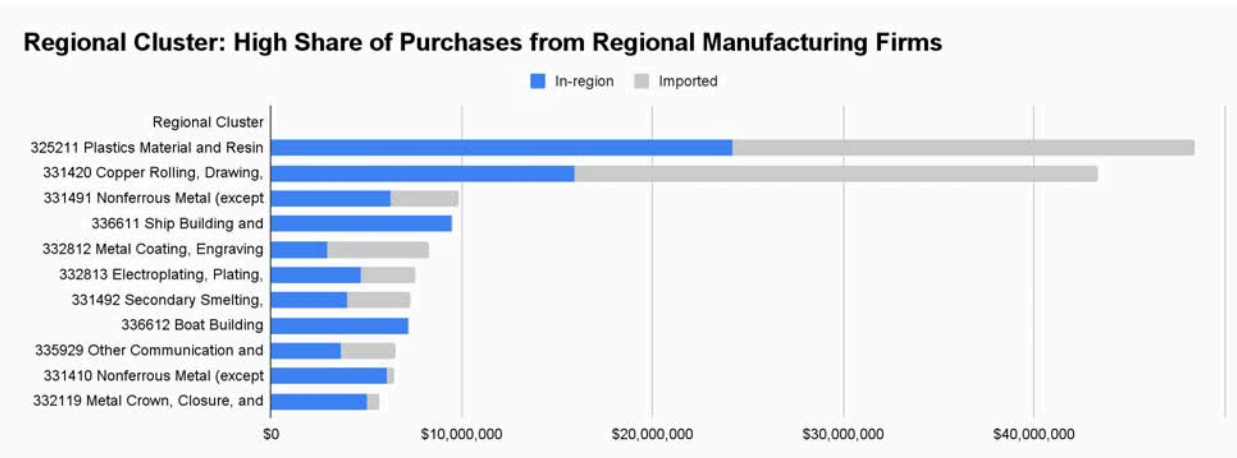
Source: Fourth Economy Analysis of Lightcast™

The region has the **opportunity to capture some of the out of the region spending** from the following industries:

- 334413 Semiconductor and Related Device Manufacturing
- 333618 Other Engine Equipment Manufacturing
- 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
- 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing
- 332710 Machine Shops
- 331318 Other Aluminum Rolling, Drawing, and Extruding
- 326199 All Other Plastics Product Manufacturing
- 325510 Paint and Coating Manufacturing
- 331315 Aluminum Sheet, Plate, and Foil Manufacturing

Regional Cluster: High Share of Purchases from Regional Manufacturers

Some manufacturing industries that serve as inputs to ocean tech firms are **relatively strong in the region**—these industries include those that represent at least $5 million of annual purchases and source at least a third of all purchases from within the region.



Source: Fourth Economy Analysis of Lightcast™

The region displays a **strong cluster** for manufactured goods sourced within the region for products from the following industries:

- 325211 Plastics Material and Resin Manufacturing
- 331420 Copper Rolling, Drawing, Extruding, and Alloying
- 331491 Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, and Extruding
- 336611 Ship Building and Repairing[113]
- 332812 Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers
- 332813 Electroplating, Plating, Polishing, Anodizing, and Coloring
- 331492 Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)
- 336612 Boat Building
- 335929 Other Communication and Energy Wire Manufacturing
- 331410 Nonferrous Metal (except Aluminum) Smelting and Refining
- 332119 Metal Crown, Closure, and Other Metal Stamping (except Automotive)
- 332721 Precision Turned Product Manufacturing
- 332722 Bolt, Nut, Screw, Rivet, and Washer Manufacturing

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[113] This US industry comprises establishments primarily engaged in operating shipyards. Shipyards are fixed facilities with dry docks and fabrication equipment capable of building a ship, defined as watercraft typically suitable or intended for purposes other than personal or recreational use. Activities of shipyards include the construction of ships, their repair, conversion and alteration, the production of prefabricated ship and barge sections, and specialized services, such as ship scaling.

Competitive Analysis of Global Ocean Tech Hubs

Global Blue Economy and Ocean Tech Organizations

The Southeastern New England region is one of many geographic areas around the globe where a mix of private, public, academic, and government actors are coming together to define and advance strategies to seize economic opportunities while minimizing barriers to growth of the sector.

More than one hundred entities (clusters, hubs, funders, accelerators, business support organizations, and testing facilities) were identified. This analysis then focused on forty-eight organizations that are making a significant contribution toward advancing the blue economy in ocean tech areas related to ocean robotics; autonomous vehicles; sensors; advanced materials; and AI, machine learning, and data mapping.

