ASSESSING MAINE'S TECHNOLOGY CLUSTERS

MAINE SCIENCE & TECHNOLOGY FOUNDATION

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PREFACE

Dear Colleagues:

This report breaks new ground in the study of Maine's economy. It represents the first systematic attempt to analyze the growth of the state's technology-intensive industries. The findings reveal what we believe is needed to promote greater innovation and increased economic competitiveness.

Since 1998 the state of Maine has pursued an economic development strategy of investing in seven targeted technology sectors. The objective is to develop industries in which Maine could have a competitive advantage and spur technological innovation in the state's traditional natural resource-based industries.

The Maine Science and Technology Foundation (MSTF) is convinced that supporting the growth of technology-intensive clusters must be one of the state's highest priorities. The development of these clusters is fundamental to job growth, increased wage levels, improved rates of innovation and the formation of new businesses.

What Are Clusters?

Clusters are not synonymous with industries or sectors, although the terms sometimes are mistakenly interchanged. Clusters are more than geographic concentrations of firms in a similar industry. They are high performance centers of economic activity that drive investment, business formation, productivity and job growth.

Relationships are the key distinguishing feature of clusters. In order for industries to function as clusters, a rich network of relationships must exist between companies, suppliers, service providers and supporting institutions such as universities, colleges, research labs and industry associations. Cluster formation occurs when this network of relationships provides a competitive advantage to all related firms in the region. The competitive advantage develops because of what the report terms "regional collective learning."

At the core of this concept lies the recognition that productivity does not depend on what industries a region competes in, but on how it competes.

What's New about This Study?

The success of technology clusters in Silicon Valley, Route 128 around Boston and the Research Triangle in North Carolina has made cluster analyses one of the hottest areas of interest among economic development practitioners. This report employs a novel methodology that distinguishes it from other studies in the field.

Traditional cluster studies focus on industry outputs as the basis for identifying clusters. If the output (or employment level that produces it) is large enough, a cluster is deemed to exist. This traditional approach is not appropriate to Maine, because most of Maine's targeted technology sectors are quite small and have not yet developed the size, complexity or network of relationships to qualify as clusters. If a traditional approach were used to analyze Maine's technology-intensive economy, it would likely identify only a single cluster in Maine, the state's pulp and paper industry.

Our report, instead, focuses on technology inputs to products and processes. The report identifies 22 characteristics of successful clusters and then analyzes Maine's targeted technology sectors in terms of these characteristics. The focus on inputs highlights the critical role of relationships between a firm and its customers, workers, suppliers, competitors, investors, and sources of research.

This analysis identifies the strengths and weaknesses of each industry and leads to recommendations for building industry clusters in each sector. It is a methodology we believe could serve as a model for analyzing other sectors of the Maine economy or be used by other rural states.

Is a Cluster Strategy Appropriate for a Rural State?

Clusters are a key to competitiveness in the New Economy. But the question sometimes arises whether a cluster strategy is appropriate for a rural state like

Maine. Won't the pursuit of a cluster strategy concentrate resources where higher levels of economic activity already exist and deprive rural regions of the resources they need for development?

The answer, in short, is that a cluster strategy can benefit rural, as well as more heavily populated, areas of the state. In fact, several of Maine's potential industry clusters are built upon successful companies in rural areas. Maine's forest products industry, for example, is rural based. Lumber and paper mills are located predominantly in rural locations. Their competitiveness depends on strength in both the core industry and supporting industries such as land management, wood harvesting, secondary wood products and biomass power production.

Maine's agricultural industries are also largely rural, yet have strong cluster attributes. They, too, require strong supporting industries to remain competitive. With good organization and marketing, they can compete in both regional and national markets.

If one looks at the geographic distribution of the other targeted technology industries, it becomes clear that they, their suppliers and their supporting industries are located in many parts of the state. Geographic concentrations are a key element of clusters, but not all of Maine's developing clusters are themselves clustered together.

Moreover, cluster development strategies can benefit firms throughout the state, even those currently operating somewhat in isolation, by helping them identify possible linkages and opportunities within their cluster, as well as in the larger national or global industry.

MSTF believes that Maine's economic vitality hinges on its ability to support the growth of clusters. We are publishing this report in the hope that it impacts economic development planning in the state.

The report launches what we propose to be a four-stage process of cluster-based economic development. In this first stage we have assessed the seven targeted industry sectors and the economic infrastructure that supports cluster performance. The next step involves convening both demand-side stakeholders (industry associations and companies in each cluster) and supply-side stakeholders (public and private supporting economic institutions) to identify priority challenges and initiatives to address shared problems.

In the third stage we envision partnering with stakeholders to implement these initiatives, while the fourth stage would involve another round of assessment to

measure progress being made and identify new or continuing barriers to cluster growth. Only such an ongoing, dynamic, collaborative process will achieve the cluster-based development needed for economic competitiveness.

This work complements other studies that MSTF is conducting. Our ongoing *Evaluation of Maine's Public Investments in Research and Development* assesses the state's public investments in R&D, while our *Maine Innovation Index* tracks Maine's progress and compares us to other states. This cluster report looks beyond the state's R&D investments and examines both publicly funded and unfunded companies in the industries targeted for state investments. These findings, in turn, will help form the basis for the recommendations contained in MSTF's 2003 science and technology action plan.

Organization of the Report

The report may be broadly divided into three sections. The first two chapters discuss the concept of clusters and identify their key dimensions. They describe what elements are essential for cluster growth and define how the report analyzes Maine's technology-intensive industries.

The next two chapters summarize our findings about the seven technology-intensive industries. We assess the strengths and weaknesses of each of the technology sectors on eight factors that are critical to cluster success. The sectors are then divided into four groups based on their evolution or stage of development as clusters and their potential for growth and effect on the Maine economy. The terms we use to describe these four groups are stars, potential stars, base industries and industries seeking direction. The chart on page 26 summarizes our analysis of Maine's targeted technology sectors.

The remaining chapters focus on Maine's technology-intensive industries. The report devotes a separate chapter to forest products and agriculture, even though the state combines both into a single targeted sector – advanced technologies for forestry and agriculture. Our rationale for disaggregating them is that they in fact share little in terms of the infrastructure that supports their cluster performance. For similar reasons we have made suggestions in chapter four (The Evolution of Maine's Clusters) for ways in which the state's current industry groupings could be realigned to better reflect actual and potential market relationships. These changes could be made without altering the state's support programs for the targeted industries.

Acknowledgements

This report could not have happened without the cooperation of more than 170 individuals interviewed for the study. The Maine Science and Technology Foundation would like to thank all of our interviewees for their time, thoughtfulness and candor in responding to our questions.

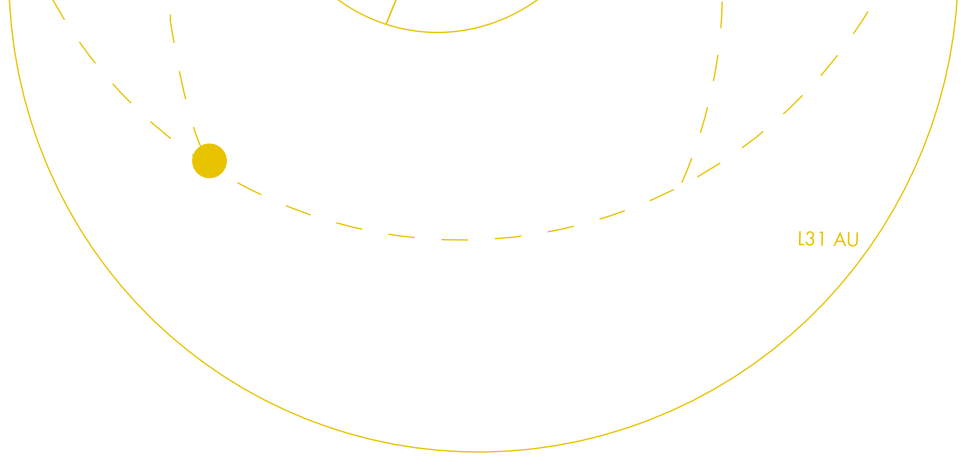
We also would like to acknowledge the valuable contribution of the cluster study stakeholders, who met regularly over the past year to provide their input during the development of this report. Their insights and understanding of economic activity in Maine industries was invaluable.

Finally, we wish to thank Charles Colgan, PhD, and Colin Baker of the Muskie School for their commitment to this project. Their work is truly path breaking research. It will serve as an example to other rural states and regions of how a cluster analysis can be conducted when industries are at a very early stage of cluster development. We also would like to thank Nan Butterfield and Mike Cote for the hundreds of hours they spent conducting interviews across the state.

The Maine Science and Technology Foundation is fully committed to working collaboratively with you to develop and implement strategies that will lead to successful cluster development and the creation of new economic opportunities and high quality jobs for the people of the state of Maine.

Sincerely,

Joel B. Russ, President
Maine Science and Technology Foundation



ASSESSING MAINE'S TECHNOLOGY CLUSTERS

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PHOTO CREDITS

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Bath Iron Works
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INTRODUCTION AND SUMMARY

Maine has recently made a significant commitment to investing in research and development as a means of increasing economic growth in the state. The expectation is that by catalyzing technological innovation, Maine may attract a larger share of faster growing technology industries. There is also an expectation that investments in technological innovation will increase the competitiveness of traditional Maine industries, such as those utilizing the state's natural resources.

Seven industry groups have been identified by the Maine legislature for specific assistance:

Information Technology
Biotechnology
Advanced Materials and Composites
Precision Manufacturing
Forest Products and Agriculture
Marine Technology and Aquaculture
Environmental Technologies

"Clusters are a type of industrial organization in which the competitive advantage of individual firms is enhanced by being located near other firms in the same industry."

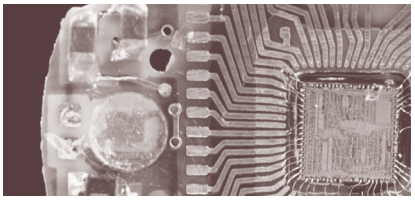
In this report, we consider forest products and agriculture separately because of significant differences between them, increasing the number of industry groups to eight.

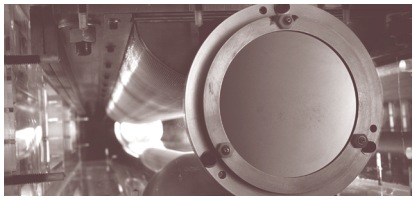
Policymakers have increased support for technological innovation with the explicit expectation that these investments will facilitate the evolution of industrial clusters in Maine. Clusters are a type of industrial organization in which the competitive advantage of individual firms is enhanced by being located near other firms in the same industry. Interaction between the individual firm and the region in which it is located increases the likelihood of faster growth and sustained economic success.

As the state of Maine has increased its investments in research and development and in supporting the growth of clusters, the governor and legislature have asked the Maine Science and Technology Foundation (MSTF) to monitor and assess the results of those investments.

MSTF has begun this assessment (Luger and Feller, 2001). The effort is specifically directed at examining the effects of the investments on the recipient firms or organizations with the goal of answering three questions:

How competitive is Maine's sponsored R&D, and has it improved over time? What is the impact of Maine's R&D investment on the development of the R&D industry?





What is the impact of Maine's R&D investment on the level of innovation and innovation-based economic development?

This report analyzes a fourth, closely related question:

Is Maine's investment in R&D contributing, in combination with other factors, to a change in the structure of the Maine economy toward more technologically innovative activities and increasing competitiveness?

The concept of clusters of economic activity provides the essential link between growth in technological innovation and increased competitiveness. It is the essence of clusters that their overall economic impact is greater than the sum of the parts. The essential characteristic of clusters is that they are defined by many different kinds of relationships among organizations and firms, by the nature and strategies of the firms themselves and by their collective ability to generate and seize opportunities in the marketplace. These issues extend beyond the outcomes of particular programs.

MSTF has responsibility for monitoring changes in Maine's innovation-driven economy. This report develops a framework for assessing the eight Maine industry groups as clusters and the current cluster characteristics of those industry groups. This framework will be used to inform MSTF's monitoring and evaluation processes over the next five years.

This report reviews the concept of clusters and then develops a framework for assessing the progress of Maine industry groups toward becoming clusters. Our fundamental premise is that the development of strong clusters in technologically innovative sectors serving rapidly growing markets is the most important outcome of Maine's R&D enterprise. The framework considers a number of factors influencing Maine's economic activity and competitive strength. These include factors in addition to R&D, since R&D's role is a necessary but not sufficient condition for success.

The framework is then applied to each of the industry groups identified by the legislature. This analysis is based on interviews with more than 150 firms, organizations and individuals throughout Maine, conducted during the period March–October 2001 by members of the research team. A detailed discussion of each of the industry groups is presented. It describes the cluster characteristics of each group, as well as other issues surrounding their growth and development that arose during the course of the interviews. Finally, a set of actions is suggested to further the development of clusters in Maine.

"The development of strong clusters in technologically innovative sectors serving rapidly growing markets is the most important outcome of Maine's R&D enterprise."

Major Conclusions

- Clusters provide an important conceptual basis for evaluating the ultimate outcomes of Maine's research and development investments and gauging whether key sectors of the Maine economy are becoming more competitive.

- The evolution of clusters can be characterized along eight dimensions:

  Innovation
  Regional Business Functions
  Entrepreneurship Objectives
  Financing
  Relationships
  Locational Advantage
  Market Potential
  Economic Performance

  This characterization is inherently imperfect, but is designed to stimulate further analysis of the strengths and weaknesses of each industry group and the ability of each group to take advantage of the competitiveness-enhancing characteristics of clusters.

"It is the essence of clusters that their overall economic impact is greater than the sum of the parts."

- Four types of clusters can be identified:

  Stars: Strong cluster characteristics and high growth potential are present. Maine currently has no star clusters.

  Potential Stars: Strong market growth potential exists, but strong cluster characteristics are not yet present. In Maine, information technology, biotechnology and advanced materials are in this category.

  Base: Strong cluster relationships exist, but markets are slow growing. This describes forest products, agriculture and aquaculture.

  Seeking Direction: Loose groups of industries and firms produce similar products or serve similar markets but lack strong cluster relationships or strong market growth potential. This characterizes precision manufacturing and environmental products.

- As Maine's clusters develop, it will be useful to explore new connections within and among them. Some of the clusters, such as environmental technologies and precision manufacturing, will need to form more coherent relationships and market presence to take full advantage of being a cluster. Other connections across the existing groups may prove to be important. The semiconductor and information/communications technology firms may link to the software firms to create new technologies. Aquaculture, fisheries and agriculture may form increasing links as part of a "food" cluster. Such changes should be monitored in the future as part of assessing how Maine's clusters are strengthening their relationships and competitive advantage. Thus attention should be paid to:

  Information Technology
  software, hardware, communication equipment and instrumentation manufacturing
  Biotechnology
  Advanced Materials
  Forest Products
  Precision Manufacturing
  fabricated metals, marine technologies and instruments
  Food
  agriculture and aquaculture
  Environmental Products

"Continued assessment of the evolution of Maine's clusters should be built into the process of evaluating Maine's R&D investments."

- Continued assessment of the evolution of Maine's clusters should be built into the process of evaluating Maine's R&D investments. This can be done in both surveys and interviews with grant recipients. However, cluster evaluation should extend beyond R&D recipients to other key institutions when needed on a periodic basis.

- Maine's R&D support programs should review how their funding could support the evolution of clusters, as well as the R&D funding recipients and industry. This can be done by targeting weaknesses in the clusters identified in this report and fostering business relationships within and between clusters. Support to cluster network organizations, such as industry associations, for development purposes should also be considered.

CLUSTERS AND THE MAINE ECONOMY

"Learning from others is easiest when communication lines are shortest...

As a preliminary to examining clusters in Maine, we should begin by defining what clusters are and why they are important. The idea of clusters has been around for many years in the economics literature, but it is only in the last decade or so that it has received considerable attention from scholars and economic development practitioners.

This new wave of interest is understandable. The growth of such regions as California's Silicon Valley, the Research Triangle in North Carolina and the region inside Route 495 (formerly bounded by Route 128) in eastern Massachusetts has shown how a region devoted to a high degree of science-based innovation can succeed in creating sustained economic growth. With the rise of such regions, the hunt was on to find the factors explaining their success and develop policies to duplicate that success elsewhere.

The success of these regions challenged widely held views of how economic development works. Traditional views of economic development derived from standard economic models of firm and industry growth. A firm produced a product, which it sold in competitive markets. The nature of competitive markets meant that a firm had little control over prices and thus succeeded primarily by reducing costs in order to lower prices and increase sales. Economic development policies thus focused on finding ways to reduce production costs in a particular location in the hope of attracting or retaining firms that had an advantage in competitive markets (Colgan, 1992).

This model certainly describes the way much economic activity and economic development works, but it ignores several important questions. Where do the ideas for products come from? How do firms figure out which products are more likely to succeed than others? Where do ideas for reducing costs come from? How is it that firms both compete with one another at times and cooperate with one another at other times? The usual assumption was that such critical knowledge came from the inspiration of individual inventors and managers.

If individual inspiration and knowledge mattered, it would make no difference where firms located. But that clearly is not the case. Long before the "high tech" clusters of Silicon Valley and eastern Massachusetts, the garment industry was concentrated in New York City (actually within a small area of Manhattan) and the auto industry was concentrated in the Great Lakes region (Michigan, Indiana, Ohio and Ontario). Thus, the explanation based solely on individual inspiration cannot account for the fact that many industries seemed to congregate in the same location and stay in those locations over many decades.

It is just these questions that the idea of clusters is meant to address.

The key concept is what has come to be called "regional collective learning." This

> … involves the creation and further development of a base of common or shared knowledge among individuals making up productive systems which allows them to coordinate their actions in the resolution of the technological and organizational problems they confront (Keeble and Wilkinson, 1999).

In other words, the knowledge that firms need to function successfully comes not only from within organizations but from other firms, organizations and individuals. Learning from others is easiest when communication lines are shortest; thus, there is an advantage to be gained when firms and organizations in the same type of business locate close to one another. Location in a particular region is a form of competitive advantage quite apart from the effect of the region's characteristics on production costs.

…thus, there is an advantage to be gained when firms and organizations in the same type of business locate close to one another."

Much is known about why clusters are important. Evidence exists to support the key role that clusters play in economic development in North America and Europe. Much of this evidence comes from studies of the history and evolution of clusters. But important questions remain unanswered. One set of questions deals with how a cluster gets started and grows and what can be done to catalyze the establishment and growth of clusters. Another set of questions deals with the elements that comprise a cluster and how best to measure the status and evolution of clusters.

If Maine is to succeed in creating and sustaining clusters as a source of economic advantage, answers to these questions are needed.

A previous study of marine biotechnology in Maine (Colgan and Baker, 2000) proposed a description of the evolution of clusters. This process consists of four stages:

Research ➲	Products
Products ➲	Firms
Firms ➲	Industries
Industries ➲	Clusters

In the first stage, research activities result in the development of ideas for new products. "Research" in this context incorporates the kinds of advanced scientific and engineering research that are the target of Maine's policies. But it also incorporates the broader process by which anyone develops an idea for a new product

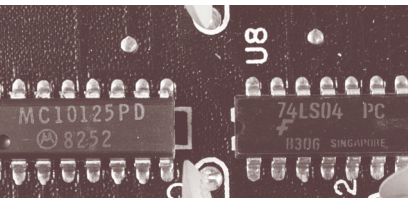
and encompasses other types of investigations as well. It includes market research, which might be a formal study or simply talking to customers. It also includes observing competitors to see what they are doing and using their experience as a guide.

"Clusters are defined by connections between production and location that enhance the competitive advantage of all firms in the cluster."

The second stage signals the creation of organizations to produce and sell the products. Such organizations might be the classic entrepreneur who sets up a company, but it could also be a new division of an existing company or even just a new manager for a product line. The creation of an organization to undertake production and sales represents a major step forward, since organizations bring additional resources to the process and some level of specialization, which is the essential ingredient in realizing economic production.

The third stage is characterized by the identification of regional "industries." This stage is somewhat automatic as industries are simply groups of firms that produce similar products. The grouping of firms into industries is largely a taxonomic process using such schemes as the Standard Industrial Classification (SIC) or the North American Industrial Classification System (NAICS). From a regional perspective, of course, it is possible to have only one firm producing a product located there (Bath Iron Works, for example, is the only shipbuilding company in Maine), so the question of what industries exist in a region is somewhat different from the question of what firms are located there.

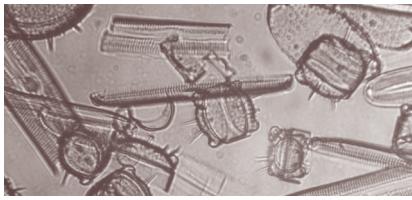
Profound differences distinguish industries from clusters. Both clusters and industries are, to some extent, organized around the production of goods or services. Clusters, however, may have much broader product classifications than industries. An information technology cluster, for example, may be composed of firms producing computers, peripherals, software and digital telecommunications equipment. A biotechnology cluster might include products for the biomedical field, the veterinary industry or the food industry.



But these distinctions are still somewhat artificial. There is already a link between information technology and biotechnology. Research in the biomedical field depends on the critical information generated about genetic codes using DNA sequencers. The Jackson Laboratory and the Spatial Engineering Department at the University of Maine are applying geographic information systems (GIS) software to the problem of mapping genetic codes using approaches developed for mapping the earth. At the leading edge of biotechnology, researchers are actually working on biologically derived materials that can be used as computers, which will further blur the distinctions among technologies (Oliver, 2000). Thus, clusters must be defined by more than what they produce or what technologies are used or developed:

Clusters are defined by connections between production and location that enhance the competitive advantage of all firms in the cluster.

There are thus two elements that comprise a cluster. The first is geography. Whatever the lead (defining) product or products are, the cluster also includes suppliers to those firms as well as customers. Clusters are also defined by a common pool of skilled labor in the region that many firms can draw on, as well as organizations such as higher education and not-for-profit institutions that are related to the firms in the cluster. These varied relationships are the key distinguishing feature of clusters. And this distinction is critical, because it is entirely possible to have groups of similar industries concentrated in a region without those industries forming the kinds of relationships that constitute clusters (Wever and Stam, 1999).



The second key element of clusters is the relationships among the firms and other institutions in the region. These relationships are the source of much of the knowledge that a firm acquires from outside its boundaries. That knowledge then becomes a further spur to innovation, which leads back to the beginning and restarts the evolutionary process. In a successful cluster, this cycle of innovation continues to enhance the competitive strength of the firms and the local economy.

The measurement of change in clusters is thus considerably more complex than the measurement of change in firms or industries. For the latter, we have good measures of employment and output, and increases in these comprise the normal measures of economic growth. For clusters, we need a different approach, focusing on traditional measures only in part.

Assessing changes in the R&D-related clusters of Maine will be an essential part of the future of Maine's R&D investments. The legislature has directed that a comprehensive evaluation of these programs be undertaken, and the question of whether and how these sectors are evolving as clusters is part of this evaluation.

Beyond the specific issues of the impacts of these public-sector support programs are questions about how key sectors of Maine's economy are changing. The concept of clusters provides an invaluable perspective to see whether Maine is increasing its competitiveness in a global economy.

"The concept of clusters provides an invaluable perspective to see whether Maine is increasing its competitiveness in a global economy."

MEASURING CLUSTERS IN MAINE

"Special attention must be paid to the key role played by research and development."

In order to provide a more complete picture of both the current and future status of the key industries in Maine as clusters, we employ eight principal dimensions, with some additional subdimensions. The dimensions chosen have been developed based on the extensive research on clusters that has been undertaken in the United States and elsewhere. We have adjusted some of these factors based on our observations of these sectors developed during the interviews conducted in the project. We explain these dimensions in this section and then evaluate each of the current leading industry sectors along the dimensions. We then consider the implications of these findings and propose modifications to the idea of clusters in Maine in order to better track changes and suggest some strategic implications for Maine's R&D support programs.

The Dimensions of Clusters

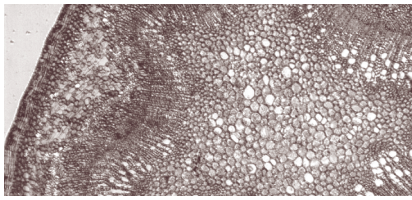
1. Innovation: To some extent, all firms must be innovative to survive, but there are differences in emphasis in the kinds of innovative activities that firms may engage in. A firm may innovate by creating new *products*, or it may innovate by developing new or improved production *processes*. In general, firms in a cluster will find the competitive pressures of other firms and the demands of the market forcing them to attempt to be innovative in *both* process and product.

2. Regional Business Functions: An important characteristic of clusters is that a large proportion of the routine activities of a business are undertaken within the region. Business functions of interest here include *research*, product *development*, *production* and *marketing*. Some firms will be large enough to perform most functions within their organization, while others are too small to do multiple functions and must purchase them from other organizations. In a well-functioning cluster, there should be a number of firms that undertake all of these functions within the region.

Special attention must be paid to the key role played by research and development. Because R&D is central to the ability of a region to be self-sustainingly innovative, it is important that a large degree of R&D be conducted within the region. The R&D may be conducted within public, private or nonprofit organizations, and these organizations may supply the results of R&D well beyond the region. For a state such as Maine, which is in a weak position in terms of conducting research and development (Luger et al., 2001), an increase in the level of R&D in the state is somewhat more important than it may be in other regions. The evaluation of this aspect of clusters is one of the key links between the evaluation of Maine's R&D support programs and the assessment of cluster evolution.

3. Entrepreneurship Objectives: Firms have certain objectives in mind in making decisions about what and how much to produce and what markets to serve. These objectives are the foundation upon which a firm's strategy is based. The normal

assumption is that business owners and managers seek to grow the size of their company in order to maximize profits. However, it has long been known that *growth* and profit maximization are not the only strategic objectives that a firm can have. Some owners/managers do not anticipate growing their companies much beyond their current size. They start their business with a view of maintaining or improving their *quality of life*, and fear that growth will negatively affect their attainment of that objective. A cluster will have a balance of firms with different strategic objectives, but a cluster heavily oriented toward lifestyle or market share objectives would not provide the same economic effect as one with a substantial number of growth-oriented firms.



4. Financing: The subject of financing is key to economic development. For current purposes, there are two critical questions. The first is whether firms fund their activities primarily from retained earnings (*inside* funding) or seek funding *outside* the firm. This is particularly important for the smaller firms that are central to several of Maine's industries. A firm that relies solely on retained (inside) funds will be relatively secure, but its growth potential is limited. A firm that seeks outside funding takes a greater risk but is more likely to grow.

"The importance of local sources of financing, particularly venture capital, is often stressed in studies of clusters."

For firms that do seek outside funding, another key question concerns the form of that funding. For many of the firms engaged in research and development in key technology sectors, grants are a very important early source of funds, whether from state sources such as the Maine Technology Institute or from federal agencies such as the Small Business Innovation Research (SBIR) program. Over time, such *grants* may remain a part of the financing picture, but should be diversified in source and supplemented with *other financing*.

This assessment of financing does not specifically address the question of financing from within Maine or from outside of Maine. A number of cluster studies have pointed to the importance of "learning, linkage and investment" (Mytelka and Farinelli, 2000). The importance of local sources of financing, particularly venture capital, is often stressed in studies of clusters. In the financing of highly speculative and risky new technologies, the financer's personal familiarity with firms receiving funds is considered not only an advantage but almost a necessity (Oliver, 2000). However, Maine's venture capital market is still immature, and, at this stage in the evolution of Maine's technology clusters, the geographic location of the source of funds remains less important than the type and volume of funding.

5. Relationships: Porter (1990) emphasizes the importance of related and supporting industries within a region. There are several types of relationships that are key. The first is with other firms. There should be both strong *vertical* and *horizontal* relationships. Strong vertical relationships are those where a substantial number of suppliers and customers are located in the region, permitting growth

of the key industry to have both forward and backward linkages. Strong horizontal relationships indicate that firms have both strong cooperative and competitive relationships with one another.

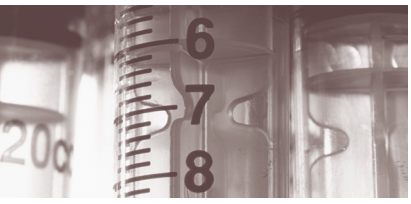
Another key characteristic of clusters is that they develop and draw on a strong common pool of *labor*. This common pool of labor is defined primarily by the skills needed to operate in the cluster of firms. A large pool of skilled labor in the region means firms do not have to look far to find the employees they need; it also means that employees have a deep market of opportunities in which to seek jobs. A vibrant and flexible labor market also contributes to the likelihood that new companies will be formed (Saxenian, 1994).

"Another key characteristic of clusters is that they develop and draw on a strong common pool of labor."

Institutions other than business firms are also a key ingredient. These institutions include organizations such as the universities and research organizations in the region. But they may also include other relationships outside the region. Contacts with leading innovators in a field, even if those innovators are outside the immediate region, are also important, for they indicate a high degree of interest in innovation.

An important vehicle for establishing and maintaining relationships among firms in a cluster is the presence and strength of *industry associations*. Industry associations provide regular means of communication, the opportunity to share resources to address common needs and, through events such as regular meetings, an opportunity to showcase industry trends and issues.

Research and development facilities and organizations are key to the potential for innovation in a region. To be effective, such organizations must produce significant research and be connected to the commercialization of technologies and research findings within the region. The organizations and facilities should be large enough to conduct research in a number of different areas at the same time, because the nature of research is that successes usually arise from failures and false leads.



The final type of relationship of interest is whether there are *lead organizations*. Lead organizations play several important roles. They are large enough so that they can be key suppliers or customers (or both) for many other firms. Most importantly, they grow large enough to be the source of multiple spinoff companies as employees leave to start their own companies. In many studies of clusters, key research institutions such as MIT and Stanford University have been identified as lead organizations. Large firms may also play this key role, even in the absence of a major research university (Meyer, 2001).

6. Locational Advantage: There are two sources of competitive advantage that may derive from location in a particular region. The first is *geographic* characteristics

such as the availability of natural resources. This includes forest resources, good agricultural land or marine resources. The second source is the cumulative *knowledge* in the region that results from the interaction of firms, other organizations, successful creation of new products, etc. It can reinforce the advantages of geography by ensuring long-term (sustainable) use of natural resources. Areas in which this shared cumulative knowledge exists can be considered "learning regions." Geographic advantage is a natural advantage that already exists; knowledge-based locational advantage is created. Created advantage transforms economic activity that can take place anywhere into economic activity that can best take place in a certain region.