While some entities are narrowly focused on filling one particular role, such as providing access to capital, others offer a cross-cutting range of services from funding to entrepreneurship support to testing and validation facilities. The table below summarizes the overarching roles these organizations serve and the support functions they provide.

Ocean Tech Location Analysis

The below table examines the activities and impacts of ocean technology support organizations around the world. These organizations, government authorities, and public-private partnerships take on a variety of **functions, ranging from funding startups, leading R&D, generating new business opportunities for businesses, and more**. The table below serves as a model for Southeastern New England to understand as the region continues to build out its formalized ocean technology ecosystem.

Primary Role	Support Functions	Example Orgs.
Governance 17 of the 48 Organizations Included in the Analysis	● Convening industry, academia, government partners ● Conducting research ● Identifying gaps and needs ● Engaging in policy and advocacy ● Market research ● Industry networking ● Hosting events ● Forming working groups	● TMA BlueTech (US) ● GCE Blue Maritime Cluster (Norway) ● Maritime Cluster of Northern Germany ● Pôle Mer Bretagne Atlantique Cluster (France)
Funding/Capital Access 12 Organizations	● Startup funding ● VC funding ● Organizing prizes/competitions ● Grantmaking	● Schmidt Marine Technology Partners (US) ● BlueInvest (EU) ● Hatch (US) ● Canada's Ocean Supercluster
Market Formation/ Entrepreneurship Support 6 Organizations	● Accelerators and incubators ● Mentoring/coaching ● Industry matchmaking	● SeaAhead (US) ● Sustainable Ocean Alliance (US) ● Ocean Impact Organization (Australia) ● MassChallenge (US) ● Washington Maritime Blue (US) ● AFDF (US)
Testing, Prototyping, and Validation Facilities 13 Organizations	● Providing data ● Testbeds, specialized instrumentation and facilities ● Facilitating pilot programs	● MITRE Labs (US) ● SINTEF Labs (Norway) ● Ocean Technology Campus Singapore ● Ocean Innovation Norwegian Catapult Centre
Cross-Cutting Orgs 11 Organizations	Organizations that offer multiple functions from the list above	● COVE (Canada) ● MassRobotics (US) ● Cleveland Water Alliance (US) ● AltaSea, Port of San Diego (US) ● AspBAN (EU) ● China's "Blue Silicon Valley" and Shandong "New Area"

Global Geographic Strengths

Canada: Canada has made significant efforts toward developing their Ocean Innovation Ecosystem. Canada's Ocean Supercluster is seeking to leverage $500 million to support R&D and "help ocean startup companies become established and grow, support capacity building and sector workforce development, build and expand ocean networks and partnerships, and increase visibility of Canada's global ocean brand."

On Canda's east coast, the Centre for Ocean Ventures and Entrepreneurship (COVE) seeks to be a "one-stop shop" utilizing a specialized waterfront facility and programming to enable research, commercialization, business formation, education, and workforce development. A second version, COAST, has just begun operation on Canada's west coast.

China: China has been making significant investments to grow its blue economy since at least 2014. China has the unique benefit of being able to marshall all its resources to build entirely new districts from whole cloth with state-run research institutions and quasi-state-run industries. Two examples of this are China's "Blue Silicon Valley" and the Shandong Peninsula "New Area." Blue Silicon Valley is a world-class research and development center for marine science and technology contained in a 576-square-kilometer area situated to the north of Qingdao. More than 35 percent of the zone's total population is involved in research, with more than two hundred marine scientists from China and overseas conducting on-site research.

In Shandong, five national-level industrial parks have been established to date, including the Qingdao Tax-Free Port and China-Germany Environmental Development Park. The New Area aims to be an international port and testing ground for various ocean-related economic and technology initiatives.

Norway: The seas surrounding Norway are six times the size of its landmass. It should be unsurprising that Norway's ocean-based industries account for 40 percent of GDP and 70 percent of its exports. Norway's blue economy centers around shipbuilding, logistics, fishing, and energy (primarily oil and gas extraction). Norway's vast oil and gas wealth has allowed the Norwegian government to spend significant resources in developing their Ocean Innovation Ecosystem. Three organizations of note related to Norway's blue economy are SINTEF Labs, GCE Blue Maritime Cluster, and the Ocean Innovation Norwegian Catapult Centre.

SINTEF is a nonprofit research foundation funded through a mix of grants and government contracts. SINTEF has twelve research pillars, one of which is "Ocean Space," with specialty labs, facilities, and research staff dedicated to each. In addition to advancing research, commercialization and tech transfer are a major component of SINTEF. SINTEF Venture V is a seed/early-stage venture fund administered by SINTEF.

The GCE Blue Maritime Cluster is a privately run cluster of maritime companies and specialized research and educational institutions focused on shipping and shipbuilding. The cluster is notable for its resources ($5.3 billion in revenue) and scope. The cluster has supported projects around the globe and has several partnerships with agencies, companies, and organizations in North America. To date, the cluster has funded research and supported the development of two AVs (ships, not subsea vehicles). The stated goal of their ten-year strategy is to "develop full-scale zero-emission vessels that can be put directly into commercial operation. The focus is on ship types with global potential but in sectors where Norway has a head start. These comprise ocean-based energy (petroleum, offshore wind, etc), ocean-based food (aquaculture and fisheries) and ocean-based travel (cruise, ropax, roro, etc)."

Lastly, the Ocean Innovation Norwegian Catapult Centre provides a national testing, simulation, and visualization center for "rapid prototyping and efficient verification of new solutions for blue growth and green transformation in the ocean industries." Similar to COVE, Norway's Catapult Centres (there are five) offer accelerator/incubator programs, testing facilities, and assistance with business development and commercialization.

European Union: The EU is notable mainly for the amount of capital it is seeking to invest in the blue economy. Two programs, BlueInvest and the Atlantic Smart Ports Blue Acceleration Network (AspBAN), have a combined $6 billion of revenue earmarked for blue economy investments. BlueInvest, part of the overall $406 billion InvestEU fund, has invested in projects using AI/ML to improve maritime commerce, hydrogen-powered leisure boats, and digital modeling for workforce training, with dozens of other projects in the pipeline. The AspBAN project was a global accelerator competition that ran from 2021 through June 2023. The program sought to engage ports from around the globe as "acceleration hubs" and mobilized €5 billion (US$5.5 billion) in investments from partnering investment funds and strategic partners. The program attracted two hundred startups that participated in a "bootcamp" phase to refine their proposed projects. From there, fifty pilot projects were launched at thirty-three ports ultimately generating forty new startups. It should be noted, though, that the outcomes of this project are not well documented.

Notable North American Organizational Models

401 Tech Bridge

401 Tech Bridge collaborates with industry, government, and academia by providing "people, programming, and equipment" to bridge R&D gaps, accelerate commercialization, and facilitate connections among founders, funders, and talent. In addition to programming, they operate two technology centers in Rhode Island (Middletown and Providence) that offer offices, workspace, event space, and lab facilities. They are a copartner along with MassChallenge in operating the BlueTech Sprint program.

Why it's interesting: 401 Tech Bridge was the first entity to partner with the Department of the Navy's NavalX Tech Bridge initiative. NavalX Tech Bridges compose a connected network that enhances collaboration among naval labs, industry, academia, and other military branches. In addition to the navy, other partners include the URI Research Foundation, MEP National Network, NIST, US EDA, Rhode Island Commerce, the Rhode Island Foundation, and the Van Beuren

Charitable Foundation. Strong partnerships and the ability to coordinate projects and programs with other organizations have shown the organization has the ability to punch above its weight.

The Centre for Ocean Ventures and Entrepreneurship (COVE)

As previously mentioned, COVE orchestrates a variety of programs that foster the acceleration of marine technology utilizing a specialized waterfront facility. Their facility and programming enables research, commercialization, business formation, education, and workforce development.

Why it's interesting: COVE seems to do a lot with a relatively small staff and operating budget of about $500,000 a year. COVE is a good example of a true Blue Tech accelerator, offering full life-cycle services from startup to testing to commercialization.

Cleveland Water Alliance (CWA)

Cleveland Water Alliance (CWA) is a network of leading corporations, regional universities and research institutions, public agencies, and utilities in Northeast Ohio that serves to coordinate, facilitate, and foster economic development through a water innovation cluster. CWA's focus is on aquatic IoT solutions with applications in sensors, AI/ML, big data, automation, and more. CWA offers an accelerator that includes access to testbeds, data, equipment, risk mitigation, and market access.

Why it's interesting: CWA has invested more than $5 million in infrastructure to develop the largest digitally connected freshwater body in the world. This infrastructure is available to agencies, institutions, and companies to develop, test, and develop solutions. CWA has also invested over $500,000 in early-stage ventures and provided access to research, expertise, and testing facilities.

New Bedford Ocean Cluster (NBOC)

The New Bedford Ocean Cluster (NBOC) is a nonprofit organization supporting the growth of the blue economy in the Port of New Bedford and surrounding region. The NBOC's primary goals include creating a stronger local business network, positioning the port to be a leading hub for domestic offshore wind development, becoming a model for collaboration between port industries, and driving strategies that create more value from ocean-based resources. NBOC's pillars focus on offshore renewable energy, aquaculture, ocean technologies, and commercial fishing and processing.