These two types of advantage can work together. In industries dependent upon natural resources, it is not enough simply to have the resources present. There are critical skills and knowledge needed to use the resources. These become more and more important as resource scarcity makes successful intensive management of those resources essential to economic success. Thus, this report splits this criterion in two, with each cluster evaluated along both dimensions. A cluster that is primarily geographic should increasingly become knowledge based, while a cluster that is entirely based on knowledge should increasingly become part of the geographic advantage of a particular region.

"Areas in which this shared cumulative knowledge exists can be considered 'the learning region.'"

7. Market Potential: There are four important characteristics of market potential. The first is whether the markets served are *growth* markets or *mature* markets. Growth markets are ones where demand for products grows fairly rapidly each year. Mature markets see relatively slow annual growth. A good way of distinguishing between the two is that mature markets generally grow at about the same pace as the economy as a whole, while growth markets see demand increasing at rates faster than the economy as a whole. Clusters that create or serve growth markets are particularly important.

The second characteristic is breadth and *diversity* of markets to be served (Bantel, 1998). It is in the nature of clusters that they tend to be relatively specialized in some products, but it is possible to be overly specialized in a few products. A cluster should, partly as a result of the innovative forces discussed earlier, be able to produce a diversity of products serving a number of different markets.

The third characteristic of markets is the strength of *local demand*. Porter identifies strong local demand as a key to cluster strength. That is, demand within the region for a cluster's products enhances competitiveness. Suppliers can get to know their customers and their needs easily, and high standards set by local customers force suppliers to produce better products that can be exported outside the region. Therefore, the market for products inside Maine is an important factor.

"A cluster should…be able to produce a diversity of products serving a number of different markets."

The final characteristic is *export demand*. In this case, "exports" includes all sales outside of Maine, whether within the U.S. or to foreign countries. It has long been recognized that sales outside of a region are a key foundation for long-run economic growth, and this remains the case. In a strong cluster, high export demand is matched with the strong local demand just described.

8. Lead Industry Group Growth (Economic Performance): For each cluster, a group of industries takes the lead role. For the groups defined in this study, we use the industries defined by Standard Industrial Classification (SIC), as set out in Table One (page 23). For these we measure employment change for the period 1992–2000 in Table Two (page 24). Three measures are used to compare the industries' growth in employment in Maine versus the U.S.: the rate of employment growth, the change in the share of total employment in Maine and the U.S. and the change in the location quotient (a measure of specialization). Table Two shows the measure of change in employment for each industry.[1]

Environmental technologies are not included, as the definition of this sector is too diffuse in relationship to standard employment data classifications to permit meaningful analysis. Marine technologies and aquaculture are also excluded because of difficulties comparing Maine to the U. S. in this analysis. In the case of shipbuilding, the small number of firms in the industry are driven primarily by military shipbuilding and thus are more influenced by Pentagon and Congressional policies than by market forces. In the case of search and navigation equipment, the largest marine technology nationally, Maine has no significant presence. Finally, data on aquaculture employment at the national level does not permit comparison with Maine data.

Table Three (page 26) presents a summary of the scoring on these criteria for the key Maine industries. In the scale,

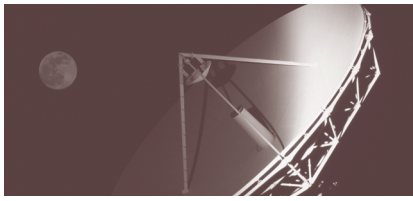
1 = a minimal level of the characteristic is present, or the industry is best characterized on the weak end of the cluster scale;
2 = a moderate level of the characteristic is present, or there is a mixture of firms with strong and weak characteristics such that the strong and weak firms are approximately in balance;
3 = the characteristic is strongly present, or strong cluster-characteristic firms significantly outnumber weak cluster-characteristic firms.

The scoring is admittedly arbitrary. It is based on our best judgment of the industries after conducting extensive interviews throughout the state. We present the scoring both as a means of establishing a baseline against which future progress

[1]Employment data used in this analysis include nondisclosable data from the Maine Department of Labor, so industry-level data are not presented.

TABLE ONE
INDUSTRIES USED IN EMPLOYMENT GROWTH ANALYSIS

INDUSTRY	SIC
Information Technology	
Computer & Data Processing Services	737
Biotechnology	
Medical Instruments & Supplies	384
Pharmaceuticals	283
Noncommercial Research Organizations	8733
Forest Products	
Lumber & Wood Products	24
Pulp & Paper	26
Furniture	25
Forest Land & Services	08
Agriculture	
Farming	01 & 02
Preserved Fruits & Vegetables	203
Agricultural Services	07
Marine & Aquaculture	
Aquaculture	0921
Search & Navigation Equipment	381
Advanced Materials	
Boatbuilding	3732
Man-made Fiber Weaving	2221
Precision Manufacturing	
Communication Equipment	366
Circuit Boards	3672
Semiconductors	3674
Measuring & Controlling Devices	382
Fabricated Metal Products	34
Industrial Machinery & Equipment	35



can be evaluated and as a means of engendering discussions within the firms and organizations of each cluster about current and future directions.

The scoring is also based on relative rather than absolute strengths. That is, we are evaluating these clusters relative to one another in Maine. The scores that are used are chosen to identify sources of strength and weakness within each cluster.

TABLE TWO
ECONOMIC PERFORMANCE DATA BY INDUSTRY, MAINE AND U.S.

EMPLOYMENT GROWTH RATE, 1992–2000

	MAINE	U.S.
Information Technology	338.5%	150.7%
Biotechnology	44.5%	12.1%
Forest Products	-12.0%	12.1%
Agriculture	16.1%	12.8%
Advanced Materials	55.1%	9.9%
Precision Manufacturing	31.8%	12.9%
Total Employment	18.0%	21.3%

CHANGE IN MAINE SHARE COMPARED TO CHANGE IN U.S. SHARE*, 1992–2000

	MAINE	U.S.
Information Technology	3.72	0.95
Biotechnology	1.22	1.15
Forest Products	0.75	0.32
Agriculture	0.98	3.23
Advanced Materials	1.31	0.30
Precision Manufacturing	1.12	1.78

LOCATION QUOTIENT**, 1992 V. 2000

	MAINE 1992	MAINE 2000
Information Technology	0.283	0.508
Biotechnology	0.711	0.942
Forest Products	4.160	3.356
Agriculture	0.315	0.333
Advanced Materials	2.500	3.628
Precision Manufacturing	0.504	0.605

*Numbers > 1 indicate increasing share of employment.
**Numbers > 1 indicate Maine is more specialized than the U.S.[2]
Source: Maine Department of Labor, unpublished data
Note: Employment data for aquaculture and environmental technologies are not available in sufficient detail to calculate for this table.

[2]This is measured as change in location quotient defined as $\frac{E_i^r / E_t^r}{E_i^R / E_t^R}$ where E_i^r = employment in region r and industry i, E_t^r = total employment in region r, E_i^R = in employment in industry i in a reference region R and E_t^R = total employment in region R. In this case, r=Maine and R=U.S.; i=industries as defined in Table One.

A 1 is a sign that this particular characteristic requires attention, while a 3 indicates a source of strength upon which to build. A 1 is no more a sign of failure than a 3 is a sign of perfection.

For factor 8, Lead Industry Group Employment Growth (Economic Performance), three factors are considered for all industry groups except marine technology and aquaculture:

A. If the Maine employment in a group grew faster than the U.S. employment from 1992 to 2000, one point is awarded. If Maine grew more slowly, no points are awarded.
B. If the share of total employment in the Maine group grew faster over that period than the share of total employment in the U.S., one point is awarded.
C. If the share of employment grew more slowly in Maine, no points are awarded. If the location quotient (a measure of economic specialization) increased in Maine over this period, one point is awarded. If the location quotient stayed the same or declined, no points are awarded.

In the case of marine technology and aquaculture, the data on aquaculture employment are not available for Maine or for the U.S. in sufficient detail to permit this calculation. Therefore, we have assigned a judgment-based score of 2, largely reflecting the strong growth in aquaculture in Maine but also recognizing the risks confronting that industry.

The results of the analysis displayed in Table Three for each industry group may be summarized as follows:

1. Information Technology: This sector has very high growth potential in export markets, and Maine has been successful in growing this sector faster than the U.S over the past decade. The markets served are diverse, but still not as diverse as other IT regions. There are relatively weak connections among firms in the software industry that do not create conditions for strong local demand, although there is an emerging concentration in geographic software that could have several connections within and across Maine clusters. In software, there are no large organizations that are playing leadership roles. There is a moderate sized labor pool of software and hardware specialists that could be broadened and deepened. Many small software firms are too reliant on self-funding and grants and too oriented to lifestyle concerns to spur rapid growth. R&D in Maine is quite limited and focuses primarily on product development, which is appropriate to this sector. Marketing Maine as a software center remains a problem.

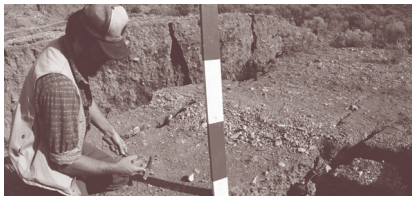
2. Biotechnology: The biotechnology sector also has high growth potential. In Maine, the sector is divided into very large institutions such as The Jackson

"Information Technology has very high growth potential in export markets, and Maine has been successful in growing this sector faster than the U.S over the past decade."

TABLE THREE
ANALYSIS OF MAINE CLUSTERS

CLUSTER CHARACTERISTIC	CHARACTERISTIC TYPE	INFORMATION TECHNOLOGY	BIOTECHNOLOGY	ADVANCED MATERIALS	FORESTRY	AGRICULTURE	MARINE & AQUACULTURE	ENVIRONMENTAL TECHNOLOGIES	PRECISION MANUFACTURING
INNOVATION	Product	3	3	3	1	1	2	2	1
	Process	1	1	2	3	2	2	1	3
REGIONAL BUSINESS FUNCTIONS	Research	1	2	2	1	2	2	1	1
	Development	3	2	3	2	2	2	2	3
	Production	1	2	3	3	3	3	1	2
	Marketing	2	2	2	1	1	1	1	3
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	1	2	2	3	2	2	2	2
FINANCING	Self—Outside	1	2	3	3	1	2	2	3
	Grants—Capital	2	2	3	3	3	2	2	3
RELATIONSHIPS	Firms—Horizontal	2	2	2	3	3	1	1	1
	Firms—Vertical	1	1	1	3	3	1	1	2
	Labor	2	3	2	3	3	2	2	2
	R&D Facilities & Organizations	1	2	1	3	3	2	1	1
	Industry Associations	2	2	2	3	3	2	1	1
	Lead Organizations	1	2	2	3	1	2	1	1
LOCATIONAL ADVANTAGE	Geography	1	1	3	3	3	2	2	1
	Knowledge	1	2	3	2	2	2	2	3
MARKET POTENTIAL	Mature—Growth Markets	2	2	2	1	1	1	2	1
	Diversity of Markets	2	2	2	3	3	1	1	2
	Local Demand	2	1	2	3	3	1	2	2
	Exports	1	2	2	3	3	3	1	1
ECONOMIC PERFORMANCE		3	3	3	1	1	2	NA	2

Laboratory and very small businesses engaged either in research and development or in producing for specialized markets, with a limited number of mid-sized organizations such as IDEXX. Most of the biotechnology sector is oriented toward producing new products for a variety of markets. A high degree of research takes place in Maine, and this could lead to a high level of product development in the future. While production and marketing of some biotechnology products takes place in Maine, production of most products, such as pharmaceuticals, takes place outside of Maine. As a result, horizontal relationships within the sector, including connections among the major research institutes, are increasing. But vertical relationships within Maine remain underdeveloped. A common pool of labor exists but requires strengthening. Economic performance relative to the U.S. has been good over the last decade.



3. Advanced Materials and Composites: This sector comprises two distinct areas: man-made fibers, such as carbon fiber, and composites involving natural and man-made fibers. In the former area, Maine has developed strong products with a high degree of research and development. This is particularly the case in the boatbuilding sector. Although rapid growth in this market is somewhat limited, Maine has achieved significant success, with strong relationships across the supply chain within the state. These characteristics of the man-made fiber industry are counterbalanced by the still-emerging natural/man-made fiber industry. Maine's composite wood products sector is at an early stage of evolution. Early research has demonstrated technical feasibility and there is high potential demand, but this has not yet been fully demonstrated in the market. Cluster relationships for advanced materials as a whole are somewhat limited by the division between primarily man-made and primarily natural products and the fundamentally different markets the two industries serve. This limits communication between organizations and may limit future development of the technologies involved.

"The forest products industry demonstrates the strongest cluster characteristics of any sector in Maine."

4. Forestry: Although the legislature designated "Advanced Technologies in Forestry and Agriculture" as one of the sectors for which support programs are designated, the differences between these two large and diverse sectors require separate analysis. The forest products industry demonstrates the strongest cluster characteristics of any sector in Maine. Maine has strong, world-class competitive firms and a substantial knowledge base about forestry and forest products manufacturing. Important research is being conducted in both the private and university sectors. Much of that research is focused on improving production processes in order to lower average costs rather than creating new products. This is because forest products is a mature industry. A strong network of relationships exists among firms and other organizations, with a common pool of skilled labor for all parts of the sector. Despite these strengths, however, Maine's forest products industry has not grown well relative to the rest of the U.S. over the past decade.

"Maine aquaculture has grown rapidly over the past decade to become a major center of the industry in North America."

5. Agriculture: As with forest products, Maine agriculture enjoys the support of a dense web of networks. In terms of relationships, the only weakness is in labor, where the problem of younger people leaving farming and farm communities is draining the pool of skilled labor. Like forest products, agriculture faces mature markets that are not likely to see rapid growth, except perhaps in some niche areas. Though dominated by potatoes, Maine agriculture is fairly diverse, and the development of a specialty foods industry over the past decade has greatly improved local demand for Maine products.

6. Marine Technology and Aquaculture: This sector comprises two vastly different industries: boat- and shipbuilding, which dominate the category, and aquaculture. Boat- and shipbuilding are covered in the sections of this report dealing with composite materials and precision manufacturing. Maine aquaculture has grown rapidly over the past decade to become a major center of the industry in North America. New aquaculture research organizations dedicated primarily to improving processes of aquaculture production have enhanced Maine's efforts; however, aquaculture has become such a competitive industry worldwide that it will be difficult to sustain rapid growth, unless significant newly cultured species become commercially viable.

7. Environmental Technologies: We found this sector to have the weakest cluster characteristics. There are several firms involved in developing new ways of handling wastes and by-products, but these firms have little in common in either technologies used or markets served. The result is that the kinds of relationships needed to form a cluster are lacking, although the pool of labor interested in the field does provide some degree of commonality. Because the sector has not yet coalesced around a particular approach or market segment, it is difficult to gauge market potential.

8. Precision Manufacturing: Like environmental technologies, this is also a loose agglomeration of firms in a number of different industries. As currently defined, it includes firms in the fabricated metals, electrical and electronic equipment and instruments industries. R&D activities vary from strong to weak in these industries and are oriented toward improving processes. The sector includes both very large and very small firms, some of which are world-class, while others serve local markets. There is a good pool of common labor, although there is some question as to the adequacy of the pool in the electronics field. Although the sector has done well compared to the U.S. over the last decade, the markets served are relatively mature.

THE EVOLUTION OF MAINE'S CLUSTERS

In selecting which industries would be the focus of research and development assistance, the legislature chose industries that clearly play, or have the potential to play, important roles in Maine's economy. However, when we assess the evolution of these industries as clusters, they do not present a coherent picture.

The connections among the industries as grouped by the legislature are sometimes so tenuous that it will be difficult to follow their progress in the future. More importantly, the very process of research and development, which state policy seeks to accelerate, will lead to new ways of organizing the activities.

For purposes of administering the various programs that have been established, the current division has proved both useful and appropriate for the various organizations involved. This report does not recommend changes in these programs or their organizational arrangements.

We do suggest ways of conceptually regrouping the state's seven targeted technology-intensive industries. We think this regrouping makes sense for two important reasons. First, it may more closely reflect the future development of the clusters and the connections emerging within and among industries. Second, it may help reduce the confusion we found among the organizations interviewed about their classification.

"This description separates marine technology from aquaculture and agriculture from forest products."

The industry groups are based on three different organizational principles describing what each group makes:

Technology that can be used for different products
- Information Technology
- Biotechnology
- Advanced Materials and Composites
- Marine Technology

Products made from Maine natural resources
- Forest Products
- Agriculture
- Aquaculture

Other
- Precision Manufacturing (defined by process rather than product or technology)
- Environmental Technologies (defined by a loose assortment of markets)

It will be noted that this description separates marine technology from aquaculture and agriculture from forest products. There is no real interaction between forest products and agriculture and thus each should be assessed according to its own progress. Nor is there a relationship between marine technology (as generally defined) and aquaculture. Bath Iron Works has little in common with aquaculture aside from a coastal location.

While this report separates some industries, it recombines others. This is the case with agriculture and aquaculture, both of which could be considered part of a food products cluster. Using food products is actually more consistent with the actual organization of these industries in Maine, because there are important links between growing and processing industries that have been and continue to be an important part of the Maine economy.[3]

A regrouping of the industries selected by the legislature based on their economic interrelationships is set out below. It reflects two additional changes. The first moves marine technology from its own category to precision manufacturing, reflecting the limited number of firms in marine technology in Maine. At this stage, it does not make sense to define these firms as a separate group. Firms that do fit into the category tend to have more in common with firms in the precision manufacturing group than any other group, so we include them there.

"Indeed, the entire purpose of Maine's investment in R&D is to create new ways of looking at problems and developing commercially viable solutions."

The other change moves firms making computer hardware, electronics and communication and instrumentation components for the information technology sector together with firms making software. This is done to reflect more accurately the information technology sector as defined elsewhere.

Technology Group
- Information Technology
  - Software
  - Hardware, electronics, communication and instrumentation equipment
- Biotechnology
- Advanced Materials and Composites

Resource Products Group
- Forest Products
- Food Products

Other
- Precision Manufacturing
- Environmental Products

In making these suggestions about reorganizing the groups of industries that form potential clusters in Maine, we do not mean to imply that these are the only organizations that should be used, or that they will remain immutable. Indeed, the entire purpose of Maine's investment in R&D is to create new ways of looking at problems and developing commercially viable solutions. These new solutions will inevitably change the way we have described today's economic activities and relationships.

[3]The question naturally arises whether the fishing industry ("capturing" as opposed to "culturing") should be included in this cluster. There is certainly a strong case to include it in a general food cluster and to examine that cluster on its own merits. However, the traditional fishing industry was not specifically included in the legislature's focus on strategic industries, although fishery research is considered part of marine technology. We recommend that agencies involved in Maine's research and development programs review potential applications to traditional capture fisheries.

TABLE FOUR
ANALYSIS OF REORGANIZED MAINE CLUSTERS

CLUSTER CHARACTERISTIC	CHARACTERISTIC TYPE	TECHNOLOGY: INFORMATION TECHNOLOGY	TECHNOLOGY: BIOTECHNOLOGY	TECHNOLOGY: ADVANCED MATERIALS	PRODUCTS: FORESTRY	PRODUCTS: FOOD[4]	OTHER: PRECISION MANUFACTURING	OTHER: ENVIRONMENTAL TECHNOLOGIES
INNOVATION	Product	3	3	3	1	1	1	2
	Process	2	1	2	3	2	3	1
REGIONAL BUSINESS FUNCTIONS	Research	2	2	2	1	3	1	1
	Development	3	2	3	2	2	2	2
	Production	2	2	3	3	3	3	1
	Marketing	2	2	2	1	2	3	1
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	2	2	2	3	2	2	2
FUNDING	Self—Outside	2	2	3	3	3	3	2
	Grants—Capital	2	2	3	3	3	3	2
RELATIONSHIPS	Firms—Horizontal	2	2	2	3	2	1	1
	Firms—Vertical	2	1	1	3	3	3	1
	Labor	2	3	2	3	3	2	2
	R&D Facilities & Organizations	1	2	1	3	3	1	1
	Industry Associations	2	2	2	3	3	1	1
	Lead Organizations	1	2	2	3	1	1	1
LOCATIONAL ADVANTAGE	Geography	1	1	3	3	3	1	2
	Knowledge	2	2	3	2	2	3	2
MARKET POTENTIAL	Mature—Growth Markets	2	2	2	1	3	1	2
	Diversity of Markets	2	2	2	3	3	2	1
	Local Demand	2	1	2	3	1	2	2
	Exports	1	2	2	3	2	2	1
ECONOMIC PERFORMANCE		3	3	3	1	1	2	NA

[4]Includes aquaculture and agriculture. Future assessments should explore connections to food processing in general, as well as to marketing and distribution.

Table Four on the previous page presents an assessment of the cluster characteristics of these groups. Table Five shows the recalculated economic performance data for the reorganized clusters.

TABLE FIVE
ECONOMIC PERFORMANCE DATA FOR REORGANIZED INDUSTRIES

EMPLOYMENT GROWTH RATE, 1992–2000

	MAINE	U.S.
Information Technology	109.5%	87.4%
Biotechnology	44.5%	12.1%
Forest Products	-12.0%	12.1%
Agriculture	16.1%	12.8%
Advanced Materials	55.1%	9.9%
Precision Manufacturing	29.8%	12.3%
Total Employment	18.0%	21.3%

CHANGE IN MAINE SHARE COMPARED TO CHANGE IN U.S. SHARE*, 1992–2000

	MAINE	U.S.
Information Technology	1.78	0.92
Biotechnology	1.22	1.15
Forest Products	0.75	0.32
Agriculture	0.98	3.23
Advanced Materials	1.31	0.30
Precision Manufacturing	1.10	0.93

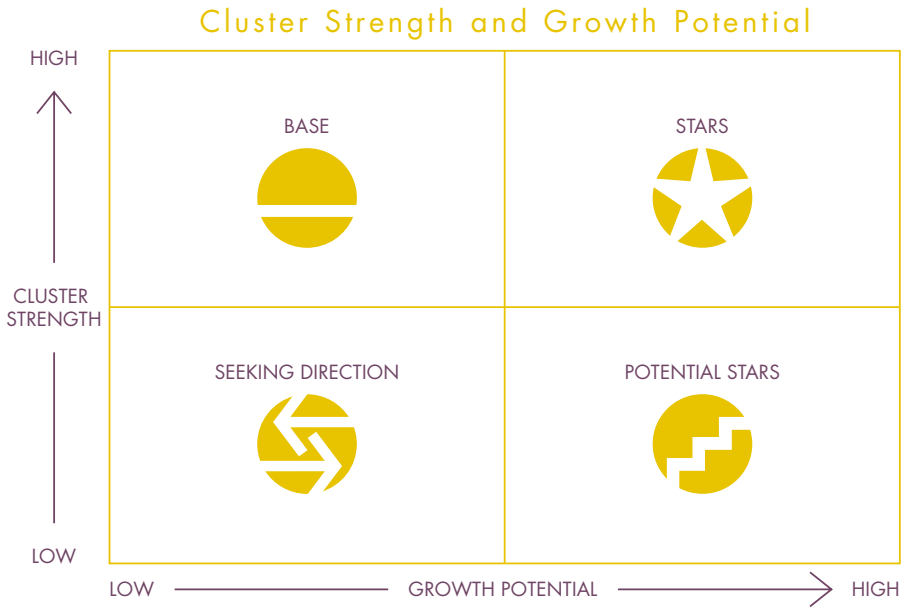
LOCATION QUOTIENT**, 1992 V. 2000

	MAINE 1992	MAINE 2000
Information Technology	0.611	0.702
Biotechnology	0.711	0.942
Forest Products	4.160	3.356
Agriculture	0.315	0.333
Advanced Materials	2.500	3.628
Precision Manufacturing	0.418	0.497

*Numbers > 1 indicate increasing share of employment.
**Numbers > 1 indicate Maine is more specialized than the U.S.
Source: Maine Department of Labor, unpublished data
Note: Employment data for aquaculture and environmental technologies are not available in sufficient detail to calculate for this table.

THE ROLE OF CLUSTERS IN THE MAINE ECONOMY

The complex nature of clusters requires the use of multiple factors for assessment, but the result can be difficult to interpret. Therefore, a further refinement is shown in Table Five (page 32). The most important question about clusters is their ultimate effect on the Maine economy. That effect depends on the strength of each cluster's characteristics and economic performance. The latter, in turn, is measured by both past performance and the potential for future performance. These two dimensions result in four possible types of clusters:



"The most important question about clusters is their ultimate effect on the Maine economy."

Stars are clusters that have numerous strong cluster characteristics along with strong economic performance and market potential involving diverse products in both local and export markets.

Potential Stars rate highly for both performance and potential but currently lack strong cluster characteristics. Their good performance derives from the firms and industries comprising the lead industry group. But the absence of strong cluster characteristics means that they are vulnerable to competition from other areas that do have strong clusters. In addition, they may be vulnerable to relocation outside the state.

Base industries have strong cluster characteristics but weak economic performance. These industries have strong ties to Maine, but they will not contribute to

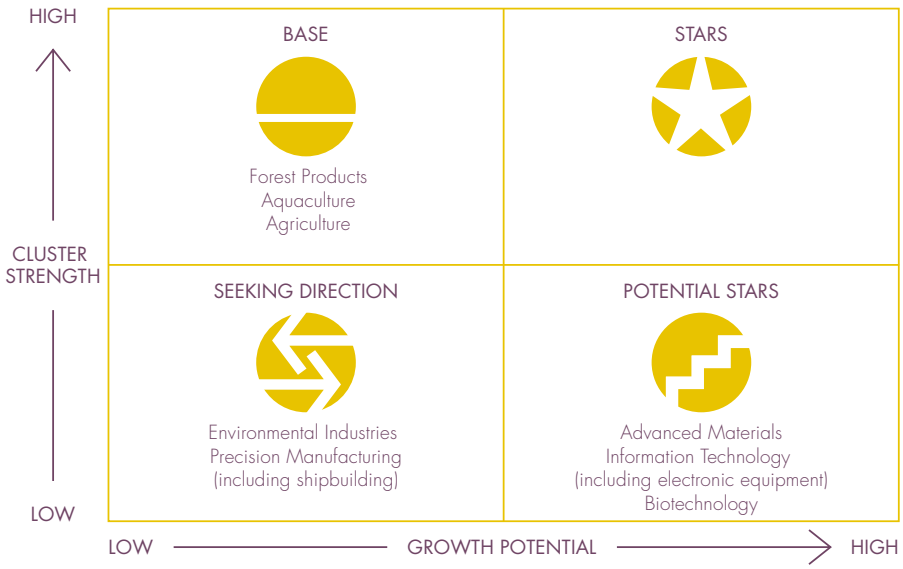
overall economic growth as much as their potential cluster characteristics would suggest because of limited market opportunities.

"At present, Maine has no Star clusters, although it does have Potential Stars and Base industries."

Seeking Direction are groups of firms that have neither strong cluster characteristics nor strong growth performance or potential. Their prospects as clusters are the most uncertain.

The chart below shows a classification of Maine's industries. At present, Maine has no Star clusters, although it does have Potential Stars and Base industries. The Potential Stars include biotechnology, information technology and advanced materials; Base industries include natural resource industries. Of the sectors we examined, environmental industries and precision manufacturing groups are Seeking Direction.

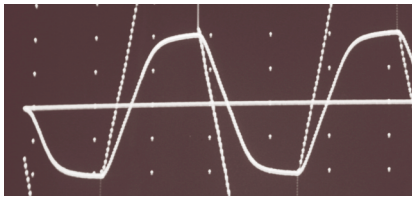
Cluster Strength and Growth Potential for Maine Industries



Suggested Actions

Maine has already begun an effort to enhance the competitiveness of its economy by investing in research and development in support of these industry groups. The expectation is that these investments will pay off in the short term in increased research and development activity in the state, in the medium term in increased creation of commercially successful products and in the long term in the reorientation of Maine's economy to a greater emphasis on technologically innovative industries.

A process beginning with R&D investments and ending in a significant transformation of the Maine economy is necessarily long. It will require orienting investment and other economic development policies toward cluster development. It will also require monitoring the changes underway in each cluster to ensure favorable change.



Our suggestions below are meant as general guidance, rather than specific program-level policy recommendations, as this would exceed the scope of the study. We leave those details to program administrators and others.

1. Target Investments that Strengthen Clusters.

When investments are made in support of research and development, there are opportunities to strengthen clusters. These opportunities differ from cluster to cluster and consist of two types:

Opportunities to Address Issues Within Clusters. The assessment of each cluster presented above provides a guide to weaknesses to be addressed and strengths to build upon.

Opportunities to Support Subclusters. Subclusters are concentrations of economic activity that fit within larger clusters that show stronger cluster characteristics or other distinctive features. Subclusters are found, for example, in biotechnology, environmental engineering, forest products, agriculture and boatbuilding, among others. Subclusters should be supported, but not to the exclusion of other opportunities.

Opportunities to Foster Connections Across Clusters. The pace of technological change is so rapid that any division of the economy according to current views of technology could obscure critical future opportunities. Thus, supporting investments that create new intersections between clusters can be as important as supporting activities within clusters. In his recent study of national clusters, Porter (2001) noted, "new firm and cluster opportunities arise at the intersection of existing clusters." Our research suggests some examples of these cross-cluster connections:

- Information technology applications (e.g., geographic information systems) in natural resource management
- Advanced materials in creating new products for the forest products industry
- Aquaculture and other food processing products/processes

"When investments are made in support of research and development, there are opportunities to strengthen clusters."

"Recent increases in funding for R&D and for a variety of incubators and support activities must be sustained if they are to pay off."

A particular note should be made of Bath Iron Works, which can play a critical role in helping to support a number of Maine's nascent clusters. Finding ways to tap into the expanded research and development funding coming to BIW should be a high priority.

Support Network Connections. If the essence of clusters is found in the relationships among organizations and firms, then it is critical that these relationships be fostered. Support to establish or strengthen industry associations may be one approach. Support for firms to take advantage of opportunities such as trade shows or international trade development trips can create opportunities to stimulate horizontal relationships among firms in similar industries.