Why it's interesting: The NBOC focuses on the integration of its four pillars to create new market opportunities and business growth. An outgrowth of the New Bedford Port Authority and Economic Development Council, the organization demonstrates how major existing assets can develop new initiatives that drive industry growth and commercial competitiveness. Instead of relying on companies and government actors to catalyze industry expansion and R&D, the Port of New Bedford takes a leadership role to ensure the region's ocean industries remain competitive in the long term.

MassChallenge

MassChallenge is a Boston-based nonprofit offering entrepreneurship support and access to capital. They run accelerator programs targeting various phases of entrepreneurship from early stage (startup and ecosystem development) to mid or late stage challenge programs. Additionally, they run competitions and programs specific to four industry sectors: Climate Tech, Dual Use, Health Tech, and Sustainable Food Systems. These programs typically connect industry or government with startups to solve innovation challenges and advance commercialization.

Why it's interesting: Though Blue Tech is not one of their industry sectors, they did run a BlueTech Sprint focused on accelerating marine and undersea technologies with a goal toward identifying new markets, refining use cases, and ultimately securing SBIR/STTR grants. Partners for the BlueTech Sprint were 401 Tech Bridge, BAE Systems, and MITRE.

MassRobotics

MassRobotics is the largest independent robotics hub that accelerates robotics innovation and adoption. The hub runs several competitions with industry and offers an accelerator program, startup support, educational programming, and specialized prototyping and testing facilities.

Why it's interesting: While MassRobotics does not have a specific Blue Tech focus, many of its projects have applications in the blue economy, and the organization serves as an excellent model of a niche organization seeking to accelerate innovation in a specific field that has attracted a lot of interest from industry.

Port of San Diego Blue Economy Incubator

This modest program ($1.7 million has been committed to date) is building a portfolio of businesses and partnerships that deliver multiple social, environmental, and economic cobenefits to the port and the region by removing barriers to entrepreneurs and providing funding, key assets, support services including entitlement and permitting assistance, and pilot project facilitation. To date, the port has committed funding, provided use of port-owned property, assisted with obtaining all necessary regulatory and operational permits, coordinated the installation of the pilot projects, and helped with community and media relations. This incubator program is complemented by another incubator space operated by TMA BlueTech, the region's leading blue economy organization.

Why it's interesting: Operating on a modest budget, the project has provided a host of services and has made good use of port facilities for running pilot projects. Relevant projects include sensors for stormwater and water quality monitoring, advanced materials for bioremediation and shoreline anchoring, and AVs for debris removal.

Appendix A - Leading Businesses, Products and Services

Company	Scope	ROVs	AUVs	ASVs and AUVs	Marine Sensors	AI, ML, and Data Mapping	Advanced Materials
General Dynamics Corporation	International	✔	✔	✔			
Deep Ocean Engineering	International	✔					
Atlas Maridan	International	✔					
ECA SA	International	✔					
International Submarine Engineering Ltd.	International	✔					
Bluefin Robotics Corporation	International	✔					
Inuktun Services Ltd.	International	✔					
SAAB AB	International	✔	✔	✔	✔		
L3 Harris	International	✔	✔	✔			
Boeing	International		✔				
Kongsberg Group ASA	International		✔	✔			
Lockheed Martin	International		✔		✔		
Exail Technologies	International		✔				
Fugro NV	International		✔	✔			
International Submarine Engineer Ltd.	International		✔				
XOcean	International		✔				
Ocean Infinity	International		✔				
Thayer Mahan	International		✔		✔		
Jaia Robotics	Regional		✔	✔	✔	✔	

<u>**Company**</u>	<u>**Scope**</u>	<u>**ROVs**</u>	<u>**AUVs**</u>	<u>**ASVs and AUVs**</u>	<u>**Marine Sensors**</u>	<u>**AI, ML, and Data Mapping**</u>	<u>**Advanced Materials**</u>
HII (Hydroid)	Regional		✔				
Textron Inc.	International			✔			
Thales Group	International			✔	✔		
ASV	International			✔			
Elbit Systems	International			✔			
5G International	International			✔			
Liquid Robotics	International			✔			
Honeywell International	International				✔		
Raytheon	International				✔		
BAE Systems	International				✔		
Garmin	International				✔		
E2SOL	Regional				✔		
Hanna Instruments	Regional				✔		
Lowell Instruments	Regional				✔		
Juice Robotics	Regional				✔		
Dartmouth Ocean Technologies	Regional				✔		
Cytec Industries	International					✔	
DuPont	International					✔	
Owens Corning	International					✔	
Hexcel Corporation	International					✔	
Toray Industries	International					✔	
Teijin Ltd.	International					✔	

Company	**Scope**	**ROVs**	**AUVs**	**ASVs and AUVs**	**Marine Sensors**	**AI, ML, and Data Mapping**	**Advanced Materials**
Mitsubishi	International					✔	
3A Composites	International					✔	
Clear Carbon	Regional					✔	
Deep Blue Composites	Regional					✔	
Composite Energy Technologies	Regional					✔	
Cognizant	International						✔
IBM	International						✔
Mercator Ocean International	International						✔
Sofar Ocean	International						✔
Dassault Systemes	International						✔
Infused Innovations	Regional						✔
INSPIRE Environmental	Regional						✔
Spear AI	Regional						✔
Havoc AI	Regional						✔
Blue IQ	Regional						✔

Appendix B - Detailed Supply Chain Analysis

Ship and Boat Building

Industry Sales

The top purchasers of the Ship and Boat Building industry are the Military (Federal Government), Fishing companies, and other companies within Ship and Boat Building. The Military (Federal Government) is the top customer, responsible for two thirds of total sales. Top industries purchasing goods from Ship and Boat Building include:

- 901200 Federal Government, Military
- 336611 Ship Building and Repairing
- 114112 Shellfish Fishing
- 336612 Boat Building
- 114111 Finfish Fishing

The majority of sales for Ship and Boat Building – 90% – are clustered within these handful of industries.

Inputs/Purchases

Supply chain inputs to Ship and Boat Building include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Ship and Boat Building include:

- 333618 Other Engine Equipment Manufacturing
- 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
- 331110 Iron and Steel Mills and Ferroalloy Manufacturing
- 336611 Ship Building and Repairing
- 331318 Other Aluminum Rolling, Drawing, and Extruding
- 333613 Mechanical Power Transmission Equipment Manufacturing
- 331315 Aluminum Sheet, Plate, and Foil Manufacturing
- 336612 Boat Building

These ten industries supply more than 50% of the manufactured good inputs for the Ship and Boat Building industry.

Many inputs for Ship and Boat Building are purchased as imports from out of region, rather than in-region purchases – 82% of purchases for manufactured goods for the industry come from suppliers located outside the region. However, several industries in the region buck this trend. The region displays a strong cluster for manufactured goods sourced within the region for products from Industrial Valve Manufacturing, Semiconductor and Related Device Manufacturing, Hardware Manufacturing, and within the Ship and Boat Building industry.

Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing

Industry Sales

The top purchasers of the Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing industry are the Military and Federal Government, Ship and Boat Building, and other Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing companies.

- 901200 Federal Government, Military
- 336611 Ship Building and Repairing
- 901199 Federal Government, Civilian, Excluding Postal Service
- 336612 Boat Building
- 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing

These industries make more than 93% of sales, with the Military accounting for 74% of sales for Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing.

Inputs/Purchases

Supply chain inputs to Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for this industry include:

- 334515 Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals
- 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
- 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing
- 334413 Semiconductor and Related Device Manufacturing
- 334419 Other Electronic Component Manufacturing
- 334519 Other Measuring and Controlling Device Manufacturing
- 331420 Copper Rolling, Drawing, Extruding, and Alloying

These seven industries supply more than half of the manufacturing inputs supplying the Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing industry.

Many inputs for this industry are purchased as imports from out of region, rather than in-region purchases – 78% of purchases for manufactured goods for the industry come from suppliers located outside the region. However, several industries in the region buck this trend. The region displays a strong cluster for manufactured goods sourced within the region for products from Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing; Other Measuring and Controlling Device Manufacturing; Bolt, Nut, Screw, Rivet, and Washer Manufacturing; Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing; and Relay and Industrial Control Manufacturing.

Engineering Services

Industry Sales

The top purchasers of the Engineering Services industry are military, federal and state government, computer design services, and wireless telecommunications carriers. These industries make more than 40% of all purchases for Engineering Services:

- 901200 Federal Government, Military
- 902999 State Government, Excluding Education and Hospitals
- 541512 Computer Systems Design Services
- 901199 Federal Government, Civilian, Excluding Postal Service
- 517112 Wireless Telecommunications Carriers (except Satellite)

Inputs/Purchases

Supply chain inputs to Engineering Services include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Engineering Services include:

- 325199 All Other Basic Organic Chemical Manufacturing
- 334516 Analytical Laboratory Instrument Manufacturing
- 324110 Petroleum Refineries
- 326199 All Other Plastics Product Manufacturing
- 327320 Ready-Mix Concrete Manufacturing
- 331110 Iron and Steel Mills and Ferroalloy Manufacturing
- 332322 Sheet Metal Work Manufacturing
- 325193 Ethyl Alcohol Manufacturing
- 332312 Fabricated Structural Metal Manufacturing
- 325998 All Other Miscellaneous Chemical Product and Preparation Manufacturing
- 327331 Concrete Block and Brick Manufacturing
- 325211 Plastics Material and Resin Manufacturing

These industries supply nearly half of the manufactured good inputs for the Engineering Services industry. Many inputs for Engineering Services are purchased as imports from out of region, rather than in-region purchases – 81% of purchases for manufactured goods for the industry come from suppliers located outside the region.

Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)

Industry Sales

The top purchasers of the Research and Development in the Physical, Engineering, and Life Sciences industry are the military and federal government, state and local government, and other research and development companies. These industries make more than 96% all purchases for Research and Development in the Physical, Engineering, and Life Sciences. The federal government and military account for 85% of all sales:

- 901199 Federal Government, Civilian, Excluding Postal Service
- 901200 Federal Government, Military
- 903611 Elementary and Secondary Schools (Local Government)
- 902999 State Government, Excluding Education and Hospitals
- 903999 Local Government, Excluding Education and Hospitals
- 902612 Colleges, Universities, and Professional Schools (State Government)
- 551114 Corporate, Subsidiary, and Regional Managing Offices
- 541715 Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)

Inputs/Purchases

Supply chain inputs to Research and Development in the Physical, Engineering, and Life Sciences include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Research and Development in the Physical, Engineering, and Life Sciences include:

- 336992 Military Armored Vehicle, Tank, and Tank Component Manufacturing
- 325414 Biological Product (except Diagnostic) Manufacturing
- 326199 All Other Plastics Product Manufacturing
- 325412 Pharmaceutical Preparation Manufacturing
- 325199 All Other Basic Organic Chemical Manufacturing
- 332710 Machine Shops
- 324110 Petroleum Refineries
- 334111 Electronic Computer Manufacturing

- 334419 Other Electronic Component Manufacturing
- 325998 All Other Miscellaneous Chemical Product and Preparation Manufacturing
- 325612 Polish and Other Sanitation Good Manufacturing
- 323111 Commercial Printing (except Screen and Books)
- 325180 Other Basic Inorganic Chemical Manufacturing
- 336350 Motor Vehicle Transmission and Power Train Parts Manufacturing
- 334413 Semiconductor and Related Device Manufacturing
- 326291 Rubber Product Manufacturing for Mechanical Use
- 326299 All Other Rubber Product Manufacturing

These industries supply roughly half of the manufactured good inputs for the Research and Development in the Physical, Engineering, and Life Sciences industry. Many inputs for Research and Development in the Physical, Engineering, and Life Sciences are purchased as imports from out of region, rather than in-region purchases – 80% of purchases for manufactured goods for the industry come from suppliers located outside the region. Regional strengths include Polish and Other Sanitation Good Manufacturing; Rubber Product Manufacturing for Mechanical Use; All Other Rubber Product Manufacturing; Petroleum Lubricating Oil and Grease Manufacturing; and Custom Compounding of Purchased Resins.

Semiconductor and Other Electronic Component Manufacturing

Industry Sales

The top purchasers of the Semiconductor and Other Electronic Component Manufacturing industry are electronics manufacturing, telecommunications, computing, and other electronic components. These industries make around half of all purchases for Semiconductor and Other Electronic Component Manufacturing:

- 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing
- 517111 Wired Telecommunications Carriers
- 336611 Ship Building and Repairing
- 517112 Wireless Telecommunications Carriers (except Satellite)
- 541512 Computer Systems Design Services
- 336320 Motor Vehicle Electrical and Electronic Equipment Manufacturing
- 339920 Sporting and Athletic Goods Manufacturing
- 335314 Relay and Industrial Control Manufacturing
- 326113 Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing
- 811210 Electronic and Precision Equipment Repair and Maintenance
- 334220 Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing

- 334419 Other Electronic Component Manufacturing
- 513210 Software Publishers
- 334413 Semiconductor and Related Device Manufacturing
- 333310 Commercial and Service Industry Machinery Manufacturing
- 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
- 518210 Data Processing, Hosting, and Related Services

Inputs/Purchases

Supply chain inputs to Semiconductor and Other Electronic Component Manufacturing include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Semiconductor and Other Electronic Component Manufacturing include:

- 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing
- 334413 Semiconductor and Related Device Manufacturing
- 334419 Other Electronic Component Manufacturing
- 331110 Iron and Steel Mills and Ferroalloy Manufacturing
- 331410 Nonferrous Metal (except Aluminum) Smelting and Refining
- 331420 Copper Rolling, Drawing, Extruding, and Alloying
- 331491 Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, and Extruding
- 334515 Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals
- 334412 Bare Printed Circuit Board Manufacturing