Promote Leadership Development. Maine's economic development efforts extend beyond research and development initiatives. While not every economic development program at the state, regional or local level needs to be oriented toward cluster support, the leadership to strengthen Maine's clusters must come from a broader pool than just those interested in research and development. Thus, the concept of clusters, and their strengths and weaknesses, need to be broadly understood within the economic development community. In particular, leaders of regional and local economic development efforts should be informed about Maine's R&D and cluster development initiatives and should be enrolled in the process of transforming the Maine economy in this direction.

2. Continue and Expand Existing Initiatives.

Recent increases in funding for research and development and for a variety of incubators and support activities must be sustained if they are to pay off in the kinds of cluster development envisioned. These increases are significant by Maine standards, but as Luger and Feller (2001) made clear, as Maine has increased its investments in the hope of creating competitive technology-oriented clusters, other states have increased their investments, too—often by much larger amounts.

State funding for research and development is intended to catalyze investment by others, particularly the federal government and the private sector. One area in which additional nonstate funds would be welcome is the development of additional technology/industrial parks. The Mead Corporation and other private firms, which are playing an important role in the River Valley and other incubators are an example. An opportunity may exist for a biotechnology park in southern Maine, and the possibility of creating an IT technology park in southern Maine is being pursued.

Several state economic development initiatives are proposed or underway that will provide significant additional support to these industries. These include programs to expand the availability of venture capital and other financing for firms seeking to commercialize new products. All of these efforts will be important.

The research for this project suggests that marketing and business management remain the most difficult challenges for many small firms. Support in these areas for information technology, biotechnology and advanced materials firms, perhaps through Maine's network of Small Business Development Centers, could be an important addition to Maine's cluster development strategy. We single out these industries because they have the potential for the fastest growth. This may mean greater payoffs sooner; moreover, rapid growth almost inevitably puts small business management skills to the severest test.

3. Monitor and Evaluate Results of R&D Investments.

The Maine legislature has mandated that the impact of the state's R&D investments be monitored and evaluated. A process has been put in place to begin that evaluation for each of Maine's public R&D investments. Beyond program-level evaluation, we must measure the long-term effects on the structure of the Maine economy. The cluster framework developed here provides a basis for that assessment.

"Marketing and business management remain the most difficult challenges for many small firms."

Implementing this framework for monitoring and evaluation will require three steps:

Surveys. Most recipients of R&D funds will be surveyed annually by MSTF. Questions will relate to issues raised in this study, particularly concerning the development or strengthening of relationships.

Case Studies. Interviews with R&D recipients and others will continue to form an important part of the monitoring process. This will generate opportunities to explore issues related to cluster development in much the same format as was used for this study.

Assessments. Surveys and case studies will include appropriate assessments of the factors affecting cluster growth as identified in this study.

Care must be taken not to overburden data collection processes that are designed primarily to address program and legislative requirements. However, these processes represent an opportunity to look at important larger questions.

"A follow-up study...could...provide a much more complete picture of the extent to which Maine is, or is not, transforming its economy in the directions desired."

The final element in the monitoring and evaluation process should be a periodic restudy of each of the clusters along the lines of this project. This is needed because the survey and case study data alluded to above will focus primarily on recipients of research and development assistance. But this group, important as it is, is only a subset of the many firms and organizations affecting the growth and development of Maine's clusters. A follow-up study, conducted perhaps every five years, could build upon information collected during R&D monitoring and evaluation to provide a much more complete picture of the extent to which Maine is, or is not, transforming its economy in the directions desired.

4. Other Issues

In the course of the 168 interviews with private-sector firms conducted for this project, a number of issues arose often enough to warrant noting here.

Air Transportation. Several companies expressed concern about the availability and cost of air transportation, particularly through Portland. For many smaller IT and biotech companies requiring frequent personal contact with customers, suppliers and collaborators outside Maine, air transportation is a problem. (Most of these comments were made prior to the reductions in air service following September 11, 2001.)

Availability of Broadband Communications. Parts of Maine have good access to affordable broadband telecommunications, but many do not. For some firms, the lack of broadband communications makes growth difficult. The problem is not unique to Maine. The spread of cable Internet and DSL has been uneven across the country, and problems in the communications industry resulting from the recent dramatic decline in the stock market only compound the barriers.

University Programs and Support. Recent increases in research and development capacity at both the University of Maine and the University of Southern Maine are neither well-known nor well-understood in the private sector. The perception remains that Maine continues to give insufficient support to its public universities, especially compared with other states. There is also a perception among firms in southern Maine that they are particularly disadvantaged in access to research and a skilled technical workforce. These perceptions limit firms' willingness to work with the campuses of the university system and lead them to question their long-term competitiveness in Maine.

ANALYSIS OF MAINE'S CLUSTERS

INFORMATION TECHNOLOGY

Introduction

Information technology (IT) is one of Maine's top growth industries, showing rapid growth over the last five years. There is hardly a business in Maine that does not depend on computers and software for some key functions, and more and more companies rely on information technology for functions ranging from communications, to accounting, to inventory and process control.

"Information technology is one of Maine's top growth industries, showing rapid growth over the last five years."

Nationally, IT provides software, services and e-commerce to essentially all other industries, from banking and insurance to a wide range of manufacturing industries.

Studies of information technology clusters typically include industries that manufacture computers and supporting networking and communication equipment. In Maine's classification of targeted technology clusters, information technology has been confined to the software side of the industry. The hardware side, that is, firms involved in manufacturing computer chips, electronics and communication equipment, has been grouped with precision manufacturing.

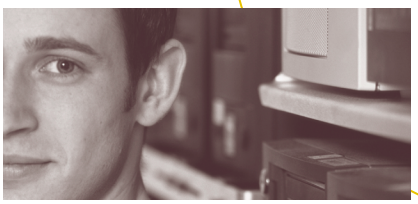
This approach separates two key parts of the IT sector and reduces our understanding of the cluster potential of this sector. For the purposes of this report, we examine the hardware side under its original categorization in precision manufacturing. Software and services are discussed in this section. But in future cluster analyses, it would make better sense to group the software and hardware sides of information technology together.

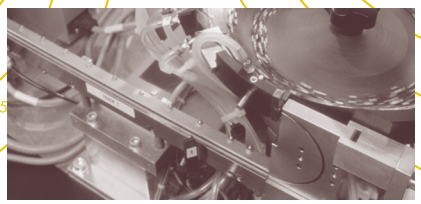
Information technology is now so widely diffused throughout the economy that it is not easy to find an activity untouched by it. For that reason, it is important to make a distinction between "IT producers" and "IT users."

This division focuses attention on the activities of greatest interest for cluster development. It is somewhat of an oversimplification, although a useful one. The nature of IT requires high degrees of similar expertise in both IT-producing and IT-using organizations, spread across numerous Maine industries.

Distinguishing IT producers from IT users, we can divide IT in Maine into two categories:

- Firms that create and market software products or solutions using existing software used by any organization, or provide services (Web, e-commerce, data storage, connectivity) to those organizations;





- Established companies in insurance, banking, health care and other industries such as tele-services (call centers) that are heavy IT users. These companies use IT to serve their original markets and are referred to as legacy industries.

Legacy industries are important in Maine because they create much of the local demand for IT software and services. The IT industry that has grown in Maine over the last decade is strongly tied to serving that demand. Some newer IT companies are not tied to local demand but those that have been in existence for longer periods often have legacy industries as clients and customers.

This analysis will focus only on companies that create software or provide services, as several of Maine's legacy industries are examined in other chapters. Eighteen firms or organizations were selected for this analysis based on their high level of innovation in product or service development. Efforts were made to diversify the sample according to firm size, niche and geographical location.

TABLE SIX
SELECTED MAINE INFORMATION TECHNOLOGY COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT	EMPLOYEES
Animated Images	Camden	Apparel design software	Jack Bullock	10–24
Blue Marble Geographics	Gardiner	Geography software	Jeff Cole	10–24
Blue Note Technology	Waldoboro	Business support software	Michael Laing	10–24
Common Census	Westbrook	Business support software	Daniel Freund	10–24
Commtel	Portland	Web connectivity and service	Scott Roberts	50–99
DeLorme	Yarmouth	Geography software	Gordon Pow	100–249
HCI Systems	Kennebunk	Business support software	Jim Kavanaugh	NA
NFR Partners	Moody	CAD software development	John Coelho	1–4
Northern Geomantics	Hallowell	Geography software	William Duffy	5–9
Professional Software Solutions	Falmouth	Business support software	Daniel Knowles	5–9
Rowse & Loring	Falmouth	CAD software support	Robert Rowse	10–24
Standard IO	Portland	Application service provider	Jesse Chun	5–9
Tech Ventures	Portland	Business growth services	Tony Perkins	NA
Time Warner-Road Runner	Portland	Cable & business support	Rick Preti	50–99
TSI Systems	Wiscasset	R&D (primarily DOD)	Charles Benton	5–9
UM Computer Science	Orono	Research and education	George Markowsky	NA
USM Information Science Research Institute	S. Portland	Research and education	Julie Ellis	NA
Wright Express	S. Portland	Fleet management services	Jack Spradley	>500

INFORMATION TECHNOLOGY

An *IT Industry Survey Report* (2000) prepared by MESDA (Maine software and information technology industry association) found employment in Maine's IT sector totaled 45,500. This included employment in software and network service companies, as well as IT-related employment in industries such as banking, insurance and telemarketing that are heavily IT dependent. Call centers, which are heavy users of IT but focus on customer service or telemarketing, account for 20,000 of the 45,500 IT-related jobs in Maine.

"The high wage scales of the core IT industry make it one of the state's most important growth sectors."

MESDA estimates that nine percent of private-sector workers in Maine are in IT or IT-related positions and that IT employers generated more than $3.1 billion in revenues during 1999. This represents more than 10 percent of Maine's gross state product.

The total number of IT firms in Maine is approximately 1,600, according to MESDA. While call centers may employ up to 1,500 employees at a single location, most large IT companies in Maine employ at maximum only a few hundred employees. Over 90 percent of the companies have fewer than 16 employees.

The segment composed of software companies and service providers employs about 13,500 and is strongly driven by continued innovation in technology, software and services. Firms such as UnumProvident and Anthem/Blue Cross are also large IT employers and employ about 12,000 in Maine.

Legacy industries are important because they create strong local demand for sophisticated software and network services and are continually upgrading both hardware and software. Legacy industries may be one reason Maine's IT industry has been relatively unaffected by the collapse of the dot-com boom and the associated decline in technology industries. While major IT industry centers around the country have seen leading IT firms fail or shrink, Maine, with its smaller, diversified IT industry, has been spared this steep decline.

The high wage scales of the core IT industry make it one of the state's most important growth sectors. Average wages rose to $47,800 in the industry in 1999, up 30 percent from 1995 (MESDA, 2000). In addition to strong wage growth, the sector has seen rapid proliferation of IT businesses, with the number of firms increasing 115 percent in the last five years. This makes IT the fastest growing Maine industry in terms of both wages and number of companies.

Call centers and telemarketing firms are not IT companies per se, even those, such as EnvisioNet (now part of Microdyne Outsourcing of California), that provide software support services. But call centers play an important role in training thousands of new employees in basic computer use and IT systems, thereby increasing the size of Maine's IT-skilled workforce. Employees in these companies often have

opportunities to receive advanced training and move up in IT skills and salary if they choose to do so. Call centers, which are heavily IT dependent, also provide a potential source of local demand for software services and applications.

Business Characteristics

The national and international IT industry produces a huge array of products and services including business software applications, e-commerce and packaged software for business and entertainment. While packaged software is familiar to most consumers, much of the industry is focused on complex business software applications. The advent of e-commerce in the last few years rapidly expanded this market, generating strong demand for access and services following what amounted to the re-creation of the information technology sector as the Internet developed.

Consumer-related e-commerce has grown significantly, but business-to-business ("B2B") applications have proved to be one of the more profitable and successful growth areas, with revenues 10 times greater than those on the consumer side. B2B markets have moved from traditional markets into manufacturing and related industry, further broadening markets. B2B e-commerce transactions are expected to reach $2.7 trillion in 2004 (Forrester Research, 2001).

"Software has become a worldwide industry characterized by both intense competition and intense rates of innovation and product development."

Software has become a worldwide industry characterized by both intense competition and intense rates of innovation and product development. While the United States remains the dominant force in software, significant challenges in business software are arising in the developing economies of Eastern Europe and India, as well as in the already strong economies of Western Europe.

An important characteristic of the industry is the nature of the work done. Some firms are product oriented, producing new software products for particular markets. This segment of the computer software industry is characterized by significant expenses for upfront development, marketing and technical support infrastructure for initial versions of software products.

Web-based software and marketing systems developed by dot-com companies also fall in this category. With startup companies, venture capital typically plays a key role, while established companies may use stock sales, product sales or other mechanisms to finance development costs.

The availability of financing fueled explosive growth in the late 1990s as pioneering Web applications and new markets were developed, but the slowdown in the U.S. economy and failure of consumer markets to develop as projected led to

INFORMATION TECHNOLOGY

the collapse of this speculative bubble. Recent growth has focused on the far more lucrative and predictable business-to-business market.

The line between services and products has blurred considerably, as software firms provide more services for customers and as industries that are heavy users, such as insurance, start to develop the capacity to develop software in-house.

"A remarkable 82 percent of the core IT businesses in Maine employ eight or fewer individuals."

The growth of IT has created opportunities for companies to provide a range of services, including network services, system maintenance and software support. It has also fueled the growth of Application Service Providers (ASPs) that provide companies with full access to software and hardware systems located off site, with all maintenance and support performed by the ASP. These services can be labor intensive, but revenues offset costs, and upfront capital requirements are less than those associated with development and testing of new software.

IT in Maine is relatively homegrown. It is not dominated by large out-of-state corporations. Most firms started in Maine and are still run by their founders.

Most of the firms are also small. MESDA reports that 1,400 companies, or a remarkable 82 percent of the core IT businesses in Maine, employ eight or fewer individuals. Total employment among these small firms was approximately 4,200 at the time of the survey.

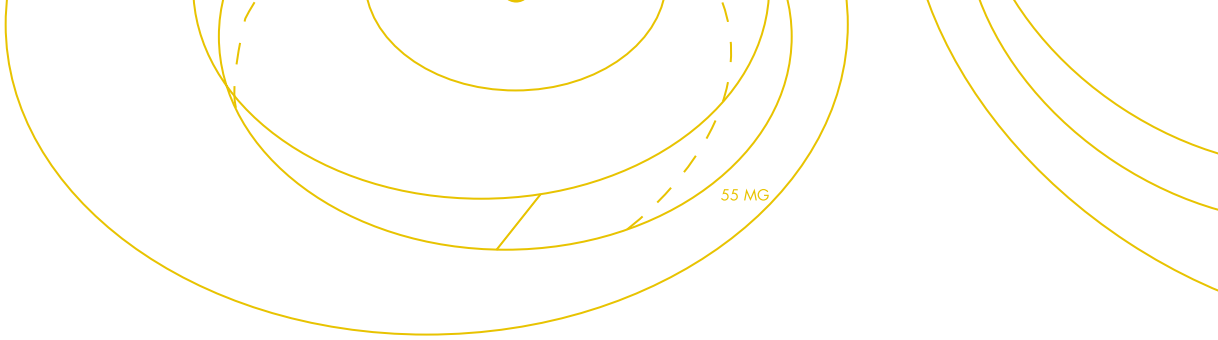
Larger companies, however, employ a majority of the core IT workers. In Maine, the survey showed, 112 companies had more than 25 employees, with total employment of approximately 8,000.

Maine firms operate in both rural and urban locations. The only major locational factor is the availability of adequate data communications.

Activity and revenues in Maine's IT industry are primarily generated from the integration of prepackaged software, custom applications and systems used to manage business resources.

In terms of customers, MESDA reports that 78 percent of surveyed companies have business as their primary market, with the remaining 22 percent focusing on consumers, government and education.

Much of Maine's software and information services industry grew from a support sector for legacy industries such as insurance and manufacturing. Insurance companies such as UnumProvident and Anthem/Blue Cross, with a computer on every desk, have very high demand for IT services, including data storage and transfer. In the mid-1980s, Maine lumber mills, led by Hancock Lumber, needed software



for running new automated mills, and Logical Systems of Yarmouth opened to answer the need. In the last decade, this industry grew as computer and software systems became integral parts of many companies in Maine, and demand for support services for increasingly complex software systems and internal computer networks intensified.

Applications of information technology create new ways for business to provide services and have fueled the growth of companies both in Maine and nationally. Wright Express has become an industry leader in systems for managing vehicle fleets and fuel supplies. I-many of Portland has become an industry leader in business contract management and receivables collection and has caught the attention of the national IT industry. Clareon of Portland is a leader in B2B e-commerce with Internet-based accounting and financial software, while Intellicare, also in Portland, offers patient management software for the healthcare industry. Blue Tarp of Portland has developed a card-based accounting system for building contractors. Most of these companies are market innovators and have been in existence only a few years.

One of Maine's oldest and most recognized IT companies is DeLorme in Yarmouth, a leader in map products and software for more than 20 years.

Maine also has a number of large companies that are heavy software users. These companies, such as EnvisioNet (now part of Microdyne Outsourcing in California), MBNA and UnumProvident, greatly increase the size of the software labor pool in Maine and provide potential local demand for software services. Companies such as Professional Software Solutions of Falmouth have grown to meet the demand, but connections between software writing firms and large software users in the state depend on the types of specialized software and services available and the needs of the user.

"Applications of information technology create new ways for business to provide services and have fueled the growth of companies both in Maine and nationally."

Many Maine software firms increasingly derive much of their income from out-of-state clients—a pattern also found in MESDA's survey. While local industry generates some demand for software, software companies must look to broader markets with larger numbers of customers.

International business accounts for a much smaller proportion of revenues, with fewer than 20 percent of surveyed companies conducting significant international business (MESDA, 2000).

Many of the small firms interviewed indicated that their main competitive advantage is a function of previous end-user experience. For example, previous users of CAD systems understand the systems' technological limits and set up shop to address the problems they know their former colleagues face. Similarly, former

employees of the insurance industry in Maine have used what they learned as insiders in launching new firms. This pattern typifies a number of Maine's small companies.

"Maine is widely viewed as an IT backwater, a significant problem in an industry in which reputation and cutting-edge applications are critical."

Maine's IT industry faces some important marketing challenges. Interviewees reported that Maine is widely viewed as an IT backwater, a significant problem in an industry in which reputation and cutting-edge applications are critical. This perception affects the firms' ability to attract new customers, new employees and out-of-state financing.

One technique for combating this problem, used by companies with out-of-state markets, is to open a sales office in Boston and print business cards with Boston and Maine addresses. Similarly, firms in southern Maine often bill themselves as being only a short drive from Boston.

The MESDA survey indicated that 62 percent of the state's IT firms are located in Cumberland and York Counties. The location offers advantages in terms of access to labor, access to customers both locally and in the Boston metro area and proximity to services. In addition, the rise of nationally recognized firms such as I-many and Wright Express helps boost Maine-based firms' recognition and reputation.

Horizontal relationships among software firms in Maine are relatively weak. While a few firms enter strategic alliances on a project basis with other IT firms, these relationships tend to be the exception rather than the rule. More commonly, Maine firms form such partnerships with out-of-state firms. These alliances often are necessary for small firms with limited resources and expertise.

Forming strategic alliances out of state builds Maine firms' overall capabilities and can be an essential part of building strong networks. Vertical relationships between product developers and production companies are probably less important in software than in other industries, because software can be distributed cheaply and easily via CD-ROMs and the Internet.

All interviewees agreed that a firm's ability to market its product or service is vastly more important than its technical abilities. For companies with national markets, teaming with out-of-state firms that are strong in marketing can be an effective strategy. Firms that are struggling, for the most part, have bonafide products that the market should support; however, inability to position and promote their products often slows their growth. Marketing and sales pose challenges for many Maine firms, especially those started by technically skilled entrepreneurs. This is true not only in IT, but in other industries as well.

Subclusters

Maine may be gaining recognition in one software area: geography-related programs. This is in part because of DeLorme, a leader in the field, but smaller, value-added software firms such as Northern Geomantics, Blue Marble and various software applications development and service firms also provide services related to geographic information systems. The University of Maine's Department of Spatial Information Science and Engineering and the National Geographic Data Center at Orono are complementary research programs, and the state Office of Geographic Information Services has made digital geographic data widely available. This subcluster suggests a future path for Maine's software industry.

Finance

While venture capital (VC) funded much of the explosive dot-com growth in the late 1990s, Maine IT companies have found this source of funding difficult to access. Several Maine companies did receive venture capital in 2000, but large VC firms generally funneled most of their capital into Massachusetts- and New York-based IT companies. Some of the companies that received venture capital such as Gofish and HCI have subsequently declared bankruptcy, proving that while IT companies have great potential, they may also pose a high degree of risk.

Several smaller VC firms operate in Maine and have established IT portfolios, but the amounts available for investment are relatively small. Companies such as Commtel, seeking large venture capital investments for construction of a planned data center, find the perception of Maine as an IT backwater a major obstacle. Also, extended debate over TIFs and BETR tax credits for business receive media attention and fuel a perception by large VC firms that Maine is not supportive of business.

Meeting the requirements for VC funding has grown more difficult since the demise of the high-flying dot-coms, and loss of control and rigorous business requirements may also discourage small local companies. Alternatives to conventional financing programs such as MTI and the Small Enterprise Growth Fund have recently played an important role. These programs are particularly useful for small firms with promising products in the early stages of startup. A key to the future of IT companies in Maine will be how rapidly growing firms in Maine can set up to take advantage of a new round of venture capital funding.

"A key to the future of IT companies in Maine will be how rapidly growing firms in Maine can set up to take advantage of a new round of venture capital funding."

Research and Development Facilities and Organizations

"Recently, Maine's IT industry received a boost with the opening in Orono of a $1.75 million R&D technology center for computer science applications."

The software industry in Maine is not heavily research oriented. Companies such as Applied Thermal Sciences of Sanford and TSI of Wiscasset conduct research, but generally, the industry in Maine is most interested in the development of commercial applications. Research activity is concentrated largely in the computer sciences departments at the University of Maine (UM) and the University of Southern Maine (USM) and in the Department of Spatial Information Science and Engineering at the University of Maine, which collectively have two dozen or more faculty. The UM Computer Sciences Department has research programs in areas including software agents, ocean modeling and parallel computing systems. The Department of Spatial Information Science has a National Center for Geographic Information Analysis, which will be relocated to the new IT Technology Center and incubator in Orono. USM is developing the Information Science Research Institute (IRIS) as a focal point for research in computer science, with the goals of spurring collaborative research with local companies and offering Ph.D. programs in computer science.

While these programs are important locally, they should be viewed in context. Strong IT research programs, such as those at Carnegie Mellon University or the University of Washington, have several hundred faculty and staff and hundreds of graduate students. The University of Washington alone has over 150 Ph.D. candidates. By contrast, the UM Computer Sciences Department has 11 faculty, one Ph.D. candidate and several master's-degree candidates. Clearly, large programs located in IT clusters have huge advantages. Research programs at major universities such as Washington and Carnegie Mellon are themselves small relative to industry-based research programs. With intense competitive pressure to create innovative products or solutions to existing problems and billions of dollars at stake, the research capacity within the industry far exceeds that of the universities.

Recently, Maine's IT industry received a boost with the opening in Orono of a $1.75 million R&D technology center for computer science applications. The center was developed by Bangor Target Development Corporation, a private not-for-profit organization that fosters economic development. Some of the space is leased to UM, which will relocate six researchers from the university's National Center for Geographic Information Analysis to the center; the site will also house the university's new parallel computing system, which links 200 small computers to form a supercomputer. Applied Thermal Sciences, an R&D firm in Sanford, will open an office there to collaborate with UM on the supercomputer contract. The center will also function as a business incubator, with low-cost leases for

startup IT companies, centralized business services and technical assistance in business planning and management.

Demand for an IT business park or technology center to serve as a hub for commercial IT activity in southern Maine is increasing. While the Old Port Technology Center in Portland has some of the necessary attributes, it lacks the size and facilities to function as a major technology center and does not offer below-market rents for startup companies. Interest in a larger facility combining research, incubation and commercial activity has spurred efforts to develop such a center in Portland.

Labor

IT companies are especially knowledge based and are particularly dependent on employees' skills, training and experience. Companies must be able to recruit the talent they need, particularly high-end employees with significant expertise, or be organized to train existing staff. Broadly speaking, high-end personnel perform more sophisticated applications or R&D-oriented tasks, command salaries in the $60,000–$100,000 range and are typically hired from outside the state. While a few people with advanced training may be available from UM, typically the pool is small.

"Companies must be able to recruit the talent they need, particularly high-end employees with significant expertise, or be organized to train existing staff."

Recruiting top talent can be a challenge. The best expect high salaries, a benefit that only larger, financially strong IT companies can afford. In addition, Maine's reputation as a backwater deters career-oriented employees, who see few opportunities in the state for movement within the industry. Companies must often recruit talent from other local companies, which does nothing to add to the local labor pool. Finding people with the right sales and marketing experience is particularly difficult, and many companies end up training people themselves.

For positions requiring only undergraduate education, UM, USM and other four-year colleges in the state have good programs in computer science. Yet graduates tend to leave the state to find work, as pay scales in Boston and other metropolitan markets have been considerably higher than in Maine. A recent class from UM saw 50 of 52 graduates commit to high-paying jobs out of state. While this is viewed as a loss, many predict that a good percentage of these graduates will eventually return to Maine, often with valuable expertise and experience not readily available locally. To retain these graduates, Maine companies must be willing to match the pay scales found elsewhere.

Companies interviewed reported an ample supply of labor for entry-level, non-R&D work. However, while the labor pool may have the requisite technical skills,

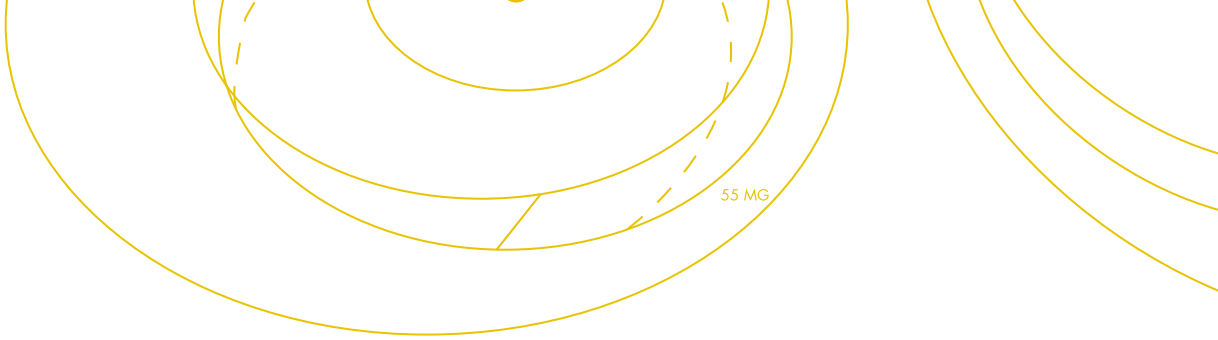
"While Maine claims a lead in statewide telecommunications and data infrastructure, in fact affordable broadband access is available only in certain areas of the state."

several companies noted that these workers often have poor communication skills (both written and verbal), do not understand the business environment (deadlines and cost consequences) and lack the social sophistication required to interact with clients and colleagues. One innovative firm grooms a significant portion of its future talent by means of an informal internship program that recruits students from local high schools. Other firms use freelancers, allowing companies to bid on a broad array of projects without carrying a large staff. Further, freelancers bring new ideas, a boon to small firms that rarely attract top talent.

Special Issue: Telecommunications Infrastructure

While Maine claims a lead in statewide telecommunications and data infrastructure, in fact affordable broadband access is available only in certain areas of the state, primarily around major cities and towns. Many rural areas do not have good access to high-speed connections, so businesses tend to concentrate in areas such as greater Portland, Augusta, Bangor and other cities where service is available. Aroostook County is fortunate to have excellent service as part of the Time Warner franchise area, a feature that can be a significant advantage for small companies that need affordable, fast access to the Internet. Companies such as L. L. Bean or Commtel that have large connectivity and data handling requirements must often contract with multiple providers, including Verizon, AT&T, Sprint and MCI to get the capacity and redundancy necessary for continuous, reliable, high-volume data transfer.

Time Warner has pioneered low-cost cable access to high-speed networks in Maine with its Road Runner service. The state was most fortunate that this occurred, as this process would have happened much more slowly, if at all, had smaller companies with fewer resources attempted it. Road Runner invested $11 million to develop two-way digital infrastructure, not only in Portland, but also in more rural areas like Presque Isle, and has demonstrated that such investments can produce excellent returns. The availability of cable Internet service is dependent on investments by cable companies and by the extent of their franchise areas. Some companies, such as Adelphia, are not pursuing cable Internet service in some of their franchise areas; DSL service is available from Verizon and other providers, but it can be costly to get needed service. Wireless technology is replacing cable technology in some areas, and some rural areas of the state may be most efficiently served by these systems.



Trade Associations

MESDA, the trade association for Maine's IT companies, has a large membership base and is the industry's only Maine voice. MESDA's user groups have attracted interest, meeting a need for users of Java and other software platforms. While some of the smaller firms interviewed suggested that trade associations were of little use, others had actually taken advantage of these relationships to solve problems, particularly in developing client relationships and looking for job prospects. In short, although not universally used to the full extent, most interviewees applaud the efforts of trade organizations, especially in raising public awareness, and many use these relationships when the need arises.

Lead Organizations

Among Maine's older software companies, only DeLorme is large enough to play a leadership role. It has done so to a limited extent and has spawned a few smaller companies that provide services and software for GIS applications or related areas. Wright Express, which currently is halfway through a four-year project to rewrite all its software to accommodate future growth, hired over 100 software personnel for the project. After the work is completed, this large pool of expertise may form the nexus for additional growth in software development. Growth in research institutes devoted to IT and in university-based computer science programs may provide additional leadership organization services.

Locational Advantage

There is no particular geographic advantage for information technology companies, although limitations on broadband access can be a constraint. Software can be written anywhere, as the development of a global market in software development attests. Fiber optic connections mean service providers do not have to be local and can readily operate from other cities. Thus, the only source of locational advantage is tied to a specific knowledge base. Maine is beginning to develop a knowledge base in fields such as geographic software and within firms dealing with such fields as insurance claims processing, but it is still nascent and at this point cannot realistically be said to be a source of locational advantage.

"Maine is beginning to develop a knowledge base in fields such as geographic software and within firms dealing with such fields as insurance claims processing, but it is still nascent."

TABLE SEVEN
SUMMARY OF CLUSTER CHARACTERISTICS[5]

INNOVATION	Product	3
	Process	1
REGIONAL BUSINESS FUNCTIONS	Research	1
	Development	3
	Production	1
	Marketing	2
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	1
FUNDING	Self—Outside	1
	Grants—Capital	2
RELATIONSHIPS	Firms—Horizontal	2
	Firms—Vertical	1
	Labor	2
	R&D Facilities & Organizations	1
	Industry Organizations	2
	Lead Organizations	1
LOCATIONAL ADVANTAGE	Geography	1
	Knowledge	1
MARKET POTENTIAL	Mature—Growth Markets	2
	Diversity of Markets	2
	Local Demand	2
	Exports	1
ECONOMIC PERFORMANCE		3

[5]See the chapter *Measuring Clusters in Maine* for discussion of factors.

"Information technology is now so widely diffused throughout the economy that it is not easy to find an activity untouched by it."

BIOTECHNOLOGY

Introduction

"Biotechnology is playing larger and larger roles in product development for several industries in the biomedical, chemical and agricultural sectors."

The biotechnology sector in Maine includes a diverse group of organizations in the biomedical, biotechnology, aquaculture and environmental fields and includes both biotechnology companies and users of biotechnology products. Some of these companies provide services in the biomedical or biotechnology sectors but are not classified as biotechnology companies, such as biomedical testing laboratories, or they use biotechnology products but do not employ biotechnology processes themselves.

The biotechnology sector overlaps significantly with the biomedical sector, a vast market in which many biotechnology firms compete as suppliers of both intermediate and final products used in biomedical research and healthcare applications. The biotechnology sector also overlaps with environmental testing and aquaculture, both users of biotechnology products. The addition of testing and healthcare laboratories, biomedical supply companies, educational institutions and specialized operations in environmental testing and aquaculture brings the total to approximately 80 firms and institutions. Including supporting institutions such as law firms, venture capitalists and accounting firms increases the total for these combined sectors to over 100 organizations.

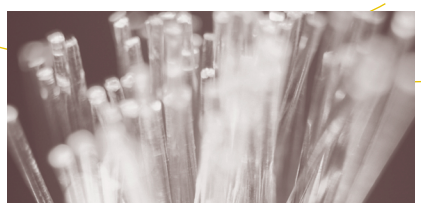
For purposes of this discussion, the initial focus will be on biotechnology companies only. As a working definition, these are companies or institutions that, in the course of their business or research, combine biological and technological processes to produce new products or innovations and research that may ultimately lead to new products. Biotechnology companies tend to be particularly innovative, as they operate in a market where competitive advantage is directly tied to innovation. A review of the markets in which Maine biotechnology companies compete serves to illustrate the importance of innovation.

Business Characteristics

Biotechnology is playing larger and larger roles in product development for several industries in the biomedical, chemical and agricultural sectors. Revenues for the biotechnology industry in the U.S. reached $20 billion last year, and venture capital investment in biotechnology rose from $667 million in 1998 to $1.04 billion in 1999 (Price Waterhouse-Coopers, 2000). The industry is small compared to the pharmaceutical industry (annual revenues of $107 billion), but it plays an increasingly important role in drug development (Ernst and Young, 2000).

Biotechnology is also used in a number of industrial processes, even though it has become widely associated primarily with genetic engineering of agricultural





products, from new strains of herbicide-resistant corn to new forms of drugs produced by genetically modified bacteria. Genetic science ("genomics") holds great potential for finding solutions to human disease, and the field is growing rapidly. Other fields in biotechnology also show strong growth potential, although they receive less public attention. While genetic engineering for disease treatment or prevention is welcomed, other applications, such as genetically modifying grain and produce crops for weed resistance, face an uncertain future as public unease over possible consequences of genetic manipulation continues to rise.

1. Health Care

This sector includes services and products ranging from human disease detection and genetic research to healthcare services, medical products, instruments and pharmaceuticals. Inclusion of animal health products and veterinary applications adds additional breadth to the sector. Biotechnology plays an increasing role in developing and producing new products, particularly in the pharmaceutical industry. With healthcare revenues totaling $838 billion (*Business Week*, 2000), the sector outscales most others in the national economy.

Product development pathways for biomedical applications vary considerably, depending on whether the product is used directly in the human body, outside the body or in the laboratory for research purposes only. Products used in the body, such as drug treatments or surgical instruments, face the most rigorous, time-consuming and expensive approval process. Products used outside the body (lab diagnostics, some medical supplies) face a less rigorous but still demanding process. Products used for research only (lab supplies, equipment, genetic samples or tests) face the least rigorous approval process (though still tougher than for many nonmedical applications) and can be developed, tested and marketed in much shorter time periods. Most biotechnology companies in Maine compete in the healthcare and veterinary arenas, and make products used outside the body, such as diagnostic materials, or produce materials used for research.

2. Pharmaceuticals

The demand for new potential drugs for the U.S. and global markets is very strong, and the outlook is for continued growth over the next five years. The value of industry shipments for the U.S. drug sector was $107.7 billion in 1998, an increase of 13.1 percent from 1997; the global market for prescription and non-prescription drugs is estimated at $300 billion, with a growth rate of 7 percent per year (U.S. ITO, 2000). Research-based U.S. pharmaceutical companies increased R&D expenditures from $18 billion in 1998 to an estimated $24 billion in 1999, a 33 percent increase (U.S. ITO, 2000). Some small companies in Maine, such as Phylogix in Scarborough and Coastside Bio Resources in Stonington are working on development of potential pharmaceuticals, but product development and testing require large amounts of time and capital and are relatively high risk.

"Biotechnology is also used in a number of industrial processes, even though it has become widely associated primarily with genetic engineering of agricultural products."

"The industries that use biotechnology represent significant growth opportunities and have been attracting a great deal of investment."

3. Nutriceuticals

This industry includes the growing market for nutritional supplements, herbal or "natural" remedies and other forms of nontraditional medicine. The industry has grown dramatically in the last five years as a number of companies have developed and expanded the mass market for nutritional supplements and "natural" remedies. The alternative medicine market grew to nearly $30 billion in the U.S. in 1999, with $14.7 billion spent on nutritional supplements alone (*Nutrition Business Journal*, 1999).

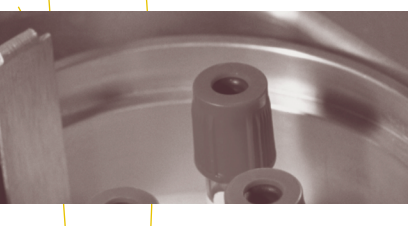
Nutriceuticals hold considerable attraction from a business perspective due to potentially high profit margins, the immature or unconsolidated nature of the market and opportunities for direct marketing through the Internet. In addition, the reduced testing requirement for naturally derived nutritional supplements and herbal remedies can expedite product development and marketing. Nutritional supplements do not require FDA approval and can be brought to market in a year or less.

4. Agricultural and Chemical Industries

A separate but also important source of demand comes from the agribusiness and specialty chemical industry. This includes pesticides, herbicides, specialty chemicals and additives and other applications such as adhesives. The market is large and diverse, and contains areas such as pesticides that are research intensive and tightly regulated. While the global pesticide market, with $31 billion in sales in 1998 (U.S. ITO, 2000), is not growing rapidly, change is evident. The U.S. Environmental Protection Agency is restricting the use of an increasing number of pesticides and herbicides that have been mainstays for the agricultural chemical industry, and few new pesticides are available that do not have undesirable side effects.

In summary, the industries that use biotechnology represent significant growth opportunities and have been attracting a great deal of investment. There are several reasons for this:

- The industry's scientific base is just beginning to expand. The range of potential products that could be built on that base remains unknown, but is expected to be quite large (Oliver, 2000).
- Potentially high profit margins, particularly in the biomedical and nutriceuticals industries, suggest to investors the possibility of significant returns.
- The ability to tap into specialized markets for goods for which consumers will pay premium prices and/or the possibility of tapping into large global markets with potentially high demand hint at long-term growth.



- The industry has the power to license discoveries, processes or products to mid-size or large multinational companies that have the financial resources, expertise and/or marketing skill to capitalize on potential.

Biotechnology in Maine

The core of the biotechnology sector in Maine has about 35 firms and four not-for-profit research institutions actively engaged in research, production of biotechnology products for the market or supplying other companies with research materials or inputs for production. Organizations range from large (The Jackson Laboratory and IDEXX) to small. The addition of direct support organizations such as the Biotechnology Association of Maine, educational institutions with biotechnology programs and key funders such as the Maine Technology Institute pushes the total to about 45 firms and institutions.

Maine biotechnology includes over 30 small firms and institutions with 100 or fewer employees each. Over 80 percent of these companies have five to 25 employees, and total employment among the smaller companies is approximately 570 people. Annual revenues for the smaller companies and institutions range from less than $500,000 to $10 million. In contrast, IDEXX, the largest firm in Maine's biotechnology industry, has over 900 employees in Maine (2,250 worldwide) and revenues of $367 million in 2000. Among the not-for-profit institutions, The Jackson Laboratory is the largest, with 1,025 employees and $68 million in revenues in 2000. Maine's other not-for-profit research institutions, which include Maine Medical Center Research Institute, Foundation for Blood Research and Mount Desert Island Biological Laboratory, all have fewer than 100 employees. Total employment in biotechnology companies and institutions, exclusive of closely related companies, is estimated at 2,520 employees in Maine.

"The core of the biotechnology sector in Maine has about 35 firms and four not-for-profit research institutions."

In order to better understand the current state of the industry in Maine, interviews were conducted with senior management at 30 firms or organizations around the state. Interviews focused on the growth of the company or institution, the role of innovation both for the industry and the organization and the factors in Maine that contributed to the success of the organization. Some companies were contacted previously for the report *Prospects for Marine Biotechnology in Maine* and are included here. The following companies and individuals were interviewed:[6]

[6]Of the companies contacted for this report, all are working on products for the pharmaceutical, biomedical or agricultural/industrial chemical industries. Aquaculture applications for biotechnology are covered in the report *Prospects for Marine Biotechnology in Maine* (Colgan and Baker, 2000).

TABLE EIGHT
SELECTED MAINE BIOTECHNOLOGY COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT	EMPLOYEES
Beacon Analytical	Portland	Environmental immunoassays	Brian Skoczenski	5–9
Binax	Portland	Human & animal diagnostics	Roger Piasio	100–250
Biode/Virostat	Westbrook	Biosensors/diagnostics	Doug McAllister	5–9
BIODESIGN International	Scarborough	Immunobiologicals	Linda Diou	25–50
Biotechnology Assoc. of Maine	Augusta	Industry trade association	Cheryl Timberlake	NA
CEI Ventures	Portland	Venture capital	Nat Henshaw	1–4
Curtis, Thaxter, Stevens and Micoleau	Portland	Legal services	Charlie Micoleau	NA
Envirologix	Portland	Environmental immunoassays	Bruce Ferguson	25–50
Farrell & Associates	York Harbor	Biotech patent law	Kevin Farrell	1–4
Foundation for Blood Research	Scarborough	Not-for-profit research—disease	Jane Sheehan	50–100
IDEXX	Westbrook	Veterinary diagnostics	Deborah Coyman	>500
Immucell	Portland	Veterinary pharmaceuticals	Michael Brigham	11–24
The Jackson Laboratory	Bar Harbor	Not-for-profit research—genetics	Tish Tansky	>500
Kennebec Valley Technical College	Fairfield	Biotech training	Barbara Woodlee	NA
Maine Biological Labs	Waterville	Poultry vaccines	Tom Swieczkowski	50–100
Maine Biotechnology Services	Portland	Antibodies	Joe Chandler	25–50
Maine Manufacturing Extension Partnership	Portland	Technical assistance	John Karp	NA
Maine Medical Center Research Institute	Scarborough	Not-for-profit biomedical research	Edmund Lovett	25–50
Masthead Venture Capital	Portland	Venture capital	Bob Foster	1–4
Preti, Flaherty, Beliveau, Pachios & Haley, LLC	Portland	Legal services	Harold Pachios	NA
Phylogix	Scarborough	Cell therapy biotechnology	Jeff Moore	1–4
T. M. Teague Biotechnology Park	Fairfield	Biotech park/incubator	Clyde Dyar	NA
UNE College of Osteopathic Medicine	Biddeford	Medical school	Dave Manyan	NA
USM Applied Medical Sciences	Portland	Graduate immunology program	Brian Hodgkin	NA
Previously Contacted				
BioWhittaker Molecular Applications	Rockland	DNA testing kits	Shawn Cavanaugh	50–100
Capricorn Products	Scarborough	Immunodiagnostics	Jane Havey	5–9
Coastside Bio Resources	Stonington	Marine-based biomed. products	Pete Collin	1–4
East Coast Biologics	N. Berwick	Immunodiagnostics	Clark McDermith	1–4
PhycoGen	Portland	Marine-based antifungal agents	Randall Alberte	0 (failed)
SeaRun Holdings	Arundel	Fish-derived biomed. products	Evelyn Sawyer	1–4

Maine's biotechnology sector is heavily shaped by several factors, both historical and geographic. Almost all of the biotechnology companies are located in southern and central Maine, while the largest research institution, The Jackson Laboratory, is in Bar Harbor. The reason for this geographic spread is apparent when historical factors are considered. The founders of many of the companies in southern Maine were former employees of two early biotechnology companies, Ventrex Laboratories and Atlantic Antibodies, both in the greater Portland area. These companies specialized in production of antibodies and/or development of tests used to diagnose disease or other health conditions, a field generally referred to as immunodiagnostics.

Ventrex and Atlantic, which no longer exist, brought many highly trained employees to Maine from other parts of the country. Ventrex reached its zenith in the early 1980s with several hundred employees, then underwent consolidation and acquisition by Hycor Biomedical of Garden Grove, California. Atlantic Antibodies underwent a similar change when it was purchased by INCSTAR and both manufacturing and marketing were relocated to Minnesota, while the farm facility remained in Windham and subsequently became part of Strategic BioSolutions. In the mid- and late 1980s, when these companies began to stagnate, many employees left but stayed in Maine to start their own companies. A dozen or more companies in southern Maine can trace their genesis to these two companies.

While expertise is available in genetic research (The Jackson Laboratory, MDI Biological Laboratory and Foundation for Blood Research) and (thanks mainly to IDEXX) in an increasing range of veterinary applications, there are many areas of biomedical research with important economic potential for which Maine lacks research capabilities. Maine Medical Center Research Institute (MMCRI) has established an important center for cardiovascular research, which has created an area of strength where none existed before. Further expansion of research capabilities will significantly broaden the opportunities for new commercial entities to emerge. Attraction of biotechnology companies from out of state, particularly the Boston area, may be the most cost-effective way to build biomedical research and development capacity in disciplines that Maine lacks. For example, companies using gene splicing or recombinant DNA technology could provide benefits for Maine's immunodiagnostics industry, allowing local companies to move more easily to the next generation of research and production technology.

"Attraction of biotechnology companies from out of state...may be the most cost-effective way to build biomedical research and development capacity in disciplines that Maine lacks."

Subclusters

Southern Maine's numerous descendants of Ventrex and Atlantic Antibodies currently comprise the state's most commercially significant biotechnology subcluster. Of the 35 biotechnology companies in the state, 17 are in immunodiagnostics. The field has diversified and grown over the years, creating market

"Southern Maine's numerous descendants of Ventrex and Atlantic Antibodies currently comprise the state's most commercially significant biotechnology subcluster."

niches in environmental and veterinary fields in addition to the core field of human disease diagnostics. Several Maine companies have diversified and supply key reagents for immunodiagnostic research and production, and a broad range of services, from contract production of monoclonal and polyclonal antibodies to distribution of antibody strains developed by researchers from around the world, is available in Maine.

Finance

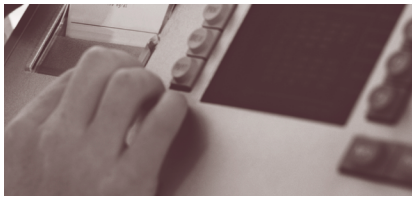
Most small companies report adequate access to capital, depending on the level of organization of the company and the sophistication of its business plan. Many companies have been self-financed—that is, revenues were used to make improvements with little or no debt assumed. The Maine Seed Capital Tax Credit program was widely viewed as beneficial, as it provided tax breaks for investors and helped encourage investment in local companies. For companies that do not or cannot assume debt for special projects, the availability of grant money can make a big difference. The availability of MTI seed, challenge and development grants was widely viewed as a key factor enabling companies to take on new research and development projects. Beacon Analytical, Immucell, Phylogix and other companies indicated that recent product development efforts and expansions would not have occurred or would have occurred several years later had MTI funding not been available. A few companies have also used the Small Enterprise Growth Fund, set up by the legislature during the 1996–1997 session and run by the Finance Authority of Maine, although some early applicants found the financing conditions too complex and restrictive. The fund has recently invested in several startup biotechnology companies.

A few companies have tapped the venture capital markets, but this avenue was not generally popular due to high costs of capital and concerns about loss of control. CEI Ventures, the venture capital arm of CEI, was widely viewed as less demanding and easier to work with, and the firm has invested successfully in several local biotechnology firms. Other VC firms, such as Masthead Venture Capital, also played key roles in biotechnology startups. Phylogix of Scarborough recently received a $3 million investment of venture capital from a San Francisco VC firm, with participation from the Small Enterprise Growth Fund.

In addition to obtaining funding, small biotechnology startups may face growth hurdles common to all new ventures: concerns related to patenting, legal services and business management. Several companies indicated that patenting for biotechnology discoveries often requires specialized and costly legal services from firms in Boston, New York or Washington that retain Ph.D.-level staff for that purpose. One or two small firms are doing biotechnology patent law in Maine, but the market is modest. Generally, biotechnology firms have considerable knowl-

edge of patenting issues. One small firm underwent extended legal battles that would have bankrupted the company in the absence of product liability insurance.

A more common problem is the general lack of business management experience among startup companies. Many founders reported that large amounts of time were spent learning the requirements for accounting systems, tax filings, personnel, insurance and general business management. Typically, founders had strong technical backgrounds and had worked in research or product development, but had not been exposed to business management and the financial accounting needed to satisfy investors. The steep learning curve often hampered company growth, drawing founders' time away from critical product development issues. Only when the company reached a size where it could dedicate specialized personnel to these functions did problems diminish significantly. Often, business issues can be handled better when networks are established among companies in a sector to encourage formal and informal dialogue regarding business practices and financing. Incubators and technology parks also play an important role in helping new companies master business management skills.



Another common problem, according to investors, is a lack of knowledge about marketing. Well-planned and effective marketing can make a significant impact on revenues, and only a few of the smaller companies are proficient at it. Marketing expertise for biotechnology companies is hard to find as it requires a technical background as well as marketing training. Some companies, such as BIODESIGN in Saco, report sales positions are the most difficult to fill, and the problem is compounded by high turnover. New employees with good skills may require as much as a year of training to be fully effective and familiar with the company's product lines.

"The most successful biotechnology companies and institutions in Maine, both large and small, are continually innovating."

Innovation

Innovation is integral to biotechnology, both in driving development of new technologies and in driving the application of new technologies to existing problems. The most successful biotechnology companies and institutions in Maine, both large and small, are continually innovating, searching for new products that better serve the customers' needs or improving existing ones. Maine biotechnology companies, despite limited relationships with strong supporting research institutions or universities, have developed successful businesses that are highly competitive in terms of product quality, cost and customer service.

In immunodiagnostics, much of IDEXX's success has been through adaptation of testing techniques and technologies available for the human health market to the market for veterinary products and services. This market was essentially untapped

"The market for immunodiagnostics continues to grow as increasing numbers and types of tests are made available to larger and larger portions of the world's population."

when the company entered it, and with a series of successful products to its credit, the company has become a leader in the field. IDEXX invested 7 percent of gross revenues in research and development in 2001, primarily in product development. Because of the company's size and capabilities, it operates independently of the other biotechnology companies in Maine, and collaboration with other local companies has been unnecessary. While this strategy has been successful, it has not produced spinoff supplier or related companies that would enhance the competitiveness of the local biotechnology sector. Otherwise, IDEXX, as Maine's largest private biotechnology employer, provides enormous benefits to the state economy and surrounding communities.

Meanwhile, the market for immunodiagnostics continues to grow as increasing numbers and types of tests are made available to larger and larger portions of the world's population. There has been and promises to be continued expansion of the diagnostics market, although the technologies may remain largely unchanged.

Many of the numerous small companies in southern Maine that are engaged primarily in some form of immunodiagnostics are competitors. Most have licenses to unique lines of antibodies and enjoy the resulting advantages. All serve a global market, with some reporting that close to 50 percent of their business is international. But there are also close ties among the companies. The company founders all know one another, either from working at Ventrex or Atlantic Antibodies, or from subsequent work.

Generally friendly relations make it possible for Maine's immunodiagnostics firms to share (or lease on an as-needed basis) equipment and lab space. This unique and important feature has allowed self-incubation of a number of small companies over the years, many of which are now successfully established in the marketplace. This has occurred without any formalized program or plan, and the formation of new companies continues today.

The companies also work together frequently, performing contract services for each other that optimize the use of their facilities or capabilities. The ability to cooperate and share resources enhances each company's competitiveness. The ability to compete successfully in global markets, and the capacity of companies in an area to be competitors, partners and customers to each other, are features found in successful technology clusters in other states (Porter, 1999).

Maine's immunodiagnostics companies often market antibody strains developed elsewhere, often at universities or research hospitals located throughout the country. Most companies have commercial relationships with investigators who work elsewhere. Generally, the diagnostics sector in Maine lacks significant research capacity. Maine companies, while highly entrepreneurial, cannot devote time and

resources to efforts that do not lead directly to marketable products. At the University of Southern Maine, shortages of faculty and equipment have hampered research efforts until recently, when investments by the university in its labs spurred research. USM is developing a BioSciences Research Institute and has attracted some excellent research scientists; but building the program into a significant regional research asset will take years of work and much funding. As a consequence, Maine's current overall research capacity in this economically important field remains slim.

By contrast, the state's research capacity in basic genetic research is large. The Jackson Laboratory, with over 100 Ph.D.s and several hundred support staff, boasts research capabilities rivaled by only a few institutions in the country. Pursuit of research excellence is a primary goal at Jackson, as nationally recognized researchers strive to unravel the complexities of genetic structure and function in both animal and human systems. Innovation is integral to scientific inquiry, and the most innovative researchers are often highly successful. Moreover, in an institution in which researchers are expected to bring in large grants capable of supporting themselves and their staffs, innovation is a key part of every researcher's job.

Preserving this level of success demands that the institution maintain a tight focus on the cutting edge of basic genetic research; broader statewide growth goals necessarily take a back seat. Focusing on research has helped The Jackson Laboratory more than double in size over the last decade to over 1,000 employees, and further growth is planned. With this growth will come increasing opportunities to export capabilities and knowledge to other areas of the state, including the Teague Biotechnology Park in Fairfield (see below) and university doctoral programs. Opportunities to enhance the growth of the institution offer potentially large returns on such investments, as has been achieved recently by Jackson's capture of large grants from the National Institutes of Health with matches provided by state biomedical research funds. Should this growth offer opportunities to enhance southern Maine's genetic research capabilities—an area that is currently sorely lacking—the benefits could be especially important for the biotechnology industry in Maine.

"The Jackson Laboratory... boasts research capabilities rivaled by only a few institutions in the country."

Maine's biotech industry thus consists of firms and research organizations of greatly varying sizes. They serve a variety of markets, with some concentration in diagnostic materials. The industry is actively involved in research and development, but with the exception of IDEXX, there is little production or marketing of biotechnology products. Horizontal relationships among firms and organizations are moderately strong; the diagnostics subcluster has fairly strong horizontal relationships among firms, but vertical supplier/customer relationships remain weak.

Research and Development Facilities and Organizations

"With the small size and limited resources of many Maine firms, research capacity is very limited, and innovation is constrained."

After Ventrex and Atlantic Antibodies moved out of Maine, southern Maine had no major research organization in biotechnology until the establishment of the Maine Medical Center Research Institute (MMCRI). Biotechnology is heavily driven by research, and the sector is changing rapidly as discoveries or innovations emerge every week, spread across numerous fields or specialties. MMCRI is still establishing its research programs, only some of which are related to biotechnology, so research capacity in the area remains limited. Small private-sector firms with small research budgets have had to play the principal role in biotechnology research in southern Maine. This is in contrast to biotechnology industry clusters in other parts of the country, where companies within clusters often command formidable resources, both in financial backing and research capacity. With the small size and limited resources of many Maine firms, research capacity is very limited, and innovation is constrained by the availability of resources and personnel.

IDEXX has the size to conduct research, but the company is driven not by research but by product and market development. Moreover, IDEXX specializes in products for the veterinary industry. There is little research done in veterinary medicine in Maine, and IDEXX relies on contacts with veterinary schools outside the state as sources for research.

On the not-for-profit side, southern Maine has two research institutions and a medical school, all of which have emerged in the last 20 years, plus a new research organization. The recent growth of Maine Medical Center Research Institute has brought in nine new research scientists in fields such as cardiovascular research that were undeveloped in Maine and has formed a focal point for the expansion of clinical research for dozens of area physicians. This growth is still in its early stages, and the institution plans to expand research capacity considerably. The Foundation for Blood Research has brought in researchers in genetic screening and public health, but the organization is growing less rapidly.

The University of New England (UNE), through patience and determination, has established an increasingly important osteopathic medical school. This has occurred without any state assistance, a remarkable feat, when other states are saddled with the high costs of supporting medical schools. UNE's bootstrap approach to institutional development has drawbacks in that the school's resources are totally devoted to meeting the educational needs of its medical students. While the School of Osteopathic Medicine continues to grow, limited financial resources and the absence of a research development office have resulted in almost no growth in the institution's research capacity. There is significant unmet potential in this area, as

medical schools in other parts of the country often form a crucial part of biotechnology clusters.

The University of Southern Maine's Biosciences Institute is a newly formed research center that expands research capacity and increases opportunities for collaborative research with local companies and institutions. The three-floor, $10.7 million facility will bring together academic programs in such areas as biology, chemistry, immunology and molecular biology and enable collaboration with associates from the Foundation for Blood Research, the Maine Medical Center Research Institute and various biotechnology companies. The facility will add some 25,000 square feet of space and include animal facilities, a nuclear magnetic resonance unit and bioscience research labs.

None of these smaller institutions in southern Maine operates at the scale of The Jackson Laboratory in Bar Harbor, the state's largest biotechnology employer. Founded in 1929 as a research center for cancer, the laboratory is one of the top genetic research centers in the world and a highly valuable asset in the emerging genetic revolution. Yet Jackson is under-recognized, in part because it has been fairly insular in the past, and in part because it necessarily remains tightly focused on the genetic research community, which is spread across the country at top universities and research institutions. Only recently, with the formation of the Biomedical Research Coalition, has The Jackson Laboratory found an effective way to inform the public of its leading role in genetic research.

"The absence of this research capacity in some important biomedical disciplines significantly restricts the biotechnology industry in Maine."

When The Jackson Laboratory is included, Maine has significant research capacity for a state of its size. Historical and geographical factors make it difficult to integrate this capacity with the biotechnology industry in central and southern Maine. With southern Maine lacking a research-oriented medical school, a large research institute or advanced graduate programs in many biomedical disciplines, the growth of the biotechnology sector has been limited to those areas, such as immunodiagnostics, in which expertise is currently available. The absence of this research capacity in some important biomedical disciplines significantly restricts the biotechnology industry in Maine.

Until this year, Maine lacked business parks dedicated to biotechnology. With construction of the Teague Biotechnology Park in Fairfield, Maine now has a facility to attract and nurture biotechnology companies. The Teague Park, with The Jackson Laboratory as an anchor tenant, will be in position to provide important business support and incubator services for central Maine. Maine Biological Labs, a poultry vaccine manufacturer, and Northeast Labs, a testing facility, are key technology employers in the area. In addition, the University of Maine at Farmington (UMF), Husson College and Kennebec Valley Technical College (KVTC) will all play important roles at the Teague Park. UMF is interested in

internship opportunities for its students, while Husson will offer business management assistance for startup companies. KVTC will provide training programs for technicians and information specialists for The Jackson Laboratory. The Teague Park also has linkages to Canadian and southern New England institutions interested in the formation of an international biotechnology corridor

"Southern Maine ...lacks any biotechnology park or research center that can serve as a focal point for business, research and incubation activities."

Southern Maine, despite having the majority of the state's biotechnology companies, lacks any biotechnology park or research center that can serve as a focal point for business, research and incubation activities. Privately financed proposals to create a biotechnology business park have been developed but have yet to come to fruition. Senior management at several small companies in Portland have indicated that such a facility would be highly beneficial in terms of the potential for shared lab facilities, easy networking and exchange of ideas and technologies. Masthead Venture Capital indicated that demand for lower cost facilities for firms located in high-cost areas could make such a facility attractive to companies outside of Maine.

The Center for Innovation in Biotechnology (CIB), unlike other Maine innovation centers, was neither an incubator nor a technology transfer organization. Instead it was set up primarily as a grant-making institution, re-granting $100,000 to $150,000 provided by the state each year as small grants to companies that were developing new technologies and/or products. As such, CIB played an important role for years in spurring research and development in the biotechnology sector. Its role has now been supplanted by the Maine Technology Institute, and the scale of funding available though MTI has increased. MTI has funded $2.7 million in research grants to the Maine biotechnology community as of June 2001. Still, CIB can continue to play an important role on the strength of its status as a not-for-profit organization. This status allows it to receive grant funding from a variety of federal and state programs for support of technology transfer and economic development. The Biotechnology Association of Maine (BAM), due to its role as lobbyist for its members, is not eligible for funding from a number of these sources.

Trade Associations

The Biotechnology Association of Maine (BAM) has over 100 members, including biotechnology companies, aquaculture companies, medical testing laboratories, medical supply companies, research institutions and educational institutions, as well as accounting and law firms. BAM provides an important voice for companies in the sector and is a focal point for organizing initiatives important to the biotechnology sector. The association has been effective in reducing tax burdens for biotechnology companies and was active in the creation of the Maine Technology

Institute. There are other industry support functions, including marketing and promotion of Maine biotechnology out of state that are not handled by BAM. Promotion of the industry in Maine could be an effective tool for attracting companies from outside the state.