These industries supply 60% of the manufactured good inputs for the Semiconductor and Other Electronic Component Manufacturing industry. Many inputs for Semiconductor and Other Electronic Component Manufacturing are purchased as imports from out of region, rather than in-region purchases – 68% of purchases for manufactured goods for the industry come from suppliers located outside the region. However, a high percentage of inputs from the following industries are purchased from within the region: Nonferrous Metal (except Aluminum) Smelting and Refining; Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum); Precision Turned Product Manufacturing; Bolt, Nut, Screw, Rivet, and Washer Manufacturing; and Metal Crown, Closure, and Other Metal Stamping (except Automotive).

Other Electrical Equipment and Component Manufacturing

Industry Sales

Nearly 30% of sales for the Other Electrical Equipment and Component Manufacturing are concentrated in the following industries:

- 517112 Wireless Telecommunications Carriers (except Satellite)
- 335931 Current-Carrying Wiring Device Manufacturing
- 541512 Computer Systems Design Services
- 238210 Electrical Contractors and Other Wiring Installation Contractors
- 335929 Other Communication and Energy Wire Manufacturing
- 331420 Copper Rolling, Drawing, Extruding, and Alloying
- 333310 Commercial and Service Industry Machinery Manufacturing
- 901199 Federal Government, Civilian, Excluding Postal Service
- 541990 All Other Professional, Scientific, and Technical Services
- 541330 Engineering Services

Inputs/Purchases

Supply chain inputs to Other Electrical Equipment and Component Manufacturing include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Other Electrical Equipment and Component Manufacturing include:

- 331420 Copper Rolling, Drawing, Extruding, and Alloying
- 331110 Iron and Steel Mills and Ferroalloy Manufacturing
- 325211 Plastics Material and Resin Manufacturing
- 331318 Other Aluminum Rolling, Drawing, and Extruding
- 332710 Machine Shops
- 331410 Nonferrous Metal (except Aluminum) Smelting and Refining
- 331315 Aluminum Sheet, Plate, and Foil Manufacturing
- 327215 Glass Product Manufacturing Made of Purchased Glass
- 332119 Metal Crown, Closure, and Other Metal Stamping (except Automotive)
- 331523 Nonferrous Metal Die-Casting Foundries
- 335931 Current-Carrying Wiring Device Manufacturing
- 331491 Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, and Extruding
- 331524 Aluminum Foundries (except Die-Casting)
- 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing
- 331529 Other Nonferrous Metal Foundries (except Die-Casting)
- 335921 Fiber Optic Cable Manufacturing

These industries supply around 60% of the manufactured good inputs for the Other Electrical Equipment and Component Manufacturing industry. Many inputs for Other Electrical Equipment and Component Manufacturing are purchased as imports from out of region, rather than in-region purchases – two-thirds of purchases for manufactured goods for the industry come from suppliers located outside the region. However, some industries within the region supply a high percentage of manufacturing inputs for this industry, including Nonferrous Metal (except Aluminum) Smelting and Refining; Metal Crown, Closure, and Other Metal Stamping (except Automotive); Current-Carrying Wiring Device Manufacturing; Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, and Extruding; Precision Turned Product Manufacturing; Bolt, Nut, Screw, Rivet, and Washer Manufacturing; and Other Communication and Energy Wire Manufacturing.

Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing

Industry Sales

The top purchasers of the Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing industry are other plastics and resin manufacturers. These industries make more than 60% all purchases for Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing:

- 325211 Plastics Material and Resin Manufacturing
- 326199 All Other Plastics Product Manufacturing
- 326121 Unlaminated Plastics Profile Shape Manufacturing
- 325991 Custom Compounding of Purchased Resins
- 326112 Plastics Packaging Film and Sheet (including Laminated) Manufacturing

Inputs/Purchases

Supply chain inputs to Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing include:

- 325199 All Other Basic Organic Chemical Manufacturing
- 325211 Plastics Material and Resin Manufacturing
- 325110 Petrochemical Manufacturing
- 324110 Petroleum Refineries
- 325193 Ethyl Alcohol Manufacturing
- 325180 Other Basic Inorganic Chemical Manufacturing
- 325194 Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing
- 326199 All Other Plastics Product Manufacturing

- 322211 Corrugated and Solid Fiber Box Manufacturing
- 332710 Machine Shops

These 10 industries supply 92% of the manufactured good inputs for the Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing industry. Many inputs for Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing are purchased as imports from out of region, rather than in-region purchases – 76% of purchases for manufactured goods for the industry come from suppliers located outside the region.