Labor

Most companies that hired entry-level employees reported good success with graduates from area technical colleges, and this has led to the creation of new jobs in biotechnology. Kennebec Valley Technical College (KVTC) in Fairfield is one of the most entrepreneurial of the colleges, capturing over $5 million in federal grant money for expanded training programs over the last five years. KVTC is the primary reason The Jackson Laboratory chose to open a new training facility for technicians at the adjacent Teague Biotechnology Park, currently under construction. Maine Biological Labs and Northeast Labs in nearby Winslow are also pleased with the KVTC graduates they have hired. Recently, Southern Maine Technical College has started offering courses in biotechnology, addressing a significant need in southern Maine for training for technical and lab personnel. Companies in the Portland area report varied results with technical college graduates. Low unemployment rates in southern Maine and competition for employees may be factors, as some companies report significant improvements in the quality of their entry-level workforce with only modest improvements in starting wages.

"Salaries in Maine are typically below those found in states with strong biotechnology industries."

Most companies say they can recruit college-level personnel locally from UNE, USM and UM. Some southern Maine companies also look to the University of New Hampshire for well-trained graduates. Recruits' levels of training and lab capabilities may be modest, but, with sufficient training, most entry-level employees perform well. Master's-level employees were harder to find. The number of graduates from USM's master's-in-immunology degree program was small, and local firms already employ many degree candidates while they are still in school. Recruiting in the local market was usually successful, though some firms looked to the Boston market to meet personnel needs.

Most firms did not require Ph.D.-level training, but larger companies, such as IDEXX or Binax, that employ numbers of Ph.D.s report difficulty in attracting the talent they need. Binax has recruited Ph.D.s from overseas; IDEXX has had to recruit nationally and internationally to find individuals with the right qualifications. Salaries in Maine are typically below those found in states with strong biotechnology industries, so employees who move here are often motivated by other factors, such as quality of life. Highly specialized Ph.D.s are reluctant to move to Maine, as the market for their skills is small and options few, should the offered position not turn out as expected. Opportunities for the often highly educated spouses of

these individuals is also an issue, although companies in Portland fair better in this respect than do firms like BioWhittaker Molecular Applications in Rockland, where alternatives for employment are comparatively slim. In Bar Harbor, The Jackson Laboratory actively searches for employment opportunities for the spouses of its researchers.

The recent development of a collaborative Ph.D. program in molecular genetics and cell biology offers good potential to produce highly trained scientists in key disciplines. The Jackson Laboratory, MMCRI, the Foundation for Blood Research, USM and UM are participating in this program, through which Ph.D. students will have access to researchers and expertise statewide in disciplines from biomedicine to research genetics. The program represents an important step in collaboration among these institutions, although it will take substantial time for its role to become clear.

"The Jackson Laboratory and IDEXX...are the two most likely to provide leadership for the future."

Lead Organizations

Maine's biotechnology industry clearly benefited from the leadership roles played by Ventrex and Atlantic Antibodies in the 1980s. These two companies helped bring to Maine a large number of highly qualified researchers in the field of diagnostic materials. While these firms have merged and relocated outside of Maine, they left a legacy of small firms that are giving Maine a growing presence in the field.

Today, the largest players in biotechnology in Maine are The Jackson Laboratory and IDEXX, together employing close to 2,000 people in-state. The companies are the two most likely to provide leadership for the future. Presently, however, neither company does so to the extent it might.

Locational Advantage

Biotechnology in Maine is rooted in institutions and companies that have chosen to locate here. Some, such as The Jackson Laboratory and the MDI Biological Laboratory, may have come originally to take advantage of the coastal climate and resources, but these locational advantages have long since declined in importance. Indeed, in the case of The Jackson Laboratory, the remote (from other research centers) location, once an attraction, is now at times a disadvantage. However, the presence of these institutions, and the addition of new organizations at universities and hospitals, provides a knowledge base for the biotechnology industry that has yet to be transformed into commercial activity. That transformation will be key to the emergence of a biotechnology cluster in Maine.

TABLE NINE
SUMMARY OF CLUSTER CHARACTERISTICS[7]

INNOVATION	Product	3
	Process	1
REGIONAL BUSINESS FUNCTIONS	Research	2
	Development	2
	Production	2
	Marketing	2
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	2
FUNDING	Self—Outside	2
	Grants—Capital	2
RELATIONSHIPS	Firms—Horizontal	2
	Firms—Vertical	1
	Labor	3
	R&D Facilities & Organizations	2
	Industry Organizations	2
	Lead Organizations	2
LOCATIONAL ADVANTAGE	Geography	1
	Knowledge	2
MARKET POTENTIAL	Mature—Growth Markets	2
	Diversity of Markets	2
	Local Demand	1
	Exports	2
ECONOMIC PERFORMANCE		3

"A knowledge base... transformed into commercial activity... will be key to the emergence of a biotechnology cluster in Maine."

[7]See the chapter *Measuring Clusters in Maine* for discussion of factors.

ADVANCED MATERIALS

Introduction

Historically, the term *composite materials* in Maine has meant "an oriented, continuous fiber covered with a thermoset resin matrix." While the most common such material is fiberglass used in boatbuilding and other manufacturing processes, the materials used in composites have diversified greatly. Composites based on fiberglass and new fibers such as carbon have found application in automobiles, boats, planes, bicycles and sports equipment, as well as in aerospace, defense and other industries. Although hardly immune to the vagaries of the business cycle, composites undoubtedly constitute a major growth market. Worldwide, the industry is growing at a rate of 5.2 percent per year (Market Research Group, 2001).

"Although hardly immune to the vagaries of the business cycle, composites undoubtedly constitute a major growth market."

Composites offer high strength, light weight, corrosion resistance and durability, making them particularly useful in transportation industries. One of the materials' most important features is design flexibility, which allows fabrication of an infinite variety of shapes without the heavy industrial molds and presses required for steel. This has allowed small firms with limited resources to produce high-technology products.

Use of low-cost and abundant wood fiber in composites further broadens the potential applications (Kline, 1999). Wood-composite products have captured a large part of the building materials market and are finding increasing use as substitutes for steel and wood in structural applications such as bridges and piers; they may also have potential in shipbuilding, by reducing weight and increasing strength.

For purposes of this study, we use the term *advanced materials* in lieu of *composite materials* to mean "two dissimilar materials joined such that they can be used in any structural function."

Business Characteristics

Nationwide, over 2,000 composite manufacturing installations employ more than 150,000 people (CFA, 2001). About 65 percent of the composites in this category involve glass fiber and polyester or vinyl resins, while the remainder use either high-tech fibers like carbon or alternative fibers such as wood. The composites industry has a large R&D component, and new applications are frequently developed. Over 40 universities nationwide support centers for composites research; among them are MIT, Rensselaer Polytechnic, Penn State and Georgia Tech. Nonetheless, much of the innovation and development in the field comes from industry, with many companies continuously engaged in development of new products or refinement of existing ones.

While growth in composite use is subject to the ups and downs of the industries that utilize them, such as the automotive, aerospace and marine industries, the overall outlook for the industry remains highly favorable. This is due to the increasing substitution of composites for other materials, a process that occurs continuously, regardless of business cycles. In addition, composites are so diversified that slumps in one industry, such as aircraft construction, may have little effect on the composites industry as a whole. While the aircraft industry slowed considerably after the events of September 11, the boat market has remained stable. Demand in automotive applications has also stayed fairly stable due to brisk sales in that sector.

World composite market growth rates are estimated at 5.2 percent per year, and industry research indicates that a few sectors in composites are estimated to grow at more than 20 percent a year (Market Research Group, 2001). In the infrastructure market, estimates suggest that applications for fiber-reinforced polymer (FRP) composites will grow over 525 percent between 2000 and 2010 (Composites Worldwide, 2001). FRP composites typically have less than a 1 percent market share of these target applications, so the potential is enormous. Glass fiber, plus isopolyester, epoxy and vinyl ester resins will see the greatest growth, but there is a significant continuing market for carbon fibers as well.

To better understand the current state of the industry in Maine, MSTF conducted interviews with senior management at 24 firms and organizations (almost all the firms in the composites industry in Maine). Interviews focused on the growth of each company and the importance of innovation both for the company and for the industry. The following companies and individuals were interviewed:

"Composites are so diversified that slumps in one industry...may have little effect on the composites industry as a whole."

ADVANCED MATERIALS

TABLE TEN
SELECTED MAINE ADVANCED MATERIALS COMPANIES

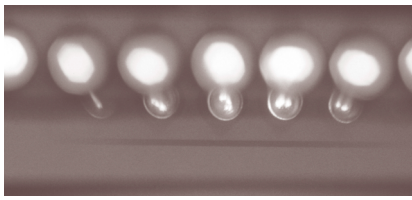
COMPANY	LOCATION	PRODUCT	CONTACT	EMPLOYEES
Applied Thermal Sciences	Sanford	R&D	Bob Carr	24–49
Aegis Bicycles	Boothbay, Van Buren	Bicycles	Keith Baumm	24–49
Bath Iron Works	Bath	Composites in shipbuilding	Jim Baskerville	>500
Correct Building Products	Biddeford	Plastic lumber decking	Martin Grohman	5–9
Hinckley Company	Southwest Harbor	High-end pleasure boats	Peter Smith	250–499
Kenway Corporation	Augusta	Corrosion-resistant piping	Ken Priest	25–49
Landing School	Kennebunkport	Boatbuilding technology	Dennis Collins	NA
Lincoln Canoe and Kayak	Yarmouth	Kayaks & canoes	Sandy Martin	5–9
Maine Composites Alliance	Newcastle	Industry association	Bill Lemos	1–4
Maine Composites, Inc.	Westport	Tool design	Keith Burgess	1–4
Martin Grimnes	Brunswick	Consulting engineering	Martin Grimnes	NA
Multi-Composites	Rockland	Multi-hulled sailboats	Steven Neil	1–4
North End Composites	Rockland	Molds, final composite parts	Jonathan Spaulding	50–99
Northern Spars	Boothbay	Carbon fiber spars	Thomas Blevins	1–4
Pepin Associates	Greenville	Engine-containment shields	John Pepin	1–4
M. L. Pettegrow	Southwest Harbor	High-end pleasure boats	Malcolm Pettegrow	10–24
Quantum Racing Shells	Brunswick	Rowing shells	Jim Raslavsky	5–9
Sabre Corporation	S. Casco	High-end pleasure boats	Chris Evans	100–249
St. Gobain BTI	Brunswick	Composite fabric	Bill Dubay	50–99
Surge Marine	Westport	High-end sea kayaks	Kerry King	1–4
Tex-Tech Industries, Inc	Portland, Monmouth	Engineered materials	Steve Rossi	100–249
UM AEWC	Orono	Research—laminated wood	Bob Lindyberg	NA
UM Dept. of Indust. Coop.	Orono	University/industry	Jake Ward	NA
Warrior (Arrow-Marine)	Scarborough	Sea planes, composites	David Verril	1–4

1. Marine Uses of Composites

Gauging the size of the composites industry in Maine is difficult. Boatbuilding is the largest user in the state, and employment in this industry has grown from 1,200 to over 1,500 employees with wages totaling $46 million in 2000 (Maine Department of Labor). The number of boatbuilding companies has actually dropped slightly in the past five years due to consolidation. Boatbuilding in Maine is primarily an industry of small firms, with a few very large firms. It serves three markets: fishing boats, primarily lobster boats; recreational boats, either sail or power; and human-powered recreational boats such as canoes, kayaks and shells. It is in the high end of the recreational boat market that composites have become most common, although they are used in the other segments as well.

Spurred by growth in the luxury yacht and powerboat market, manufacturers such as Hinckley, Sabre and North End Composites have expanded production

capacity greatly in the last three years. Companies that make carbon fiber spars, such as Northern Spars, are also benefiting. In addition, several small custom manufacturers of lightweight kayaks and rowing shells are capitalizing on the ultralight weight, strength and flexibility of composites using carbon fibers or aramid fibers such as Kevlar.



There is strong local demand for boats built in Maine. The lobster and fishing industries provide a steady market for that segment of the industry and give boatbuilders important feedback on product development. Maine's coast, rivers and lakes provide abundant opportunities for recreational boating, and this attracts customers who demand high-quality boats. Many boatbuilders have targeted this market and have seen boat sales to regional and international customers grow along with the reputation of their products. Hinckley recently opened sales offices in Florida and Michigan and has new service facilities in Florida and Rhode Island.

While boatbuilding makes up much of the local market for composites, other applications are driving innovation. Use of composites in the aerospace and automotive industries is growing due to the products' light weight, strength and design flexibility. Pepin Associates of Greenville is working in this area, and Warrior (Aero-Marine) plans to build seaplanes using design advances made possible by composite construction. Aegis Bicycles of Van Buren and Boothbay builds composite bike frames that are sought after by racers and triathletes.

"While boatbuilding makes up much of the local market for composites, other applications are driving innovation."

The corrosion resistance of composites gives these materials an advantage wherever highly corrosive chemicals are used. Kenway Corporation of Augusta manufactures custom pipes, tanks and flanges for use in handling industrial corrosives and has a well-established business in the Northeast. Bath Iron Works has numerous uses for composites in the next generations of warship design, helping to make ships lighter and less detectable by radar.

The final segment of the advanced materials industry in Maine is the manufacturers of the materials themselves. For the most part, advanced materials such as carbon fiber and Kevlar are made outside of Maine; however, some Maine firms are engaged in making the materials. St.Gobain-BTI (formerly Brunswick Technologies Inc.) makes a variety of materials used in composite manufacturing in Maine and elsewhere; Tex-Tech Industries, Inc., manufactures composite fabrics such as tennis ball covers.

Clearly, Maine's composite manufacturers serve diverse markets. Vertical and horizontal relationships within the state are not well developed, except perhaps in boatbuilding, which is large enough to have formed a network of supplier and distributor relationships. St.Gobain-BTI sells to Maine boatbuilders as well as to those out of state. In some cases, there is also cooperation among boatbuilding

"The advantages of composites in durability are significant, and opportunities to demonstrate and test new products will be key to establishing markets."

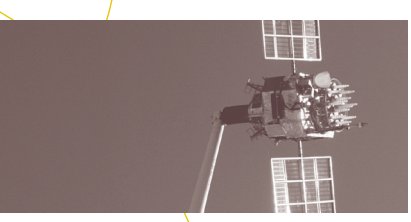
firms. Parts of Hinckley's Picnic Boat, for instance, are made by a number of different companies.

2. Wood Composites

While wood and synthetic fiber composites are considered advanced materials, distinct differences exist between the two groups. Wood composites are most often used in building and structural framing, while synthetic fiber composites are used in automotive, aerospace and marine applications. There is currently little overlap between wood and synthetic fiber markets because of differences in end markets. However, some of the structural beams made at the University of Maine's Advanced Engineered Wood Center (AEWC) now use synthetic materials to add strength, which may lead to more overlap in the future.

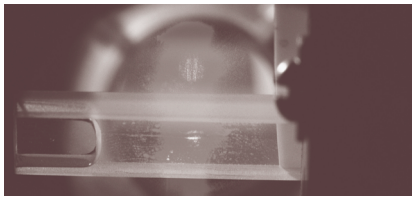
Nationally, wood product research is supported by both federal and industry funding and has been led by national centers such as the U.S. Forest Products Laboratory in Wisconsin and the research centers developed in the West by industry giants such as Weyerhauser. Engineered wood products have seen rapid growth in the last 20 years, led by wood I-beams such as the Trus Joist, which has essentially replaced large-dimension framing lumber in many residential and commercial applications. Sales of wood I-beams now exceed $1 billion per year, and the market will continue to expand as these products are substituted in increasing numbers of building products. Excellent opportunities exist for products such as these that have superior performance characteristics, can be made to any length and are cost competitive.

Most wood composite technical knowledge in Maine has come from the University of Maine and AEWC. AEWC plays an important role in developing ways to enhance the structural properties of Maine timber, which is not as strong as timber from other regions in certain applications. Substitution of engineered structural timbers for steel or concrete in bridge construction offers lighter weight, greater strength and simplified construction. The northern New England states, with hundreds of aging bridges on secondary roads, offer a ready market for improved structural beams and the associated reduced construction cost. Widespread use of these products is years away, however, as conservative design tendencies in bridge engineering will slow the adoption of new materials.



A second market waiting to be tapped is for composite replacements for marine pilings and timbers. The advantages of composites in durability are significant, and opportunities to demonstrate and test new products will be key to establishing markets. Local applications for engineered products are particularly important, as they facilitate the testing of new concepts and product feedback that are critical to the success of new commercial products. Structural beams from AEWC have been used in demonstration bridge projects around the state, and the planned

Ocean Gateway project in Portland will demonstrate commercial applications for composite pilings and decking. Should sufficient demand for these products materialize, production capacity must be developed. Unlike some of the other large timber producing states, Maine has little industrial capacity in the manufacture of engineered wood structural members. However, Maine does have three mills producing oriented strand board (OSB), an important component of some engineered wood products.



Other wood composites are already accepted in the marketplace. Plastic lumber has become well established as a highly durable material for decks and dock surfaces. Correct Building Products of Biddeford has capitalized on this demand and manufactures plastic lumber using a blend of plastic and wood fiber that competes favorably with industry leader TREX. Success in local and regional markets will be key to the company's growth.

Subclusters

Boatbuilding and related marine products comprise the most important subcluster within the composites field. The size and diversity of companies in the industry, the development of new products using composites and their commercial success foster a level of success to which other applications of advanced materials, particularly wood composites, can aspire.

"Boatbuilding and related marine products comprise the most important subcluster within the composites field."

Finance

Companies with product development plans face the same obstacles as do entrepreneurs in other industries. Composites are relatively new, so many companies do not have an established track record, making conventional financing difficult. There is also less of an established network of interested investors familiar with the industry, compared to biotechnology and information technology. In this regard, MTI has played a significant role in composites in Maine, with 12 of the companies or organizations contacted using MTI seed and development grants in product development.

Innovation

While wood is still occasionally used for building boat hulls, most boat companies have switched to durable, lightweight composite hulls, principally of fiberglass. Within the past decade, the use of advanced fibers such as carbon has moved from such highly specialized markets as racing hulls to a more general, recreational boat market because of the benefits of weight reduction and performance. Hinckley uses carbon fiber and Kevlar in making hulls for both its sailboats and

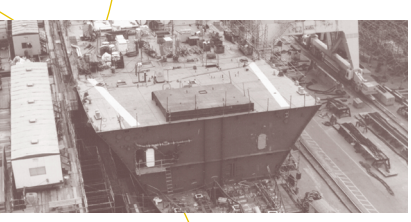
its successful Picnic Boat, making it lighter and stronger than similar fiberglass vessels. Portable boats, such as rowing shells, kayaks and canoes benefit significantly from advanced materials such as Kevlar and other composites, and several small companies in Maine have had success in this market. Carbon fiber also has applications in spars and masts for sailboats, where low weight and high strength are advantages.

Innovation in boatbuilding has led to new fibers and products. Hinckley and Sabre use a stitched fabric, produced by St. Gobain-BTI of Brunswick, that has higher strength properties and offers labor savings in lay-up. These fabrics can be custom made with advanced fibers, and the fibers can be oriented as specified to handle maximum stresses. There has also been innovation in application processes, such as the SCRIMP resin impregnation process that produces a lighter, higher quality product with reduced production time and also meets OSHA and EPA requirements concerning emissions of volatile organic compounds (VOCs). Boatbuilders are continually looking for ways to improve materials handling and application. Most of the R&D relates to product development and process/application and is conducted almost exclusively in private-sector firms without university or other research support.

"The wood composites side of the sector is clearly where most of the research is being done."

Nonmarine uses of composites are also important, but are a small part of the industry in Maine. Aegis continues to innovate in carbon fiber bike frames, and Pepin Associates and Applied Thermal Sciences have a number of potential composite applications. Aero-Marine hopes to capitalize on the benefits of composites and advanced design in seaplanes, a field in which designs have changed little in several decades.

The wood composites side of the sector is clearly where most of the research is being done, as it is a relatively new field. Research is concentrated at the University of Maine's research center. Development of a commercial sector for these products has not yet occurred; thus, the mixture of public and private research appears a healthy sign of a dynamic cluster waiting to emerge.



Research and Development Facilities and Organizations

As indicated earlier, much R&D in composites is industry driven, as many of the applications for composites have strong market potential, and custom fabrication may not require expensive equipment. Boatbuilders will continue to experiment with new fiber composites as costs for these materials come down. Bath Iron Works has a Composite Materials R&D Laboratory on site for developing innovative new processes and products: a substantial upgrade of the company's

composites capabilities. In collaboration with the University of Maine, North End Composites and others design and develop low-maintenance, lightweight superstructures for warships that could boost local composites research capabilities.

Research facilities for wood composites at the University of Maine could be used for other advanced materials applications. Some research on high-temperature composite applications occurs in the university's Mechanical Engineering Department, but as yet there is no large-scale, focused research and development effort for nonwood composites. Conceptual research occurs at Applied Thermal Sciences in Sanford, where conceptual designs are made for composite engines, jet propulsion systems and power cable systems; no fabrication of advanced composites occurs there. Sanford will also be the location of the Composite Materials Applied Technology Development Center, the last of seven incubators for the state's targeted industries. The center will have a branch in Greenville, where applications for wood composites will be developed. These facilities may play an important role, as many areas of potential growth in composites remain undeveloped in Maine.

Composites combining wood and nonwood materials such as fiber-reinforced polymers have been the focus of research at the University of Maine Advanced Engineered Wood Center, a newly opened research facility funded by the National Science Foundation and the U.S. Commerce Department's Economic Development Administration with support from industry and the university. The center houses equipment for design, fabrication and testing of fabricated wood beams and other large structures. Fabricated materials can be tested for weatherability, durability under load conditions and strength. Other labs can examine microstructural composition, polymer properties and surface bonding characteristics. Currently, about 10 percent of the work at the lab is contract work for industry, and this is expected to increase to 50 percent over time. The development of standards for the use of composite wood material will be essential to market success, and AEWC is developing the capacity to perform the testing necessary to establish such standards.

"As yet there is no large-scale, focused research and development effort for nonwood composites."

Trade Associations

The Maine Composites Alliance (MCA) is the only Maine-based association that represents the composite industry in Maine. While the industry in Maine is dominated by marine applications such as boatbuilding, MCA serves as a clearinghouse and as an advocate for new applications for composites that are not currently manufactured in the state. The broad diversity of markets for composites means that common interests among all composites companies are limited and marketing functions are best performed by the companies themselves. Boatbuilders have a number of issues in common, and several national associations exist to serve their interests.

"The broad diversity of markets for composites means that common interests among all composites companies are limited."

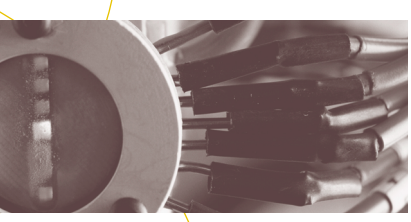
Labor

The size of Maine's boatbuilding industry generally ensures an adequate supply of labor, although many boatbuilding firms report increasing difficulty in finding workers, particularly skilled ones. Several small boatbuilding schools, such as the Landing School in Kennebunk, train students in traditional and composite building techniques. New entrants into the industry may be more limited in the future, as the coastal economies where the industry is centered have diversified. For the manufacture of composite materials themselves, firms such as St. Gobain-BTI can draw on a large pool of employees experienced in textile manufacturing. The labor force for wood composites should present no particular constraints, given Maine's large pool of skilled construction and wood products workers.

Washington County Technical College is the only one of the several Maine technical colleges that has a program devoted to composite fabrication, although the University of Maine offers master's degrees in wood science and technology that provide advanced education in wood composite analysis, testing and fabrication. Materials and design courses offered in the College of Engineering also cover the design and analysis of advanced materials. Training and certification are offered through the Composite Fabricators of America (CFA), although the advent of newer production processes such as SCRIMP have changed training needs. Individual companies have developed their own training programs, using the Governor's Training Initiative and the Maine Quality Centers Program.

Lead Organizations

AEWC is at the center of the developing field of wood composites. Its research and education programs may enable it to play a leading role once commercialization of wood composites begins in earnest. For the man-made materials segment of the industry, Hinckley may play such a role, as it has become an industry leader in high-end recreational boats. While this is a narrow market, other Maine boatbuilders have successfully developed boats to meet the growing demand for Maine-built premium boats, and, with the waiting period for boats approaching two years, it is likely that new companies will continue to enter the market.



Locational Advantage

Boatbuilding need not take place on the coast: Sabre yachts are built some 30 miles inland. But Maine's boating heritage and the popularity of recreational boating in the state make Maine a great place to build boats. However, there is little doubt that it is the knowledge and skills in boatbuilding that have given Maine boats their cachet, and this advantage appears to be growing. This strength, combined with the knowledge base being developed in other composites, including wood, will lend Maine a key advantage in the eyes of the composites industry.

TABLE ELEVEN
SUMMARY OF CLUSTER CHARACTERISTICS[8]

INNOVATION	Product	3
	Process	2
REGIONAL BUSINESS FUNCTIONS	Research	2
	Development	3
	Production	3
	Marketing	2
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	2
FUNDING	Self—Outside	3
	Grants—Capital	3
RELATIONSHIPS	Firms—Horizontal	2
	Firms—Vertical	1
	Labor	2
	R&D Facilities & Organizations	1
	Industry Organizations	2
	Lead Organizations	2
LOCATIONAL ADVANTAGE	Geography	3
	Knowledge	3
MARKET POTENTIAL	Mature—Growth Markets	2
	Diversity of Markets	2
	Local Demand	2
	Exports	2
ECONOMIC PERFORMANCE		3

"Knowledge and skills in boatbuilding... have given Maine boats their cachet, and this advantage appears to be growing."

[8]See the chapter *Measuring Clusters in Maine* for discussion of factors.

PRECISION MANUFACTURING

4.H

Introduction

Precision manufacturing was defined by the Maine legislature as a target area for research and development support. Lawmakers did not specify the industries to be included, but in practice the sector has come to encompass firms in the following industries:

- Fabricated metal parts and industrial machinery and equipment manufacturers that make a wide range of parts and equipment for many different industries
- Designers and manufacturers of electronic equipment, including silicon chips and computer and communication equipment
- Manufacturers of instruments and related products, which may include electronics, sensors or other precision instrumentation

"In short, little unites or could unite the disparate firms in this group, save their role as manufacturers."

This range of industries presents significant challenges from the perspective of cluster analysis. The manufacturing processes used are diverse, and the markets served are even more so. The technologies used and the approaches to research are also extraordinarily varied. In short, little unites or could unite the disparate firms in this group, save their role as manufacturers. To facilitate analysis of cluster relationships, we believe that electronics and communication equipment should be joined with software firms, and that firms generally categorized as metal fabricating industries should be examined under the heading of precision manufacturing. However, since the concept of precision manufacturing has encompassed these broad groups, we consider them all here.

For insight into the current state of the industry in Maine, we interviewed senior management at 24 firms or organizations around the state. The firms that were selected were among the most innovative in their sectors. Interviews focused on the current status of the industry and the importance of innovation both for the company and for the industry. The following companies and individuals were interviewed:

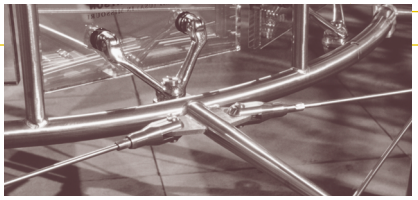


TABLE TWELVE
SELECTED MAINE PRECISION MANUFACTURING COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT	EMPLOYEES
Applied Technology Center	Mexico	Precision manufacturing incubator	Joe Derouch	1–4
Artel, Inc.	Westbrook	Lab instruments	Richard Curtis	25–50
Caron Engineering	Sanford	Machine equipment, engineering	Rob Caron	10–24
CNC Systems	Kennebunk	Precision machine equipment	Tim Good	25–50
Contemporary Products	Portland	Medical products	Barry Schwartz	10–24
D&G Machine Products	Westbrook	Precision machining	Duane Gushee	100–250
Dielectric	Raymond	Antennae components	Peter Fitch	250–500
Edwards Systems Technology	Pittsfield	Industrial signaling systems	Gary Siebert	250–500
EM Solutions, Inc.	Westbrook	Electronic equipment enclosures	George Parmenter	>500
Enercon Technologies	Gray	Electro-mechanical equipment	Ronald Marcotte	50–100
ESC America	Winthrop	Electronics manufacture	Win Jackson	50–100
Fairchild Semiconductor	S. Portland	Semiconductor manufacturer	W. T. Greer	>500
Gabriel Electronics, Inc.	Scarborough	Microwave antennas	Roger Cote	100–250
General Dynamics	Saco	Military weapons manufacture	Jon Brawn	250–500
KVP Technologies	Augusta	Micro plastic parts	Ray Lindsey	1–4
Maine Artificial Limb	Portland	Artificial limbs	Paul Hatcher	5–10
Maine Machine Products	South Paris	Precision machine work	Jeff Sutton	100–250
National Semiconductor	S. Portland	Semiconductors manufacturer	Ann Gauthier	>500
Pratt & Whitney	North Berwick	Turbines manufacturer	Tom Mayes	>500
Rich Tool & Die Co.	Scarborough	Precision machine work	Allen Estes	100–250
Rynel Limited	Boothbay	Polyurethane foam products	James Detert	25–50
SCI	Augusta	Electronics manufacture	Pat Barry	>500
Soleras, Ltd.	Biddeford	Precision machine work	Dean Plaisted	50–100
Tundra	S. Portland	Semiconductor	Dave Ferris	25–50
USM Dept. of Engineering	Gorham	Engineering program	James W. Smith	NA
ZF Lemforder	Brewer	Automotive parts	Kevin Kenny	250–500

Business Characteristics

1. Fabricated Metals and Industrial Equipment

Fabricated metal and industrial equipment manufacturers provide component parts and equipment to dozens of other manufacturing industries, ranging from aerospace and defense to automotive, electronics and telecommunications. They are primarily involved in the manufacture of intermediate goods rather than consumer goods.

Major employers in Maine include Pratt & Whitney, Lemforder, General Dynamics Armament Systems Saco Operation, General Electric and Bath Iron Works, as well as numerous smaller companies such as Rich Tool & Die and

PRECISION MANUFACTURING

4.H

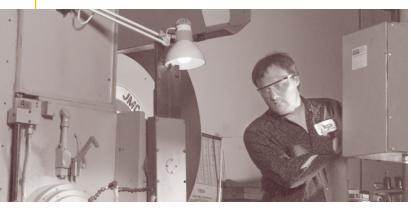
"Manufacturers in these industries have seen steady job growth in Maine in the last five years."

Maine Machine Products that provide goods to regional and national customers. At the other end of the scale, there are a large number of smaller companies making a variety of machined products, primarily for customers in Maine. Amongst these firms, there is a strong set of customer/supplier (vertical) relationships. Dielectric, one of the larger electronics firms, reports using as many as 75 machine shops in Maine to make parts for its products. BIW and the forest products industry are also major markets for small machine shops.

Manufacturers in these industries have seen steady job growth in Maine in the last five years, with both the number of companies and total employment rising nearly 10 percent since 1996 to 350 companies and 8,300 employees (Maine Department of Labor). Because of their connections to defense, firms in the industry in Maine may be slightly less cyclically sensitive than their national industry counterparts. However, troubles in the airline industry and connections to other markets more attuned to business cycles mean that the industry's long-term market prospects are tied to the health of the other manufacturing industries to which it sells.

The outlook for smaller companies depends on their ability to develop technical expertise needed by their clients and manufacture products at lower cost or on tight schedules. The expertise required may be in the form of advanced fabrication techniques or automated equipment that reduces labor input. Company size also matters, as very small firms lack the resources to purchase expensive labor-saving equipment or aggressively seek new work when existing contracts are terminated.

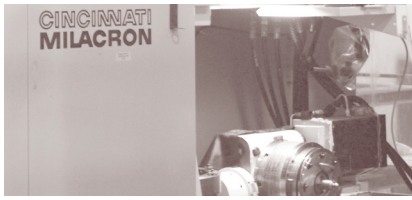
Companies that have headquarters in Maine and function as independent business units, such as Bath Iron Works and General Dynamics Armament Systems Saco Operation, have in-house research and development efforts that are important sources of innovation. (See the discussion of BIW in the chapter on Marine Technology and Aquaculture.) General Dynamics Armament Systems Saco Operation has developed new weapon designs that have established markets with specialized military forces, and the company has shifted production of other weapons to Saco. Other companies maintain R&D efforts outside Maine: Pratt & Whitney, for example, bases its research and development efforts in Connecticut; its large facility in North Berwick provides only manufacturing for turbines.



Maine's smaller machine shops and equipment manufacturers are often locally owned and operated, and some have been family-run for generations. The companies that have good management, tight cost controls and a policy of investing in new automated equipment have remained strong competitors in regional and national markets. Smaller firms with local markets may be less affected by competition from overseas manufacturers. These firms rarely engage in research or development.

2. Electronic Equipment and Instruments

Electronic equipment is a $550 billion industry worldwide, with a broad array of products that are continuously improved and upgraded. Computer technology has long been a U.S. stronghold and has formed the core of several well-known industry clusters in the Silicon Valley and Boston's Route 128. With Fairchild and National Semiconductor in South Portland, Maine has been able to benefit from the growth. National Semiconductor's chip fabrication facility is one of the most modern such facilities in North America, capable of producing highly complex chips. Fairchild Semiconductor has a fabrication facility, but more importantly its corporate headquarters, here in Maine.



This industry has seen significant changes in the last five years, and production overcapacity and price-cutting have made some elements of the computer chip business risky. Both Maine firms have established niches in specialty chips that have allowed them to be successful and expand, albeit slowly. These companies employ highly trained employees and production workers at salary scales that are considerably above those of other Maine industries, with the possible exception of the paper industry. This is a knowledge-based industry, in which competitive advantage is gained through excellence in research, design and manufacture.

As with fabricated metals, the electronics industry has its "contract manufacturing" segment. The largest firm in this field is Sanmina-SCI in Augusta, providing contract electronics assembly. A legacy of Digital Equipment Company, the SCI plant is a major employer with 600 employees and is now part of a firm with over 120 plants in 21 countries. Competitive advantage relies on assembling components quickly at the lowest cost, and the kinds of workers required tend to be relatively low wage and low skill. Two other firms, EM Solutions of Westbrook and ESC America, are smaller contract electronics assembly plants.

"This is a knowledge-based industry, in which competitive advantage is gained through excellence in research, design and manufacture."

Firms such as Dielectric in Bridgton and Raymond, which makes antennae components for the broadcast industry, and Edwards Systems Technology in Pittsfield, which makes fire and alarm systems, produce fully assembled products in Maine. These companies, owned by SPX Corporation of Muskegon, Michigan, collectively employ over 1,000 people and are an important part of the industry here in Maine. Dielectric has been spared the ups and downs of the telecommunications industry because its equipment is used for radio and TV broadcasts, which have seen steady growth.

Electronics employment in Maine has been fairly stable over the period from 1995 to 2000, with roughly 7,500 employees and little change in the number of companies (Maine Department of Labor). Some companies such as chip manufacturers have seen employment growth, while others, such as electronics manufacturers Vishay Sprague and Thomas and Betts in Sanford, which together employed over

700 people, have closed their doors. Salaries have increased 15 to 20 percent across all electronics industries since 1996 (Maine Department of Labor).

Subclusters

Machine and fabricated metal companies comprise the most coherent subcluster within precision manufacturing, although ties among companies in the group are relatively weak. They compete primarily in local (and some export) markets, but they do have some horizontal relationships and draw from a common, though small, labor pool. The long history of these companies in Maine provides some competitive advantage, but growth potential and technological innovation are limited.

"Machine and fabricated metal companies comprise the most coherent subcluster within precision manufacturing."

Finance

Financing needs vary by company size. Larger manufacturing companies have good access to capital, but many small firms are self-financing, and the high cost of state-of-the-art machine equipment puts them at a disadvantage. Some companies use MTI funding but to a lesser extent than in composites or biotechnology, where new products are continually being developed.

Innovation

The electronics industry is one of the most innovative, as product upgrades in computer hardware and consumer and industrial electronics occur frequently. Product life cycles have shortened significantly in the last decade as competition in most sectors drives an essentially continuous process of product improvement and cost reduction. Electronics is one of the few areas of consumer goods in which prices have dropped significantly while performance has increased markedly. Some areas of electronics have experienced intense competition, forcing prices down and accelerating the shift of production and/or assembly to low-cost overseas locations.

Companies have responded to this by increasing product specialization, creating niche markets where they can compete successfully. Maine's semiconductor firms are in this category, as are several other local electronics manufacturers. Electronics assembly is increasingly performed overseas to take advantage of the low cost of labor, so local firms increasingly look to innovation in technology, production or products to gain competitive advantage.

Research and Development Facilities and Organizations

Much of the R&D occurring in Maine is within industry, as modifications to design or improvements in production are ongoing at many companies. While the University of Maine has capabilities in several fields, the state lacks any sort of research and development center for advanced technology like those found in some industrial states, such as Pennsylvania and Michigan. Maine's technical colleges support R&D efforts but focus primarily on training.

Central Maine Technical College and the River Valley Growth Council, a newly formed coalition of area communities, have established the River Valley Technology Center, a business incubator and training center for precision manufacturing in the town of Mexico. This area has been plagued with declining employment in shoes, lumber and paper and urgently needs new industry. The center, housed in a large building donated by Mead Paper, will offer training for machinists and other skilled trades and provide space for both established and startup firms.

Trade Associations

The Maine Metal Products Association (MMPA) provides important support functions for machine shops and equipment manufacturers, including advocacy, legislative liaison and interface with other technology support organizations. MMPA also has a successful scholarship program that provides funding for students in the metal trades.

The electronics industry in Maine does not have a trade association, but dozens of national organizations represent each sector of the industry. Many electronics firms are also members of MESDA, the Maine software and IT industry association.

Labor

As more and more large regional and national companies outsource portions of their work, demand for skilled workers at local companies has increased. Demand for skilled machinists has outstripped supply, despite the presence of training programs at several state technical colleges. In order to attract labor, wage rates have increased 15 to 20 percent over the last five years, while wages in other manufacturing industries have not shown similar increases (Maine Department of Labor). Skill requirements have also increased as computerization and automation play a larger role in production.

"Demand for skilled machinists has outstripped supply, despite the presence of training programs at several state technical colleges."

Machine shops and industrial equipment companies often look for skilled machinists and tradespeople. In summer 2000, MMPA conducted an industry survey that revealed 1,500 skilled jobs in Maine were not filled because there were no qualified workers available. The technical colleges offer programs to address this need and work closely with companies to provide the necessary training. Finding engineers is also a challenge, but companies report that they can find employees locally or from the Boston market. Both UM and USM have undergraduate engineering programs, and UM also graduates a number of master's-degree and Ph.D. students in engineering.

Electronics firms' labor needs vary. Firms that do design and production require engineers with advanced degrees. The UM and USM Electrical Engineering programs can supply a few, but many come from out of state. The lack of advanced degree programs in southern Maine is a disadvantage, as employees moving to large firms in the state often look for advanced training programs. For routine production and assembly work, Maine generally has an adequate supply of labor available at competitive wage rates.

"Firms such as National Semiconductor and Fairchild Semiconductor are potential lead organizations."

Lead Organizations

Firms such as National Semiconductor and Fairchild Semiconductor are potential lead organizations. At least one firm, Tundra, a contract chip designer, has emerged from these companies. However, the firms' relatively recent reorganization, combined with intense competition in the semiconductor market and the current slowdown in electronics markets, has not created favorable conditions for spinoffs. Firms such as Pratt and Whitney and General Electric are large enough in the fabricated metals segment but have not generated significant spinoff activity. At the same time, the maturity of the fabricated metals and, to some extent, the electronics industries in Maine may mean that lead organizations are not critical to the sector's success.

Locational Advantage

Neither fabricated metals nor electronics is tied to any particular geographic location, as evidenced by the vigorous worldwide competition within both industries. Firms in Eastern Europe compete with Maine's fabricated metals industry, while firms throughout Europe, North America and Asia compete in electronics. Maine's tradition in manufacturing, particularly its pool of skilled labor and management, provides a key locational advantage for many of these companies, but growth of skilled labor forces in Eastern Europe and the Pacific Rim pose challenges in these highly competitive industries.

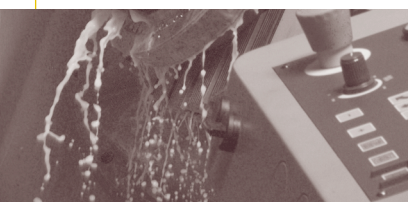


TABLE THIRTEEN
SUMMARY OF CLUSTER CHARACTERISTICS[9]

INNOVATION	Product	1
	Process	3
REGIONAL BUSINESS FUNCTIONS	Research	1
	Development	3
	Production	2
	Marketing	3
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	2
FUNDING	Self—Outside	3
	Grants—Capital	3
RELATIONSHIPS	Firms—Horizontal	1
	Firms—Vertical	2
	Labor	2
	R&D Facilities & Organizations	1
	Industry Organizations	1
	Lead Organizations	1
LOCATIONAL ADVANTAGE	Geography	1
	Knowledge	3
MARKET POTENTIAL	Mature—Growth Markets	1
	Diversity of Markets	2
	Local Demand	2
	Exports	1
ECONOMIC PERFORMANCE		2

"The electronics industry is one of the most innovative, as product upgrades in computer hardware and consumer and industrial electronics occur frequently."

[9]See the chapter *Measuring Clusters in Maine* for discussion of factors.

FOREST PRODUCTS

Introduction

The forest products industry is the largest manufacturing sector in Maine, with $5.6 billion in shipments in 1998 (NESFA, 2001). The industry added $2.2 billion in that year to the $32 billion gross state product. In Maine, forest products are often divided into three sectors: the softwood and hardwood lumber industry, pulp and paper manufacturing and wood products manufacturing. Other parts of the forest products sector that play a large role in the structure of the industry include forest ownership and management, logging, equipment manufacturing and distribution and biomass power generation.

"This diversity of markets, each with its own cycles of expansion and contraction, gives the forest products industry in Maine considerable depth."

All of these sectors are highly interconnected and interdependent, with each sector playing a key role in maintaining the health of the industry. There is a high degree of both horizontal and vertical relationships. For example, sawmills depend not only on a good market for their lumber, but also on a steady supply of logs from landowners and contractors, on a market at the paper mills for wood chips made from excess wood and trimmings and on an outlet at biomass power facilities for waste wood. Weaknesses in one of these markets can quickly affect related sectors, reducing often narrow profit margins and even forcing companies to close. Examples include the recent paper mill closure in Berlin, New Hampshire, which affected forest-related businesses and suppliers in Maine, New Hampshire and Vermont; as well as the closure of lumber mills in Costigan and Passadumkeag, which threw much of the local forest products economy and its suppliers into turmoil.

The markets served by Maine's forest products industry are generally mature and sensitive to business cycles. While lumber is driven to a large degree by the building market in the U.S. and overseas, biomass power generation is dependent on rapidly changing electricity markets. The pulp and paper industry responds to market pressures related to the demand for paper in the printing and publishing industries. This diversity of markets, each with its own cycles of expansion and contraction, gives the forest products industry in Maine considerable depth. For example, while the paper industry has seen declining market prices due to intense competition for the last several years, the lumber industry has seen, with the exception of last year, an extended period of stable or rising prices. Since changes in individual markets are difficult to predict, maintaining a highly diversified industry has provided a measure of long-term stability in the face of competitive pressures and technological change.

Firms throughout the forest products industry generally seek to maintain or increase market share either by being the low-cost producer of a product or by developing products that offer quality or cost advantages in specific markets. New product development occurs but is not a common strategy for most firms.

To better understand the current state of the industry in Maine, we interviewed senior management at 24 firms and organizations statewide. The firms that were selected were among the most innovative in their sectors. Interviews focused on the current status of the industry and the importance of innovation both for the company and for the industry. The following companies and individuals were interviewed:

TABLE FOURTEEN
SELECTED MAINE FOREST PRODUCTS COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT	EMPLOYEES
Forest Management and Production				
Huber Resources	Old Town	Land management, modeling	Peter Triandafillou	10–24
Irving Woodlands	Ashland	Maine's largest landowner	Chuck Gadzic	>500
Seven Islands Land Company	Bangor	Sustainable harvesting	John McNulty	
Sewall Company	Bangor	Information technology	Dave Edson	100–500
International Paper	Bucksport	IP timberlands and Sustainable Forest Initiative	Joel Swanton	>500
Pulp and Paper				
Great Northern Paper	Millinocket	Major investment and rebuild	Eldon Doody	>500
International Paper	Bucksport	Power generation and upgrades	Keith Cunningham	>500
International Paper	Jay	Pollution prevention program	Steve Groves	>500
SAPPI Fine Paper	Hinckley	Most modern mill in Maine	Doug Daniels	>500
Lumber				
Hancock Lumber	Casco	Integrated building products	Rich Merk	100–500
Maine Woods Company	Portage	Modern hardwood lumber mill	Greg Cyr	50–100
Robbins Lumber	Searsmont	Pine mill, diversified products	Jim Robbins	50–100
Equipment				
Lindsco Equipment	Brewer	Processing equipment	Bill French	4–10
Auburn Machinery	Auburn	Equipment	Tom Labrie	10–24
Energy				
Boralex	Montreal	Five Maine biomass plants	Jean Roy	100–500
Greenville Steam	Greenville	Independent biomass plant	Ray Kusche	10–24
Independent Energy Producers of Maine	Augusta	Trade association	Beth Nagusky	NA
Wood Products				
CF Wells Company	Buckfield	Turned wood products	Wil Lamarre	25–50
Maine Bucket Company	Lewiston	Adaptation to changing markets	Doug Boyd	25–50
Windham Millwork	Windham	Integrated CAD millwork	Bruce Pulkinnen	50–99
Supporting				
Maine Woods Products Assoc.	S. Portland	Trade association	Eric Howard	NA
Berry, Dunn, McNeil & Parker	Portland	Tax and accounting, forestry industry	Moe Bisson	NA
Farm Credit of Maine	Auburn	Finance, forest industry	Dick Robertson	NA
FAME	Augusta	Finance, forest Industry	David Markovchick	NA
UM Dept. of Chemical Engineering	Orono	Pulp and paper technology	Joe Genco	NA

FOREST PRODUCTS

"Increasing emphasis on management for sustainable yield and habitat protection has resulted in a healthier and more stable forest."

Business Characteristics

Because the segments of the industry have distinct products and markets, each is considered separately.

1. Forest Management and Production

Land ownership in Maine's forestlands has seen major changes in the last ten years, with some large tracts changing hands several times. Most notable has been the divestiture of land during the 1990s by the major paper companies in response to pressure from financial markets. In 1998 and 1999, 56 percent of the state's industrially owned forest and 24 percent of the state's total forestland were sold (Irland, 2000). This period also saw the expansion of large land-holding companies that both manage lands for forest yield and take advantage of emerging real estate markets. The last decade has seen significant increases in the value of Maine timberlands, particularly those that have high recreational value. This has driven the development of innovative land ownership transactions that allow lands to be used for timber production while simultaneously providing important recreational functions.

Changes in the Maine forest have also been driven by changes in the resource itself. The spruce-budworm outbreak of the 1970s and 1980s fundamentally altered forest use, encouraging users to shift toward greater utilization of hardwoods. With paper mills now using more hard- than softwood, and with several hardwood lumber mills in operation, markets for timber and fiber have become more diverse. Increasing harvesting pressure has also raised harvesting levels relative to growth. While the Maine forest has increased in total volume of wood over recent decades, an imbalance between older and younger trees threatens long-term harvest levels (Maine Forest Service, 2001).

The result of these changes, plus increased public concern over the forests, was expressed in three referenda that attempted to limit forest harvesting. While the referenda failed, they led to significant changes in forest management, particularly in the last five years. Increasing emphasis on management for sustainable yield and habitat protection has resulted in a healthier and more stable forest, a contrast to the negative impacts seen in the 1980s from spruce budworm and heavy harvesting. This trend will likely continue as land management becomes increasingly sophisticated and demanding.

Another force for change has been the high degree of mechanization that has become standard in the industry. The use of mechanical harvesters, combined with better land management, produces equal or lesser impacts, greater operator safety and much lower operating costs than was achieved with skidders and

chainsaw crews. While Maine has been a heavy user of harvesting equipment, it has never been a center of innovation in mechanization. Instead, much of the innovation has come from European equipment manufacturers that moved rapidly into mechanization due to high labor costs in their forest products industry. In Maine, an extensive network of firms has evolved to service and distribute this equipment.

Maine is now viewed as one of the most innovative states in both forest management and ownership. Many of these innovations have developed in the last decade in response to the complex interplay between the forest products industry, conservation interests, landowners and investors. Increasing sophistication in management has stimulated use of information technologies such as global positioning systems (GPS) and geographic information systems (GIS) in analyzing forest characteristics and developing management plans that accommodate a variety of industrial, recreational and conservation uses.

These innovations are examples of the application of information technologies to forest management. In fact, information technologies are a key part of innovation in all aspects of the forest products industry. In lumber, it is numerically controlled sawing and inventory control. In pulp and paper, computerized process controls have been used for more than three decades. Steady improvements in computing power have resulted in improvements in pulp and paper manufacturing. The connection between forest products and information technology represents one of the key fields of innovation that will determine the long-term health of the industry in Maine.

Innovations in ownership include the recent advent of forest conservation easements that restrict subdivision and development but allow timber production, recreation and conservation. This is an innovative, market-based approach that responds to the needs of investors and landowners to receive value while securing benefits for the public in terms of conservation, access and use—activities that were previously taken for granted and were not valued in financial terms. The valuing of conservation goals has led to other innovations, including the purchase of large areas by privately funded conservation groups, a trend not seen in other states to date. Some landowners and timber companies have also been innovative in developing and implementing management plans for sustainable harvesting that accommodate recreational and conservation use. The state's tradition of private ownership will likely lead to further innovative, market-based solutions to pressures for multiple use of forestlands.

"Maine is now viewed as one of the most innovative states in both forest management and ownership."

2. Lumber

The lumber industry in Maine is composed of 238 mills processing 1.2 billion board feet of sawlogs (MFS, 1998). With shipments valued at $1.3 billion in

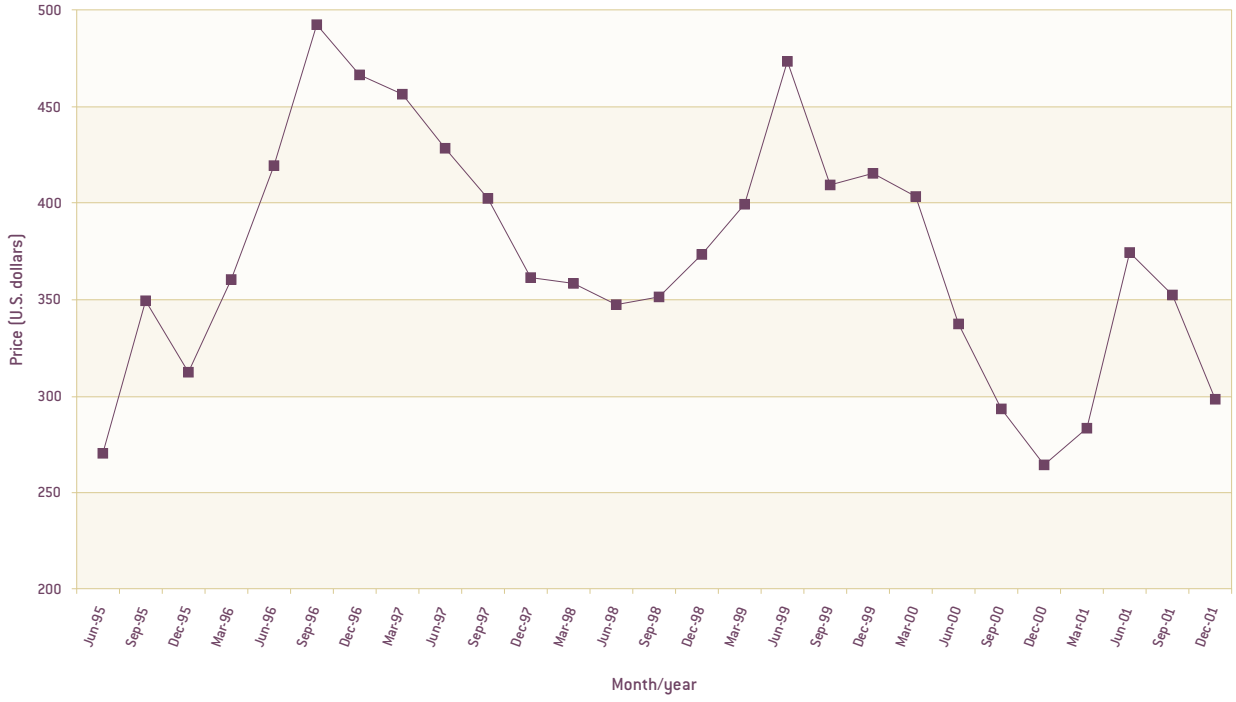
"Private ownership will likely lead to further innovative, market-based solutions to pressures for multiple use of forestlands."

1999, the industry is two to three times larger than fishing or agriculture and contributed $643 million in value-added production to the gross state product (NESFA, 2001). Employment, at 10,000+ for both lumber and manufactured wood products, has been relatively stable compared to other traditional manufacturing industries, showing only modest declines over the last two decades (Maine Department of Labor). While the lumber industry is perceived as mature, several new lumber mills using state-of-the-art technology have opened in recent years, and production capacity in Maine has remained stable or increased even as some older mills have shut down.

Throughout the late 1990s, softwood lumber prices varied considerably but were particularly strong in 1996–1997 and 1999, allowing Maine sawmills to generate significant revenues. Some mills used the opportunity to upgrade or invest in new equipment, increasing production capacity. The year 2000 saw significant declines in prices, with some grades dropping 30 to 40 percent and hastening the demise of older mills.

Increasing overcapacity in the industry nationwide, combined with a strong dollar, a surge in overseas imports and pressure from Canadian mills, resulted in strong

Lumber Prices, 1995–2001[10]



[10]Eastern SPF 2x4, kiln dried, #1+2, Boston Data from Random Lengths Publications, 2001.

downward pressure on prices. Production in commodity grades faces steep competition, with large, modern Canadian mills in both Quebec and the western provinces producing more per mill than are comparable U.S. mills. Last year saw the abrupt shutdown of stud mills in Costigan and Passadumkeag in an effort by producers to reduce production capacity. The year 2001 saw some recovery in prices as the housing market remained strong, but the outlook is uncertain.

Hardwood lumber is a smaller market that did not develop significantly in Maine until the last ten to 15 years in the wake of the spruce budworm. Several large mills now handle timber from Maine's hardwood stands, and these mills have been able to compete in producing wood for the flooring, cabinet and pallet markets, as well as material for manufactured wood products. While Maine's hardwood stands are of lesser quality than comparable southern U.S. forests, the use of modern, highly mechanized mills and competitive prices for hardwood logs have allowed some mills to succeed. Competition from mills in the Midwest and South as well as Canada is considerable as these regions have extensive hardwood resources.

Innovations in sawmill operations in Maine have been focused on increasing mechanization and decreasing labor inputs. Since most lumber is a relatively undifferentiated commodity, innovations center on process improvements that increase yields and reduce production costs. Technologies such as scanners and computerized saws that optimize cuts are widely used in the newer mills. Mechanized systems that reduce sorting and handling save significantly on labor costs but can be expensive. In some areas, such as hardwood lumber, computer systems have yet to equal the ability of trained operators to optimize cutting of sawlogs. Technology is also making improvements in inventory control, and bar coding and scanning will increasingly be used to track movement of even individual pieces of lumber.

"Innovations in sawmill operations in Maine have been focused on increasing mechanization and decreasing labor input."

Mills increasingly focus on getting every bit of value from logs, including lumber, chips for paper production, sawdust and waste wood for biomass and/or bark for bark mulch. Two decades ago, a large percentage of material was not used at all and was burned as excess or otherwise discarded. The trend toward full utilization will likely continue as companies seek to maximize production from each log. Technologies that extract additional usable lumber from discards or scrap have considerable potential, as seen in the increasing percentage of lumber on the market made from mechanically joined pieces.

Energy consumption in the lumber industry is a major cost factor; this is particularly true in Maine, where power costs are high. Nationally, the forest products industry is the third largest consumer of energy among major manufacturing industries (EIA, 2001). Large amounts of electricity are used in sawmill operation, and additional thermal energy is used to dry lumber. While heat for wood-drying

"Energy consumption in the lumber industry is a major cost factor; this is particularly true in Maine, where power costs are high."

kilns can be produced from scrap wood or sawdust, electrical energy must be purchased or produced on site. Mills that are large enough can afford to purchase boilers and turbine generators, but their operation requires continuous staffing by trained operators. Many smaller mills can afford neither the capital outlay nor the cost of operating such systems.

Other adaptations used by some companies include diversification, allowing profitable operations in building materials or manufacturing to sustain the company when lumber prices slump. A few locally owned producers, such as Hancock Lumber and Robbins Lumber, are increasingly diversified, offering new products and services in their markets. Hancock now offers a wide range of products and services for contractors and builders, while Robbins produces manufactured wood products in addition to eastern white pine lumber and markets them to major retailers. Successful diversification requires strong marketing capabilities, an area in which some lumber producers have yet to develop.

The state has a large number of older, smaller sawmills that are run as they were years ago. Equipment has not been modernized, and understanding and control of costs is limited. While these mills have long been an integral part of the local economy and culture, their outlook is poor. Some may survive as "lifestyle" businesses, but their role in the industry will steadily diminish.

Innovations in products in the national lumber market have included significant growth in engineered wood products. Products such as the I-beam, introduced over 30 years ago, are replacing structural flooring and framing in the building market at an increasing rate with the promise of superior strength and reduced cost.[11] Roof timbers are frequently replaced by engineered roof trusses that use less material. Glued laminated beams compete against heavy steel products, and new applications for structural panels have seen strong growth. Many of these innovations have been driven by demand from builders in high-volume home construction markets common in rapidly growing urban areas in other parts of the country, particularly the South and West. The lack of this kind of large building market in Maine and the Northeast has slowed innovation in building science and construction. Generally, the local market is too small and is not organized in such a way to provide significant feedback from builders: an essential component in the development of new products. Maine also lacks significant capacity in structural panel production, an important area of innovation.

Maine has seen some innovation in the area of assembly and construction. Modular housing, an industry in which Maine is a regional leader, has grown

[11] Engineered wood products are a broad category that includes the advanced composite wood products discussed in the Advanced Materials chapter. Composite wood products combine wood and other materials, while engineered wood products are generally made of wood only.

rapidly in popularity here and nationwide as a lower cost alternative to custom-built homes (MBSA, 2001). Roof trusses for homes are now often pre-assembled. Hancock Lumber has moved into off-site fabrication of walls and other structures, saving homebuilders time and labor.

Wood products research is supported by both federal and industry funding and has been led by national centers such as the U.S. Forest Products Lab in Wisconsin and the research centers developed in the western states by industry giants such as Weyerhauser. In the last decade, the University of Maine Wood Science Program has developed a national reputation as one of the more innovative research programs. Developing local applications for engineered products is particularly important, allowing the product feedback and concept testing that are critical to the success of new offerings.

3. Pulp and Paper

The pulp and paper industry has been a mainstay of the Maine economy for the last 100 years and, particularly in the more rural areas of the state, provides one of the only sources of high-paying jobs. Of the $2.2 billion in gross state product contributed by the forest products industry, over two thirds or $1.5 billion is provided by pulp and paper (NESFA, 2001). The industry has consistently been the state's highest wage manufacturing industry, with over 12,000 direct jobs in the mills themselves and a greater number in supporting industries. The industry has suffered in the last five years from intense price competition from southern U.S., Canadian and European mills, aggravated by a strong U.S. dollar. Newer mills around the world continue to produce paper with lower labor and materials costs.

"In the last decade, the University of Maine Wood Science Program has developed a national reputation as one of the more innovative research programs."