However, some industries like Plastics Material and Resin Manufacturing; Metal Crown, Closure, and Other Metal Stamping (except Automotive); Relay and Industrial Control Manufacturing; Electroplating, Plating, Polishing, Anodizing, and Coloring; and Custom Compounding of Purchased Resins are present in the region and supply a high amount of inputs to Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing.

Coating, Engraving, Heat Treating, and Allied Activities

Industry Sales

The top purchasers of the Coating, Engraving, Heat Treating, and Allied Activities industry are other manufacturers. These industries make around 20% all purchases for Coating, Engraving, Heat Treating, and Allied Activities:

- 332813 Electroplating, Plating, Polishing, Anodizing, and Coloring
- 517111 Wired Telecommunications Carriers
- 332812 Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers
- 326199 All Other Plastics Product Manufacturing
- 517112 Wireless Telecommunications Carriers (except Satellite)
- 325991 Custom Compounding of Purchased Resins
- 335314 Relay and Industrial Control Manufacturing

Inputs/Purchases

Supply chain inputs to Coating, Engraving, Heat Treating, and Allied Activities include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Coating, Engraving, Heat Treating, and Allied Activities include:

- 331110 Iron and Steel Mills and Ferroalloy Manufacturing
- 325510 Paint and Coating Manufacturing
- 332812 Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers

- 332710 Machine Shops
- 332813 Electroplating, Plating, Polishing, Anodizing, and Coloring
- 334513 Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables
- 332114 Custom Roll Forming
- 324110 Petroleum Refineries
- 325998 All Other Miscellaneous Chemical Product and Preparation Manufacturing
- 332811 Metal Heat Treating
- 334413 Semiconductor and Related Device Manufacturing
- 322211 Corrugated and Solid Fiber Box Manufacturing
- 333994 Industrial Process Furnace and Oven Manufacturing
- 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing

These industries supply more than two-thirds of the manufactured good inputs for the Coating, Engraving, Heat Treating, and Allied Activities industry. Many inputs for Coating, Engraving, Heat Treating, and Allied Activities are purchased as imports from out of region, rather than in-region purchases – 71% of purchases for manufactured goods for the industry come from suppliers located outside the region. However, many of the purchases made from Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers; Electroplating, Plating, Polishing, Anodizing, and Coloring; Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables; Metal Heat Treating; Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, and Extruding; and Precision Turned Product Manufacturing industries are made from within the region.

Special Die and Tool, Die Set, Jig, and Fixture Manufacturing

Industry Sales

The top purchasers of the Special Die and Tool, Die Set, Jig, and Fixture Manufacturing industry are other manufacturers. These industries make more than half of all purchases for Special Die and Tool, Die Set, Jig, and Fixture Manufacturing:

- 333514 Special Die and Tool, Die Set, Jig, and Fixture Manufacturing
- 332721 Precision Turned Product Manufacturing
- 331523 Nonferrous Metal Die-Casting Foundries
- 332722 Bolt, Nut, Screw, Rivet, and Washer Manufacturing
- 332119 Metal Crown, Closure, and Other Metal Stamping (except Automotive)
- 333511 Industrial Mold Manufacturing

Inputs/Purchases

Supply chain inputs to Special Die and Tool, Die Set, Jig, and Fixture Manufacturing include goods from several manufacturing industries. Top manufacturing industries supplying goods as inputs and purchases for Special Die and Tool, Die Set, Jig, and Fixture Manufacturing include:

- 333514 Special Die and Tool, Die Set, Jig, and Fixture Manufacturing
- 331110 Iron and Steel Mills and Ferroalloy Manufacturing
- 333515 Cutting Tool and Machine Tool Accessory Manufacturing
- 331318 Other Aluminum Rolling, Drawing, and Extruding
- 331315 Aluminum Sheet, Plate, and Foil Manufacturing
- 332710 Machine Shops
- 333519 Rolling Mill and Other Metalworking Machinery Manufacturing
- 333511 Industrial Mold Manufacturing
- 331511 Iron Foundries
- 334413 Semiconductor and Related Device Manufacturing

These industries supply two-thirds of the manufactured good inputs for the Special Die and Tool, Die Set, Jig, and Fixture Manufacturing industry. Many inputs for Special Die and Tool, Die Set, Jig, and Fixture Manufacturing are purchased as imports from out of region, rather than in-region purchases – 73% of purchases for manufactured goods for the industry come from suppliers located outside the region. However, a high percentage of in-region purchasing is present for Cutting Tool and Machine Tool Accessory Manufacturing.