With 16 mills, Maine is second only to Wisconsin in number of mills. Maine's mills, with the exception of one newer facility and several others that have been modernized, are mostly older, with smaller or lower volume machines that require more labor per ton of paper produced than do machines built in the last two decades. While the industry has invested in upgrading and rebuilding paper machines over the last decade, no new machines have been built in Maine in the last 15 years. The level of investment is viewed by many as significantly lower than what is required to keep the industry competitive. With one or two exceptions, Maine's mills are generally above average in costs per ton, compared to mills around the world (Jaakko Poyry, 1995). While Maine mills are generally similar to other mills in the U.S. in terms of costs for labor, wood and other raw materials, competition from overseas mills is increasing. Nationwide, 27 paper mills have closed in the last five years, and Maine has seen three small mills close. Worldwide, the industry has also suffered from overcapacity; new mill construction is often undertaken in bids to be the lowest cost producer, while older mills continue to operate. The resulting overproduction leads to declining prices for many commodity grades of paper.

"Paper mills are among Maine's largest users of applied industrial technology."

Paper mills are among Maine's largest users of applied industrial technology. They use a range of high-volume chemical and thermal processes requiring precise conditions and are significant users of computer technology for process monitoring and control. Despite aging infrastructure in Maine, many mills have become quite innovative in their efforts to remain competitive. Each mill has a unique cost structure, and continuous attention is paid to reducing costs per ton of paper produced. Some mills report costs per ton produced are equal to or less than those of five years ago, despite increases in labor and benefit costs over the same period. Cost-saving process improvements and refinements, often identified by employees on the mill floor, are a major source of innovation.

Much of the research and development of process improvements takes place in the mills or in research organizations like the University of Maine's Pulp and Paper Program within the Department of Chemical Engineering. Improvements in existing product lines that enhance paper performance in printing applications, and development of new variations of specialty papers that can capture market share, are generally researched outside of Maine in the research facilities of major paper companies.

4. Secondary Manufactured Wood Products and Furniture

This sector includes both large-volume producers of turned wood products such as golf tees as well as smaller specialty firms manufacturing furniture or craft items. There are also a number of custom manufacturers of millwork and cabinetry. Companies range from large automated wood product mills with 100 or more employees to small outfits where one or two employees perform custom work. The number of secondary wood product manufacturers is estimated to be several hundred, with total employment of roughly 2,000 in 1998 (NESFA, 2001).

The sector has long been an integral part of the forest products industry, but changing economic conditions and increased competition are posing challenges for some firms. Manufacturers of certain turned wood products face below-cost competition from China and other overseas sources as industry there purchases automated equipment and produces turned products for a fraction of the cost charged by Maine companies. Substitution of plastics is also increasing, particularly where very large quantities of product are needed. Competition from large-volume imported production has led some Maine firms to focus on smaller niche markets where quick turnaround of smaller lots is more important than low-cost production of large quantities. Entry into smaller niche markets requires good marketing skills, an area in which only a few Maine firms do well. Many older firms are not accustomed to soliciting orders, and finding qualified marketing staff in Maine can be both difficult and costly.

Some of the larger turned and flatwood products firms continue to compete successfully in national and international markets through tight cost control, investment in new machinery and attention to quality. Maine also has a number of custom millwork firms that have invested heavily in technology and are well positioned in local and regional markets. Successful firms have often taken advantage of programs like Lean Manufacturing, offered by the Maine Manufacturing Extension Partnership, as well as grants and loans for investment in new technology and training. Older firms that have not invested in labor-saving equipment or developed capabilities in marketing and sales face an uncertain future.

Maine has never had a large furniture manufacturing industry, as furniture markets have been dominated by large producers in states such as North and South Carolina. While the entry of overseas producers has put severe pressure on mass-market furniture manufacturers, Maine has a small cadre of manufacturers such as Thos. Moser Cabinetmakers of Auburn and Moosehead Manufacturing of Dover-Foxcroft that have established market niches based on design and craftsmanship. High-end manufacturers such as Thos. Moser are less subject to competition from overseas producers and have solid growth prospects.

Marketing in particular was identified by several companies and organizations as the key to survival, as established customers were lost to low-price competition and new customers had to be found quickly. Older, smaller companies also were reportedly the most likely to lack the skills in management needed to control costs and increase productivity.

"Successful firms have often taken advantage of programs like Lean Manufacturing...as well as grants and loans for investment in new technology and training."

5. Biomass Power Generation

This sector of the forest products industry is both an integral part of the paper and lumber industry and a separate sector in its own right. Many of the large paper and lumber mills operate biomass boilers to consume waste wood while generating steam and electricity to meet the plants' often enormous demand for power. Some biomass facilities are stand-alone operations that sell power to the grid.

Biomass plants were constructed rapidly in the 1980s, when contracts encouraged by federal energy policy provided above-market rates for small power generators that sold power, and currently ten plants in the state can produce over 250 megawatts for the grid. As the price of electricity increased, more plants were added at paper and lumber mills to reduce the burden of electricity costs, and some of these plants also sell power to the grid. All plants dispose of waste wood, which often poses major problems for mills. For many years, waste wood was simply burned in crude furnaces with little or no capture of energy. Today, if waste wood is not used in biomass boilers, regulations require landfilling of the material—an expensive and inefficient use of biomass.

"Some plants ...are seeking opportunities for co-location with energy-intensive businesses such as sawmills."

Recently, the state has seen the construction of several large natural gas–fired power plants with a combined generating capacity of over 1,000 megawatts. With limited transmission line capacity to lucrative urban power markets south of Maine, the result has been an excess of capacity in the state and reduced prices for power. Some biomass plants are seeing prices for power down as much as 50 percent over the last year, threatening the plants' viability. Further aggravating the situation, prices for waste wood rose significantly, in some cases as much 80 percent. Some of this is due to the rise in petroleum prices in the last two years, which caused pulp and paper mills to shift to biomass to meet energy needs. This drove up prices, as did growing markets for waste wood such as bark mulch. The result has been that several independent biomass plants are no longer profitable and face possible closure unless market conditions change.

Biomass plants have responded to the rise in prices by seeking alternative fuel sources, such as construction and demolition debris, that may be available at low or no cost. Some plants, if they are not already colocated, are seeking opportunities for co-location with energy-intensive businesses such as sawmills. These facilities can utilize excess steam for kiln drying of lumber while simultaneously purchasing electricity directly from the power plant, saving on transmission and distribution charges. Several sawmills already have their own biomass boilers and have availed themselves of the savings inherent in this system, but power plant operation and maintenance require different personnel, training and procedures than do sawmills, a factor that may favor maintaining separate companies.

Efforts are under way involving private firms such as Auburn Machinery and the University of Maine to find ways to recover, recycle and use low-value solid wood scrap typically used for biomass fuel. Equipment has been developed for converting these into higher value products efficiently and at reasonable cost. Additional work remains to be done on developing efficient markets and distribution for stock made from recovered materials. These efforts may lead to the development of new economic opportunities and interconnections within the forest products cluster.

Subclusters

As discussed above, the forest products group has the best-defined subclusters, including pulp and paper, lumber, timber harvesting, forest management, biomass generation and secondary wood products.

Finance

Access to capital does not appear to be a limiting factor for established forest products companies with good track records. The larger companies raise capital in national debt and equity markets. For small to mid-sized companies, Farm Credit and several large banks invest heavily in forest ownership, logging companies and sawmills. While these areas do pose risks, well-run companies have proved strong performers over the last five years. Additional support is provided through FAME and DECD. To gain financing from these institutions, companies must have tight cost controls, sound management, modernized equipment and significant annual reinvestment in the business.

Research and Development Facilities and Organizations

The Paper Science Program and the Pulp and Paper Process Development Center at UM, which saw considerable expansion in the 1980s, provide research, evaluation and pilot testing for mills in Maine and throughout the eastern U.S. Nationally, the U.S. remained the world leader in patents in the paper industry, with an average of 189 patents per year from 1990 to 1996 (Canadian Forest Service, 1999). Yet recent consolidations in the paper industry have resulted in an overall reduction in industry-based research capabilities, and many paper industry suppliers have cut research budgets drastically. Reduction in industry research funding over the last three years may approach $150 million (Institute of Paper Science and Technology, 2001).

University research and federal programs will play an increasingly important role as sources of innovation for the industry. An opportunity exists for the Process Development Center to serve as a center for research and development of products. With good facilities, staff and access to the resources of the Pulp and Paper Foundation, the program could become the innovation center for Maine's paper industry.

"University research and federal programs will play an increasingly important role as sources of innovation for the industry."

Programs such as Lean Manufacturing, offered by the Maine Manufacturing Extension Partnership, have been used successfully by dozens of companies in this sector. Lean Manufacturing develops steps that can be taken to streamline manufacturing and reduce costs. In order to develop these measures, companies must have cost systems in place that allow them to calculate improvements in productivity, a big step for older firms that run on simple principles. Participants view Lean Manufacturing as an important asset in enhancing their competitiveness. Extension of this program to the hundreds of wood products manufacturing firms is critical for the long-term health of the industry.

FOREST PRODUCTS

The Maine Forest Service (MFS) plays an important role in overseeing the health and productivity of Maine forests. For small landowners, the state forester and entomologist provide important services in woodlot management and pest control; larger landowners generally have their own capabilities in these areas. MFS also is the only organization that tracks the overall health, productivity and management of Maine's forestlands, and provides both policy guidance and assessment of the state's progress toward goals of sustainable production.

"The limited ability of some small wood products manufacturers to market their products effectively is a major weakness."

Trade Associations

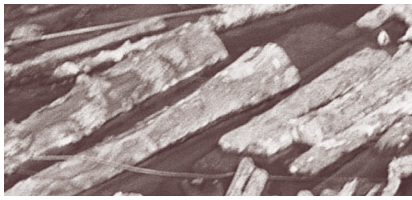
The Maine Forest Products Council and the Maine Pulp and Paper Association are oriented toward legislative issues, while the Maine Wood Products Association (MWPA) focuses on business development. MWPA has existed only since the early 1990s; prior to that time, there was no trade association for wood products manufacturers. Since the organization is not a lobbying group, it can obtain economic development funds from the U.S. Department of Agriculture, the Department of Economic and Community Development and other agencies. This is particularly important as MWPA can take on previously unmet marketing functions: essential in an era of increasing global competition. The limited ability of some small wood products manufacturers to market their products effectively is a major weakness for this sector, and expansion of efforts both to train businesses in marketing and extend the reach of their marketing efforts is crucial for long-term survival.

Independent Energy Producers of Maine serves all small power producers in Maine, not just biomass plants, so the issues it works on often are broader than just this segment of the industry. At a national level, biomass power production has long been recognized as strategically important for reducing dependence on fossil fuels. The Department of Energy's Regional Biomass Energy Programs were created to increase the use of biomass fuels of all types through research and demonstration projects. Opportunities may exist for Maine biomass plants to demonstrate advances in technology locally.

Labor

Many forest products firms retain their employees for long periods of time and hire relatively few new employees, even to replace employees who leave or retire. Employment declines over the past decade have left a large pool of skilled labor in all parts of the forest products industry in Maine. Even though many who have been laid off or otherwise left the industry are now employed in different positions, many would return to forest products if given the opportunity.

Education and training vary widely across the forest products industry. The pulp and paper industry has one of the best training programs in the country at the UM Chemical Engineering Department, with scholarship programs from the Pulp and Paper Foundation that are unmatched anywhere in the country. Graduates earn average starting salaries of $51,000, often exceeding those of new computer scientists and electrical engineers. Similarly, the University of Maine offers one of the top forest management degree programs in the nation, and graduates of the Wood Science Program are well regarded. Forest harvesting programs are available at Northern Maine, Kennebec Valley, Eastern Maine and Western Central Technical Colleges and at several high school vocational programs around the state.



Conversely, few programs address the needs of the lumber or manufactured wood products industry. With a high demand for semiskilled labor and low wage scales, obtaining qualified personnel remains a problem for many sawmills and manufacturers. MWPA has a program targeted to Maine high school students that promotes careers in the wood products industries in an effort to change perceptions of jobs and opportunities in the sawmill and wood products manufacturing sectors. Development of training programs through the technical colleges is being pursued, and some companies have used the Governor's Training Initiative program.

Lead Organizations

The forest products industry has several large, highly influential organizations in the form of the major pulp and paper companies and such firms as Irving, Plum Creek and Seven Islands Land Company. The size of these organizations gives them considerable influence in many parts of the industry, but the industry's relatively slow growth means that these companies do not produce spinoffs in the same way that firms in more technologically dynamic industries do. Some sectors of the industry, such as biomass power and secondary wood products, have no lead organizations.

Locational Advantage

The forest products industry is obviously tied to Maine by the geographic factor of the state's abundant, high-quality forest resources. But that resource depends heavily on an extensive knowledge base that is the foundation for the intensive management needed to ensure a sustainable and cost-effective supply of fiber for the industry. In Maine, that knowledge base is generally found in private, public, and university organizations. It is key to the innovations in manufacturing processes that are needed to sustain competitiveness.

"With a high demand for semiskilled labor and low wage scales, obtaining qualified personnel remains a problem for many sawmills and manufacturers."

Special Issue: Transportation

"The forest products industry places greater demands on Maine's transportation networks than any other industry."

The forest products industry places greater demands on Maine's transportation networks than any other industry. The industry is heavily dependent on transportation and vice versa, and the relationships between forest products and transportation affect both highway and rail.

Trucking remains the only practical alternative for many harvesting and transport operations. Cost-cutting efforts by both sellers and buyers of logs and fiber have squeezed the trucking industry, reducing some companies to marginal operation. Movement of low-value materials such as waste wood is particularly affected by transportation cost, and it rapidly becomes unprofitable to operate biomass plants when high-cost transportation is required. Transport of finished paper by truck is efficient for northeastern markets and works well for supplying some large-volume printing companies. Currently, however, the heavy dependence on truck transportation for all phases of operations leaves the entire forest products sector highly vulnerable to fluctuations in fuel prices.

The forest products industry is the single largest user of rail services in Maine; thus, the entire rail system in the state depends heavily on the industry's health. Several paper mills such as Great Northern also use rail to a large degree, both to move chips and logs to the mills and to move finished paper to market. Some mills indicate that costs are roughly comparable, with the benefits of rail being in the ability to store large quantities of material within the system. The unstable financial condition of the Bangor & Aroostook Railroad has been a significant concern for mills that depend on it, and its pending acquisition by RailWorld and Wheeling Corporation, operation and investment companies run by successful rail executives, suggests that B&A's prospects are improving. The maintenance of a functioning rail freight system is considered very important as a way to move heavy loads, and the system is the only alternative should fuel prices rise suddenly, as they did in 1999.

TABLE FIFTEEN
SUMMARY OF CLUSTER CHARACTERISTICS[12]

INNOVATION	Product	1
	Process	3
REGIONAL BUSINESS FUNCTIONS	Research	1
	Development	2
	Production	3
	Marketing	1
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	3
FUNDING	Self—Outside	3
	Grants—Capital	3
RELATIONSHIPS	Firms—Horizontal	3
	Firms—Vertical	3
	Labor	3
	R&D Facilities & Organizations	3
	Industry Organizations	3
	Lead Organizations	3
LOCATIONAL ADVANTAGE	Geography	3
	Knowledge	2
MARKET POTENTIAL	Mature—Growth Markets	1
	Diversity of Markets	3
	Local Demand	3
	Exports	3
ECONOMIC PERFORMANCE		1

"The University of Maine offers one of the top forest management degree programs in the nation."

[12]See the chapter *Measuring Clusters in Maine* for discussion of factors.

AGRICULTURE

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"Maine agriculture has become more innovative in both production and marketing technology."

Introduction

Agriculture has a long history in Maine, with some farms more than 200 years old. But farming has changed a great deal in the last three decades, primarily through a steady loss in both the number of farms and in farm employment combined with a shift to increased processing of output. Total agricultural production in Maine has remained relatively stable over the last decade, with modest increases bringing the state's output to $496 million in 2000 (USDA, 2001). Declines in poultry and egg production in the last few years were counterbalanced by increases in potato production, livestock and dairy.

The number of farms in Maine has decreased over the last decade to approximately 5,800 in 1997 (USDA, 2001). There are several causes for this trend, ranging from rising real estate prices in the southern part of the state, to declining population in the North, to stiff competition from both domestic and overseas producers. Over this period, Maine agriculture has become more innovative in both production and marketing technology.

To better understand some of these changes, we interviewed the following individuals. Organizations and companies were selected based on levels of innovation and ability to represent different segments of the industry. The number of employees is not listed as the numbers were small or seasonally variable.

16

TABLE SIXTEEN
SELECTED MAINE AGRICULTURE COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT
Agricultural Council of Maine	Hallowell	Trade association	William Bell
County Superspud	Mars Hill	Potato producer	Jay McCrum
Farm Credit of Maine	Presque Isle	Finance	Pete Hallowell
Fogler Farm	Exeter	Dairy	Bob Fogler
Maine Farm Bureau	Augusta	Trade association	Jon Olson
Maine Potato Board	Presque Isle	Trade association	Michael Corey
North Star Orchard	Madison	Apple producer	Rob Dimock
Bob Phillips	Cherryfield	Former consultant, Oxford Foods, Wyman's	Bob Phillips
Piper Farm	Emden	Dairy	Karen Piper
University of Maine	Orono	Agricultural research	Dr. Gregory White
Wild Blueberry Commission of Maine	Orono	Trade association	David K. Bell



Business Characteristics

Potatoes remain the mainstay of farm production for Maine, with $110 million in product in 2000 (USDA, 2001), and anchor the economy of Aroostook County. Maine potatoes have experienced strong competition from Canadian imports and domestic products for the last two decades, and total acreage in production in Maine has declined significantly over this period. After resolving quality issues and modernizing both production and processing technology, the industry has stabilized, and new investment in Aroostook County by food processors has created both employment and markets for potatoes.

Dairy products remain the state's second largest agricultural product after potatoes, with $97 million in product in 2000. Maine's dairy farms have seen a significant decline in the number of farms in the last two decades, although production quantities and value have remained stable or increased. Dairy farms that are large enough to capture some economies of scale remain competitive, but smaller farms that avoid large debt loads have also remained profitable. Maine dairies such as Oakhurst have developed a strong market niche based on quality and purity. The federal government heavily regulates dairy markets, and recent changes in this policy may threaten the continued viability of many Maine farms.

Maine's wild blueberry harvest has continued to rise over the last decade, and the dollar value of the harvest increased to a peak of $44 million in 2000 before dropping back in 2001. Production from Maine and Canada increased steadily throughout the 1990s through improved agricultural practices, including irrigation. The market for wild blueberries has broadened through efforts of the industry, trade associations and government agencies.

Eggs remain a major agricultural export for Maine, with $60 million in production of eggs and poultry in 2000. At one time, Maine was one of the top poultry-producing states, but production here has dwindled to a fraction of its former volume. Eggs from several large farms are shipped throughout the Northeast and as far away as China. The egg industry has long been dominated by large-scale production facilities that can generate significant economies of scale and use automation for feeding hens and handling and packaging eggs.

Apples have long been important in Maine, but recent low-cost production overseas has meant the demise of some of the state's larger orchards. While new varieties with high yields and high customer appeal have been developed, it remains unclear whether Maine's apple industry will survive in its current form. Shortages of labor, low prices for apples and unpredictable weather plague growers, and remaining farms often must rely on local markets and/or value-added products, such as pies or preserves.

"Potatoes remain the mainstay of farm production for Maine... and anchor the economy of Aroostook County."

AGRICULTURE

While Maine has seen its total number of farms decline in the last decade, the number of small farms has actually increased (USDA, 2001). Many small farms are engaged in production of fresh vegetables for local consumption and often operate on a part-time basis. Ten farmers' markets across the state provide outlets for a broad range of fresh produce, and many more farms have farm stands or other local outlets. Premium restaurants have become frequent purchasers of local produce, providing a steadily increasing demand for local production. These local markets provide much better prices than commodity markets and enable small farmers across the state to engage in small-scale agriculture as a viable business.

A growing proportion of the agricultural market in Maine is in value-added products for mass markets and in specialty products targeted at premium retail markets. These markets are playing a larger and larger role for almost all types of Maine agricultural products, from potatoes, beef, lamb and dairy products to blueberries, maple syrup and preserves. Success in these niche markets requires a strong commitment to marketing and customer satisfaction, areas that are relatively new to many farmers; nonetheless, with increased processing and value-added products, Maine agriculture is accessing a much wider diversity of markets than in the past. Most of these markets are outside Maine, although there are also increasing connections with the specialty food processing market within the state. While few high-growth markets are served, the increased diversity of markets and products is key to economic success.

"Maine products are showing up in more local, regional and national stores, and 'Made in Maine' has been successfully branded as a trademark for quality."

The Agricultural Council of Maine (AGCOM), in its *Strategic Plan for Maine Agriculture* (1998), identified key issues affecting Maine's farms and developed strategies to address these problems. The council's survey data indicated that only 43 percent of surveyed Maine farms turned a profit in 1997.

The AGCOM study identified several strategies to address industry problems. The top priority is to increase market opportunities for Maine agricultural products, an objective toward which there has been significant progress in the last few years. Maine products are showing up in more local, regional and national stores, and "Made in Maine" has been successfully branded as a trademark for quality. Equally important for Maine farmers is an identified need to improve access to the research and training needed for successful agricultural operations. The formation of the University of Maine Agricultural Center and the emphasis on agriculture and forestry as priorities in university research as well as state science and technology goals are important steps in that direction. Other factors such as taxes, access to capital, labor supply and environmental issues were identified as problems, and some progress has been made on those issues.

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Subclusters

Agriculture's subclusters are well defined, driven primarily by the product/commodity groups noted above.

Finance

Agricultural enterprises in Maine experience varying degrees of success in obtaining financing. Commercial lenders in agricultural areas may be familiar with the requirements for successful agricultural enterprises, but many lenders are not. Farm Credit of Maine plays a big role, as it holds about 50 percent of the loans in Aroostook County. AGCOM's survey (1997) indicated that lenders found that a majority of farm loan applicants had only fair to poor understanding of costs, prices, projections and marketing, and that almost all farmers submitted less-than-adequate business plans. Improving farmers' business skills remains a top priority for AGCOM, the Cooperative Extension and other organizations, including trade associations. Successful agricultural enterprise in Maine requires astute management, tight cost controls and avoidance of excessive debt.

Innovation

The AGCOM survey found that 44 percent of respondents report a change in commodities produced in the last five years, 66 percent had substantially changed production practices and 52 percent had made substantial changes in marketing and distribution. Computer use had increased dramatically, with 61 percent of farmers having access to a computer, either for tracking finances or accessing technical and market information.

These changes have been driven by intense competition, which requires continual attention to diversifying, increasing yields, reducing costs and improving productivity. While electronic and mechanical technologies play an important role, some of the most valuable innovations have come in the form of advanced farm, field and production management for high yields. Innovation in agricultural production can be broken down into techniques used to increase yields and innovations to increase productivity and reduce high labor inputs. Techniques to improve yields include a number of measures, some developed and effectively promoted by the UM Extension Service scientists, such as crop rotations, high-yield strains, pest management programs and fertilizers/herbicides.

"Some of the most valuable innovations have come in the form of advanced farm, field and production management for high yields."

Productivity improvements for wholesale markets in Maine have been in the form of mechanization, such as mechanical harvesters and advanced sorting equipment. With significant gains in these areas in the last decade, more attention is

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"Enhanced techniques for crop management and pest control are widely used now in Maine...

now focused on value-added processing. Wholesale producers are focusing on prepared food products for mass markets, while smaller farms that choose not to compete in wholesale markets have been highly innovative in creating new direct sale markets for a broad array of products. This has led to the development of a number of localized markets in organic produce, dairy products and specialty products, such as preserves. These niche markets have enabled small, specialized farms with little capital to survive as part- or full-time operations. Also important have been efforts by industry associations and the state Department of Agriculture to develop "Made in Maine" as a brand identity for high-quality products, a trademark that is particularly important in high-end retail food markets.

1. Potatoes

Management for increased yields has resulted in Maine producing nearly as many tons of potatoes as it did a decade ago, but on 20 percent less acreage. Improved varieties, aggressive disease control, better field management and irrigation have all been important. Two-year rotation on potato fields has led to experimentation with alternative crops for off years, with crops such as broccoli being cultivated successfully. Barley is also used as a rotation crop, but shipping costs forbid exports to national markets. Local markets, such as feed for cattle, are gaining importance, as grain otherwise must come from the Midwest. The extent to which grain grown in rotation with potatoes could serve livestock markets in Maine is unclear.

Potato production throughout North America has become largely mechanized, and Maine potato farmers, battered by low-cost producers from other regions, have extensively mechanized planting and harvesting over the last two decades. Irrigation systems, a mainstay of Idaho potato production due to federal water projects, have increased significantly in Maine, with irrigated acreage quadrupling in the last 15 years. Enhanced techniques for crop management and pest control are widely used now in Maine, and the Extension Service plays an important role in research and technology transfer. Advanced technologies, such as satellite imagery for crop health evaluation and integrated GPS systems for precise application of fertilizers and pesticides, were developed for large farms of 1,500 acres or more in the Midwest, but the cost and complexity make them prohibitive for smaller farms. Irrigation is used on some of Maine's larger farms and has boosted yields and eased the effects of dry years.

Maine potatoes have experienced difficult price competition in the market for table potatoes, and currently 70 percent of the state's production goes to potato processors such as McCain's, Northland and Maine Frozen Foods. This shift from table stock (fresh) potatoes to processed potatoes is the most important change in the potato industry over the last two decades. It has meant that Maine potato farmers are forced to find ways to improve product quality through improved production and storage. These improvements have allowed farmers to produce

the consistent quality and supply needed for year-round food processing operations. The University of Maine has received an MTI cluster enhancement award for research on improvements in cold storage.

2. Blueberries

The wild blueberry industry in Maine is dominated by two companies, Jasper Wyman's in Cherryfield; and Oxford Frozen Foods in Oxford, Nova Scotia, owner of both Cherryfield Foods and the Maine Wild Blueberry Company. These companies have been key sources of innovation, promoting advanced cultivation, switching to mechanical harvesters and introducing mechanical sorting technology. In the 1980s, demand for wild berries far outstripped supply, and the primary emphasis was on improving yields and getting more fields in cultivation. Some fields were leveled, and mowing started to replace burning as a method of field management. The advent of the herbicide Velpar, developed originally by Dupont to control vegetation around railroad tracks, further boosted yields, but groundwater contamination eventually forced more sparing use. In the 1990s, unpredictable rainfall spurred the introduction of irrigation systems, which are increasingly widespread. Competition for water supplies has forced some farmers to shift to well systems, particularly in salmon habitat areas, where efforts to protect endangered wild stocks reduce the amount of water that can be removed from streams.

Blueberry harvesting remains a labor-intensive operation, and mechanical harvesting was an important innovation. The Bragg harvester, produced in Canada in the last decade, is used widely on smooth fields, but hand harvesting is still used, particularly on rough terrain. Improved harvesters are being tested at the University of Maine. Another labor-intensive operation is sorting, as mechanical harvesters bring in quantities of leaves, twigs and unripe berries. Jasper Wyman's and the Maine Wild Blueberry Company were the first to bring in a laser-guided sorter developed by a Belgian firm, and other companies quickly followed suit. Flotation sorting similar to that used in the cranberry industry was introduced by Oxford Foods to meet the needs of the Japanese market and is widely used by most processors.

…and the Extension Service plays an important role in research and technology transfer."

3. Dairy Products

The number of dairy farms in Maine dropped from 600 to 400 in the last decade, with most of the decline in small farms. High labor requirements for dairy farming demand careful management and investment in new equipment to reduce labor costs and remain competitive, and small herd sizes may not generate sufficient revenue to justify the investment. Some dairy farmers use sophisticated microchip technology to track the health and milk output of each cow and pay close attention to quality. Finding locally produced feed can be particularly important for controlling costs, as at Fogler Farm in Emden, where managers purchase a barley rotation crop from local potato farmers. Importantly, Maine retains several locally

owned dairies, providing a vital local market for Maine milk. While the Northeast Dairy Compact provides a price floor for dairy farmers in the region, the economics of small dairy farms remain marginal.

"The number of dairy farms in Maine dropped from 600 to 400 in the last decade, with most of the decline in small farms."

4. Specialty Foods

Niche market development has proven particularly innovative. Whether in local farm stands, organic produce or specialty foods, Maine has seen these markets develop and become an integral part of the local economy, particularly for small farms. Niche markets are not confined to produce and fruit. Two dairy farms in the southern Maine, Smiling Hill Farm of Portland and Harris Farm of Dayton, have moved into direct retailing of their milk as a premium product. Expanding into direct sales requires farmers to be effective marketers and distributors and may require large amounts of labor for distribution and retail operations. This can be difficult for vegetable producers, as the labor is needed just as production peaks.

Value-added products allow the farmer to spread marketing and distribution efforts into periods when production is slack, thereby making more efficient use of labor. Such products require knowledge of marketing and distribution channels and demand that production meet the demands of the market. Wolfe's Neck Farm in Freeport, after experimenting with marketing its meat in premium markets, determined that success required expanded production, marketing and distribution. The farm now produces premium organic beef for a regional market and has a large farm in Aroostook County to meet production needs.

Research and Development Facilities and Organizations

An array of institutions provides agriculture with one of the state's oldest and best-organized capacities for research and technical support, along with education and technology transfer.

Like their counterparts elsewhere in the U.S., Maine farmers have benefited greatly from research and development conducted under various programs of the U.S. Department of Agriculture. Particularly important are the experiment stations established at the Land Grant universities in each state. Thus, almost all agricultural research in Maine occurs through the Maine Agriculture and Forestry Experiment Station (MAFES). MAFES includes four experimental farms located near agricultural production centers in Aroostook, Washington and Kennebec Counties and over 100 scientists from the University of Maine and experimental farms available to participate in research programs. MAFES' annual budget of $6.9 million (1999) is drawn primarily from federal funds and research grants, with matches provided by the state and individual agricultural industries. The

majority of these funds are directed toward agricultural research, with smaller amounts going to nutritional and fishery research.

Another key part of the technical support for agriculture comes through the Extension Service, also funded primarily by the federal government. The UM Cooperative Extension operates independently of MAFES and provides educational outreach and training programs targeted toward rural economies and agriculture. Extension operates nationwide with U.S. Department of Agriculture funding, coordinated through state Land Grant universities and county offices. The service operates offices in every county in Maine, providing technical assistance and outreach to agricultural enterprises and rural residents. In 1998, lack of coordination between MAFES and Extension was identified as a weakness, and both were brought under the umbrella of the new Maine Agricultural Center at UM in order to provide more coordinated research and technical services. Of the agricultural enterprises we interviewed, most availed themselves of Extension services. Several farmers mentioned the excellent technical information and bulletins available from Cornell University's School of Agriculture.

The Maine Department of Agriculture provides additional resources, including a state veterinarian. The department plays a key role in animal and plant disease control, specifically by regulating and inspecting products to prevent transmission of diseases and pests. While not a research organization, the department also works with other agencies in developing solutions to disease outbreaks.

Labor

Ensuring an adequate supply of labor remains a challenge for agricultural enterprises. Labor needs are seasonal, and local workers find an increasing number of alternative jobs that are full-time and less physically demanding. Migrant labor can also be hard to find, particularly for crops such as apples and other commodities that have reduced harvests. The AGCOM survey found that 62 percent of respondents listed the scarcity of seasonal and full-time labor as a moderate to serious threat to their operations.

"Bringing younger owners into the business will be essential for survival of the industry."

Of greater concern is the ability to retain or attract younger individuals and families to run existing farms. AGCOM's survey found the median age of farmers responding was 52 years old and that the average time of ownership was 26 years. Bringing younger owners into the business will be essential for survival of the industry. While good educational programs for agriculture and business are available, the problem is attracting new owners who have the tolerance for the demands of farm life. The Maine Organic Farmers and Gardeners Association (MOFGA) has had success in training young farmers to run organic farms.

AGRICULTURE

"Agriculture is a prime example of a sector whose principal advantage is connected to geography."

The University of Maine offers a number of degrees in agricultural sciences, including undergraduate and graduate programs in veterinary sciences, horticulture, agribusiness management and sustainable agriculture. The university's Cooperative Extension provides a broad array of educational programs targeted toward the working agricultural community, with specialized training in cultivation and pest control for individual products such as potatoes, dairy, blueberries and vegetables, as well as more general topics. Other organizations, including trade associations such as MOFGA, may provide seminars and targeted training in new techniques and applications. The Maine Rural Development Council also provides seminars and conferences on issues facing rural and agricultural communities.

Trade Associations

Agriculture in Maine is well represented by trade associations that provide different functions. The Farm Bureau provides advocacy on legislative issues. The Maine Potato Board, the Maine Milk Commission and the wild blueberry associations of Maine and North America are well organized and have been successful in promoting their industries (although the dairy industry is not as well organized as the others). Both the Potato Board and the Milk Commission are supported by levies on wholesale production of those products. The Potato Board and the Department of Agriculture have been particularly important in helping address quality issues and assist in marketing and promotion. In addition, national organizations for products such as milk, cheese, blueberries and other crops assist in promotion of these products in national markets.

The Maine Organic Farmers and Gardeners Association has been very successful in helping to organize and promote organic food production in Maine and has played an important role in providing certification for organic farms and products in the state. The organization's new fairgrounds in Unity provide a demonstration site for innovative farming techniques and serve as a center for information exchange.

Locational Advantage

Agriculture is a prime example of a sector whose principal advantage is connected to geography. Crops such as potatoes and blueberries require soil conditions found in relatively few locations; moreover, Maine has added to its geographic advantage a substantial knowledge base in the management of these crops. Other agricultural products, such as dairy, apples and eggs, have traditionally been tied to local markets, but this connection is fading as transportation and storage technologies improve. It is not clear whether research in improved management for these crops will be enough to establish a competitive advantage that extends beyond farmers' specific skills.

Lead Organizations

Agriculture is composed primarily of small organizations, and this is particularly the case in Maine. While food processors and other larger organizations play important roles, the structure of the industry does not lend itself to the kind of lead organizations that create large numbers of spinoffs or assume leadership in research and development.

Special Issue: Regulation

Regulatory issues are a recurring issue for farmers, although regulatory burdens have increased across most of Maine's industries in the last two decades. Ensuring adequate water supplies for irrigation remains a concern for crops such as blueberries, due to conflicts with salmon habitat, although the installation of well systems has addressed some of the problems. Regulatory barriers to construction of irrigation ponds are an ongoing issue for some farms.

"The structure of the industry does not lend itself to the kind of lead organizations that create large numbers of spinoffs or assume leadership in research and development."

TABLE SEVENTEEN
SUMMARY OF CLUSTER CHARACTERISTICS[13]

INNOVATION	Product	1
	Process	2
REGIONAL BUSINESS FUNCTIONS	Research	2
	Development	2
	Production	3
	Marketing	1
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	2
FUNDING	Self—Outside	1
	Grants—Capital	3
RELATIONSHIPS	Firms—Horizontal	3
	Firms—Vertical	3
	Labor	3
	R&D Facilities & Organizations	3
	Industry Organizations	3
	Lead Organizations	1
LOCATIONAL ADVANTAGE	Geography	3
	Knowledge	2
MARKET POTENTIAL	Mature—Growth Markets	1
	Diversity of Markets	3
	Local Demand	3
	Exports	3
ECONOMIC PERFORMANCE		1

[13]See the chapter *Measuring Clusters in Maine* for discussion of factors.

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"Regulatory issues are a recurring issue for farmers, although regulatory burdens have increased across most of Maine's industries in the last two decades."

MARINE TECHNOLOGY & AQUACULTURE

"Aquaculture is primarily about food production, while marine technology encompasses a much broader array of technologies involved in understanding and using the ocean."

Introduction

While marine technology and aquaculture are together identified as one of Maine's strategic industries, they are fundamentally different in important ways, including technologies used, production techniques and markets served. Although there are areas of overlap between the two in aquaculture technology, aquaculture is primarily about food production, while marine technology encompasses a much broader array of technologies involved in understanding and using the ocean. Because of these disparities, it is unlikely that a meaningful cluster can be formed between the two industries. From a cluster perspective, aquaculture may have more in common with agriculture, while marine technologies are more appropriately linked with precision manufacturing.

For purposes of discussion, however, we start with this sector as the legislature has defined it and consider the characteristics of each of the two industries.

Business Characteristics

1. Marine Technology

Marine technology may be defined to include the following product areas:

- Oceanographic research: samplers, sensors, sonar
- Remote sensing: digital imaging and mapping, sensors
- Defense, shipbuilding and marine industry applications: design, engineering, fabrication and marine equipment, as well as marine construction (piers, waterfront, breakwaters, marine terminals)
- Oil and gas exploration and development: seismic exploration, drilling, production technologies
- Pollution control: oil spills, containment, treatment
- Fisheries and aquaculture: technical applications for fishing and aquaculture such as instruments and specialized equipment for fish harvesting or aquaculture production

Maine has longstanding connections to the marine technology industry, primarily through the boatbuilding, shipbuilding and fishing industries. Boatbuilding is examined in detail as part of the composites industry and is not discussed here. The following companies were interviewed for marine technology:

TABLE EIGHTEEN
SELECTED MAINE MARINE TECHNOLOGY COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT	EMPLOYEES
Bath Iron Works	Bath	Marine technology for defense	Jim Baskerville	>7000
Flotation Technologies	Biddeford	Flotation systems, ocean research	Tim Cook	25–50
Thistle Marine	Ellsworth	Electronic logbooks	Rich Arnold	1–4

Oceanographic research has produced many sophisticated technical applications that have later been commercialized, particularly for the defense and oil exploration industries. Much of the growth in this sector is seen in industry clusters around oceanographic centers such as those at Woods Hole, Massachusetts, and La Jolla, California. With the exception of research at the University of Maine and Bigelow Laboratories and commercial products for marine instrumentation packages from Flotation Technologies of Biddeford, Maine is not well represented in these types of marine technologies.

One area in which Maine may develop advanced capabilities is in the field of *remote ocean sensing*. This is a rapidly growing field with many applications in oceanography, climatology and fisheries. The Gulf of Maine Ocean Observing System (GoMOOS) is the first of several planned regional ocean observatories that will integrate multiple sources of ocean information (satellite remote sensing, weather station data, ocean monitoring data) into a unified data source. The ultimate location for this information center is yet to be determined, but it could reside almost anywhere that has the necessary data storage and transmission networks; it need not be housed at a marine research facility. With several Maine research institutions, such as Bigelow Laboratories and the School of Marine Sciences at Orono, collaborating on this project, it could provide a central focus for development of commercial applications. Maine has a number of uses for remote sensing technology in both marine and nonmarine resource management, and this local demand for information will be important in the growth of this field.

Deep sea oil exploration continues to grow in importance as the search for new energy sources continues. The effort has driven major innovations in survey

"One area in which Maine may develop advanced capabilities is in the field of remote ocean sensing."

"Bath Iron Works represents a special case in the field of marine technologies and in the discussion of clusters in Maine."

technologies, remotely operated submersibles and deep sea marine equipment. Only one Maine company, Flotation Technologies of Biddeford, operates in this market as a provider of flotation systems for deep submersible instruments and equipment. Other segments of the marine technology industry, such as oil spill control, currently lack Maine companies. (JBF Scientific, a leader in oil cleanup skimmers, was located in Southwest Harbor but was purchased a few years ago and moved out of state.)

Marine construction of infrastructure is another important area for Maine. Companies such as Cianbro, Reed & Reed and others design and construct piers, terminals and breakwaters up and down the east coast. Some companies are actively pursuing new technologies as regulations restrict the types of materials allowed in construction in marine environments.

The *fishing industry* has potential to become a market for information technology as regulators and fishermen seek to manage species better. While the potential markets are relatively small and specialized, companies like Thistle Marine of Ellsworth market electronic equipment that helps lobstermen and fishermen monitor the fisheries in which they work.

Bath Iron Works represents a special case in the field of marine technologies and in the discussion of clusters in Maine. The company's size and the technological sophistication of the ships it builds make it one of the most important technological innovators in Maine. At the same time, BIW makes essentially one product for one customer, the United States Navy. Its products and markets are so highly specialized that its ability to function in a standard cluster relationship is limited.

However, recent changes in the Navy's expectations of BIW as a supplier, coupled with evolving approaches to defense policy, are changing the nature of BIW's business. This opens new opportunities for the largest private employer in Maine to play an important role in the state's shift to a more technologically advanced economy. These changes could touch on virtually all of the major technology sectors in Maine in addition to traditional marine technologies and thus fit comfortably in more than one of the areas discussed.

Historically, BIW has been an assembler of parts. For the Aegis destroyer (DD-51 class), which it has built for the last 15 years, BIW builds the hull, then installs propulsion, electronics and weapons systems manufactured by others. The hull itself actually comprises only one third of the cost of the ship. Upon completion of the assembly, BIW turns the ship over to the Navy, which traditionally has had responsibility for the ship from that point forward. However, the Navy has changed to "life cycle" contracting, under which BIW not only builds the ship but also undertakes to maintain and upgrade it over its expected 20-to-25-year life.

The Navy now expects BIW to assume a much larger role in keeping the ships technologically advanced.

At the same time, the Navy is looking ahead to the generation of surface warships that will follow the DD-51 class. For the past several years, BIW has been researching what was designated as the DD-21 ("Destroyer for the 21st Century") class, which was to exceed the DD-51 class in speed, stealth and weaponry with only one third the crew size. Recently, the Defense Department announced that it will not move to build the DD-21 but instead revise its request for proposals for an entirely new class, the DD(X). Moreover, the department wishes to use much of the research to design the DD(X) as the basis for two additional classes of ships, a new class of cruisers and the Littoral Combat Ship, designed for near-shore missions. BIW and its competitor, Litton Industries of Mississippi, will jointly, but competitively, research the new ships, as they have been doing with the DD-21. While Ingalls Shipbuilding has been designated the lead yard with principal responsibility for much of the technology used in the ships, BIW is expected to play a continuing role in technology development.

The result of these changes is that Bath Iron Works now has a research budget in excess of $100 million a year, the vast majority of which goes to highly specialized firms outside Maine. BIW itself is becoming a major research organization in several fields. These include information technology (wearable computers and automated ship diagrams), power conservation (electrostatic ventilation) and generation (fuel cells), waste disposal (microwave sewage systems) and others. BIW is also doing extensive research in the use of composites in ship construction as the new ships will likely be constructed primarily of composites. The pace and volume of research at BIW is expected to accelerate as the new ship programs get under way.

"BIW's expanded search for technologies to meet the Navy's needs could have importance beyond its role as a source of local demand."

BIW's expanded search for technologies to meet the Navy's needs could have importance beyond its role as a source of local demand. The Defense Department is interested in "dual use" technologies; that is, technologies with both military and civilian applications. General Dynamics, BIW's parent company, is primarily focused on meeting the needs of the military and will likely limit any role in the civilian market use of technologies. Firms supplying technologies to BIW may thus be able to capitalize on civilian market potential to the extent it exists. The result could stimulate not only local demand, but export demand as well.

Because these changes in BIW's role have been relatively recent, the full impact on Maine's R&D-related activities has had little time to develop. But the scale and scope of BIW's research activities and needs may create a significant node of local demand for a number of Maine's evolving clusters. That is, BIW will not fit into any cluster, but may play an important role in several different clusters.

"The Maine Aquaculture Innovation Center in 1992 signaled the importance of this industry as a potential growth center and source of employment."

2. Aquaculture

Marine aquaculture has been widely viewed as a practical way to use Maine's extensive coastline and valuable marine resources; it also provides a new industry for parts of coastal Maine hit hard by declines in traditional capture fisheries. Publicly run hatcheries for game fish have a long history in Maine, but the development of a commercial aquaculture industry is only about 30 years old. It began with shellfish culture in the midcoast region in the 1970s. In the 1980s and 1990s, a substantial salmon culture industry developed, primarily in eastern Maine. The salmon industry uses both marine and freshwater resources for cultivation of the anadromous Atlantic salmon.

The establishment of the Maine Aquaculture Innovation Center in 1992 signaled the importance of this industry as a potential growth center and source of employment. Innovation has been a driving force in the industry in the last 20 years, as entrepreneurs continually experiment with new species, techniques and markets.

The Maine aquaculture industry is composed of a wide range of firms varying in size and growth objectives. The largest firms in the salmon industry are now subsidiaries of multinational aquaculture firms. These firms have the scale and market size to seek aggressively to increase market share through cost reductions and new product development. There are also Maine-owned companies such as R. J. Peacock that have worked hard to find ways of securing market share through technology. At the same time, many small firms, particularly in the shellfish industry, are not particularly growth oriented. These, like most firms in the capture fisheries, play an essential part in the industry. Individually, they may not grow rapidly, but the future of aquaculture depends in part on their success and proliferation.

To better understand the current state of the aquaculture industry in Maine, we conducted interviews with 14 innovative firms and organizations around the state. Several firms that specialized in aquaculture-related research in biotechnology had been contacted previously for research on marine biotechnology (Colgan and Baker, 2000). Our interviews focused on the current status of the industry for each species and the constraints facing both the company and the industry. Information on individual species and the industry was provided by the Department of Marine Resources (DMR, 2001). The following companies and individuals were interviewed:

TABLE NINETEEN
SELECTED MAINE AQUACULTURE COMPANIES

COMPANY	LOCATION	PROFILE	CONTACT	EMPLOYEES
Beals Island Hatchery	Beals Island	New species culture	Brian Beal	NA
Ducktrap/Atlantic Salmon	Belfast	Salmon, value-added products	Des Fitzgerald	100–250
Great Eastern Mussel Farms	Tenants Harbor	Mussels	Chip Davison	25–50
Maine Aquaculture Assoc.	Hallowell	Trade association	Sebastian Belle	NA
Maine Aquaculture Innovation Center	Orono	Education, tech transfer	Mike Hastings	NA
Mook Sea Farms	Bristol	Spat culture, oysters	Bill Mook	1–4
R. J. Peacock Canning	Lubec	Seafood processing	Bob Peacock	10–24
Portland Fish Exchange	Portland	Market & finance technology	Sue Inches, DMR	NA
Spinney Creek	Eliot	Aquaculture, depuration	Lori Howell	10–24
University of Maine	Orono	Franklin aquaculture facility	Jake Ward	NA
Previously Contacted				
Aquabio Products (Maricul)	Portland	Marine biotech research	Bill Harris	4–10
Coastside Bio Research	Stonington	Marine biotech research	Pete Collins	1–4
Micro Technologies, Inc.	Richmond	Marine biotech, fish vaccines	Bill Kelleher	4–10
Sea Run Holdings	Arundel	Marine biotech research	Evelyn Sawyer	1–4

Aquaculture is a growing industry worldwide, and aquaculture products now comprise a significant portion of the fish products sold around the globe. Competing in global markets puts a heavy emphasis on production capacity, and multinational aquaculture companies are organized to produce large quantities of high-quality product for fresh and frozen fish markets around the world. Aquaculture is evolving rapidly as an industry to meet these needs. Numerous countries have developed extensive aquaculture industries in the last decade to produce both freshwater and saltwater species. Gross revenues for aquaculture worldwide were $46.3 billion in 1996 (UNFAO, 1998); U.S. production was valued at $978 million in 1998, according to the USDA Census of Aquaculture. The industry, particularly in salmon, is highly competitive. Maine produces 18 percent of the salmon consumed in the Northeast, but Maine's production is less than 1 percent of a global market dominated by Chile, Norway, Iceland, and Canada.

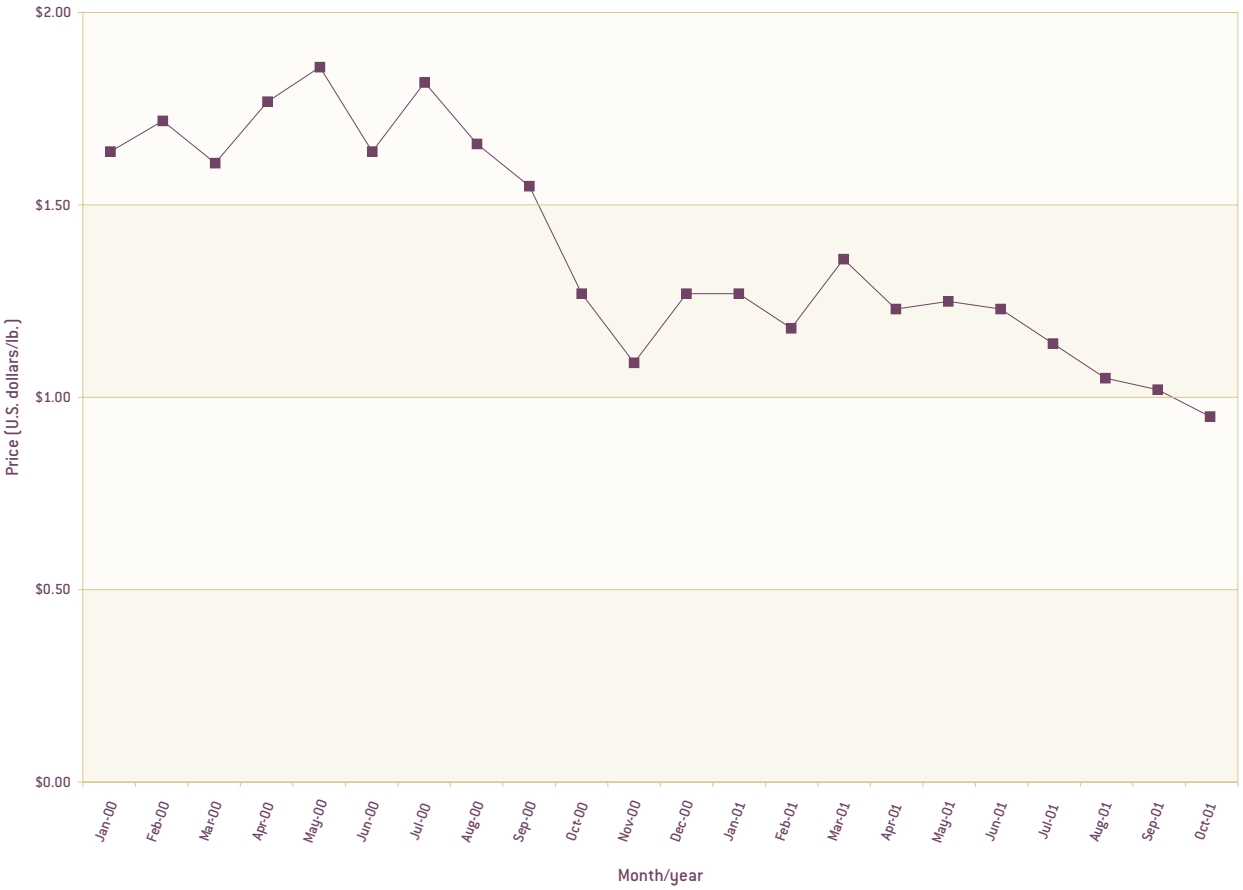
"Aquaculture products now comprise a significant portion of the fish products sold around the globe."

Maine salmon farms produced $78.9 million in landed salmon in 2000, and value-added processing increased this to an estimated $98.9 million. Value-added processing increased significantly from 0 percent of landed fish in 1996 to 40 percent in 1999 (DMR, 2001). Maine has an advantage over some other locations in that well-developed fish processing and transportation businesses for the groundfish industry have been able to adapt readily to salmon processing. In 2000, following

rapid growth in the 1990s, salmon farming employed 1,200 and was the second largest employer in Washington County (DMR, 2001). Maine aquaculture firms encompass all aspects of business operations from research to production and marketing, although many small firms engage primarily in production.

U.S. imports of salmon rose 24 percent in 1999 to $629 million, and prices in 2000 reached some of the highest levels seen in years. Prices have tumbled 30 percent to 50 percent from peaks seen last year as prolific production from several countries created an oversupply, favoring companies that have low costs of production. A wave of buyouts and consolidation is occurring throughout the industry. The largest companies, such as Fjord Seafood, owner of Atlantic Salmon of Maine and Ducktrap River Fish Farms, now own production facilities in producing

Salmon Prices, 2000–2001[14]



[14]Norway Salmon, 3–4 kg, packed, gutted, ex plant-data from Intrafish (2001).

countries such as Norway and Chile, enabling the companies to weather supply interruptions and currency fluctuations by meeting demand from multiple sources. Heavy investment in production and processing equipment in Norway has reduced high labor costs and kept production competitive. Chilean producers, accused of dumping in 1998, have seen extra tariffs imposed but remain competitive on price.

Against this backdrop of consolidation and falling prices, Maine's salmon farms face other problems. The invasion of Cobscook Bay by infectious salmon anemia (ISA) has resulted in a quarantine and destruction of almost all of the salmon stocks there. Canada and Norway have been battling this disease for years, and its appearance in Maine was not unexpected. The response has been to destroy the fish stocks in the affected area, remove and disinfect the pens and allow the lease site to lie fallow for a least a year to let the virus die out. A similar effort in New Brunswick required upwards of $50 million four years ago (*Bangor Daily News*, 2001). The likelihood of the disease reappearing is high unless a vaccine can be developed.

Maine and its congressional delegation have been able to secure a promise of $16.4 million in USDA funds to help battle the disease. This includes bringing in expertise in disease management and vaccine development, as well as financial assistance for aquaculture companies devastated by the outbreak. While restricting boat movement and monitoring water and fish closely can help, a good long-term strategy would be to switch to a different species that is not vulnerable to the disease. Yet marketable alternative species, such as halibut or haddock, are not yet ready for large-scale commercial production. So the industry must concentrate on disease eradication for salmon and rebuilding of production capacity. Federal assistance in this area is crucial, and has potential in the near term to stabilize the industry and reduce immediate financial hardship in the industry.

"Multinational aquaculture companies are often vertically integrated and include feed companies, fish product processors and distribution networks."

As the industry evolves, there is continual pressure for innovations that reduce cost and increase productivity. This has led to a wave of mergers and acquisitions that seek to capture economies of scale. Multinational aquaculture companies are often vertically integrated and include feed companies, fish product processors and distribution networks. The pressure for innovation is also spurring biotechnology research by Maine companies such as Aquabio Products, now known as Marical (growth-regulation mechanisms), and Micro Technologies, Inc., in Richmond (fish vaccines). Maine also has a number of companies and institutions that continually experiment in culturing new or existing species in order to enter new markets.

However, no other saltwater finfish species have yet been farmed at the scale used for salmon. Research efforts are focusing on species with high commercial value,

"Research efforts are focusing on species with high commercial value, such as halibut or cod, but large-scale commercial production in Maine is years away."

such as halibut or cod, but large-scale commercial production in Maine is years away. Iceland, Norway, Newfoundland and the Maritime Provinces have funneled several million dollars into research programs on halibut and cod in the last decade, and Nova Scotia has recently established facilities for halibut culture and grow-out with the Icelandic company Fiskey, a leader in halibut aquaculture. The first harvest of marketable halibut is expected next year, but large-scale production is still several years away as hatchery capacity must be developed.

The University of Maine's purchase and upgrade of a commercial-scale fish hatchery in Franklin has provided an excellent facility for experimenting with cultivation of new species, and $1.2 million in grants from EDA have been obtained for further development of the facility as a center for research and commercialization. The university's Center for Collaborative Aquaculture Research (CCAR) has been designated as one of three Advanced Technology Development Centers for aquaculture and is being designed to provide affordable research and development facilities and expertise for entrepreneurs looking to commercialize species that have market potential. This could include previously overfished species such as halibut, haddock or cod or specialty species. Unlike basic research facilities, the Franklin center is being designed to facilitate partnerships with entrepreneurs and industry interested in commercialization and provides reduced costs for equipment and facilities that would otherwise be unaffordable for startup companies. It offers land-based recirculation technology and has the permits needed to initiate development projects quickly. There are two other sites associated with the business incubator at the University of Maine: the Darling Center in Walpole and the Washington County Technical College Marine Trades Center in Eastport.

The most successful companies have produced innovations in processing and marketing. The ability of aquaculture to produce a steady supply of highly consistent product is a major advantage in the food processing and food service markets. Some companies, such as TruFresh in Lubec, are using innovative processing operations specifically to meet the needs of the food service market. Other processing operations such as Ducktrap Farms have succeeded by examining demand in these markets and developing innovative products and good service for the restaurant market, which turns out to be where an increasingly high proportion of seafood is actually consumed.

Processing operations that have shifted from handling wild species often look for opportunities to automate processing and reduce high levels of hand labor. Such investments require both a steady supply of product and large investments of capital. Processing for the fishing industry has often been hampered by erratic supplies of groundfish or shellfish, and many existing operations use old equipment and inefficient operations. Salmon processing operations for the aquaculture industry have invested in modern facilities, but are increasingly using imported salmon to meet market demand.

The growth of the processing industry has been mirrored by a similar growth in processing in Maine agricultural commodities such as potatoes and blueberries. This focus on meeting demand for processed or prepared foods for both consumer and food service markets suggests that there are a number of common interests in Maine's aquaculture and agriculture industries. Duck Trap Farms has been a leader in developing a range of salmon and other fish products, and other salmon firms such as Atlantic Salmon of Maine (both companies are owned by a major Norwegian firm) are moving into such product lines as vacuum-infused marinated salmon products in order to gain footholds in higher value markets. As the discussion of agriculture (see Chapter 10) indicates, the development of higher value processed products is becoming a major focus of Maine's food-producing industries.

3. Shellfish Aquaculture

Shellfish aquaculture in Maine is significantly different from finfish aquaculture. Finfish aquaculture is heavily organized around maximizing production for global markets, while shellfish tends to have more limited production and be focused on local and regional markets. Shellfish is sold fresh, rather than frozen, as is often the case with salmon. Thus, transportation and shelf life are key considerations, holding the market generally to one- and two-day travel times. Most shellfish operations are also smaller in scale, many are family or part-time operations, and capital outlays for equipment are often much smaller than for finfish. Value-added products are also very important in these markets.

"The development of higher value processed products is becoming a major focus of Maine's food-producing industries."

Marine shellfish that have been cultivated for production include mussels, which have developed into a $7 million industry using both wild and cultured product, and oysters, which is a $1 million to $2 million industry. Other species have been cultivated on an experimental basis, including hard- and soft-shelled clams, sea urchins and scallops (DMR, 2001). Some lobstermen suggest that lobstering has become a form of aquaculture, as sustained heavy baiting and setting of traps, combined with selective harvesting, may have created an adapted fishery. Some lobsters may be caught as many as seven times before reaching legal size.

Maine has been an innovator in mussel aquaculture since the 1970s, introducing both wild and cultivated product into the market. While the abundance of wild stocks has created low-cost competition for cultured mussels, consumers show increasing preference for the cultured product. Mussel production in Maine has started to shift to raft systems already heavily used in Canada and Europe, as the quality of product is high and shell weight lower. However, subsidized mussel operations in Prince Edward Island undercut local mussel production, and difficulties with local fishing culture and the aquaculture lease backlog at DMR pose additional challenges. Despite this, the mussel harvest, spearheaded by Great Eastern Mussel Farms, had an estimated $7.3 million in landings of both wild and cultured product in 1999.

MARINE TECHNOLOGY & AQUACULTURE

"Maine has been an innovator in mussel aquaculture since the 1970s, introducing both wild and cultivated product into the market."

The market for cultivated oysters from Maine is a small but growing niche, with sales estimated in the $1 million to $2 million range. Currently, most operations are in the Damariscotta River and serve niche markets at premium restaurants throughout the Northeast. This species, while commercially attractive, has higher production costs and lower productivity than other shellfish and faces competition from products harvested in southern and mid-Atlantic states. Good aquaculture sites are highly species specific, with optimum parameters for growth, wintering and access found at a limited number of locations. Large-scale commercial production is years away due to limitations on lease sites and the need to control diseases that plague oyster production.

Scallops remain an experimental species in this state, although one that has recently attracted interest from both scallopers and the Department of Marine Resources. Competition from a well-established wild harvest in coastal areas and the Georges Bank may be difficult, especially as areas previously closed due to overharvesting have been reopened. The Japanese have invested tens of millions of dollars in scallop aquaculture and have well-developed production facilities and techniques. Whether scallop aquaculture techniques can be adapted cost-effectively to Maine is unknown.

Soft-shell clams are in high demand, particularly in summer, and commercial harvesting produced $9.5 million in landings in 2000. Heavy harvesting, predation and other factors affecting wild populations resulted in the 1999 harvest being half the size of the harvest a decade ago. Prices have increased significantly in the last decade. Development of an aquaculture industry is stymied by the unwillingness of local communities to lease a public resource (the intertidal zone) to private companies, even though with proper management productivity can be much higher than in wild populations. Production in subtidal areas remains a possibility, as it avoids local jurisdictional issues and is regulated by DMR.

The sea urchin industry, which exports to Japan, has seen wild harvests drop from a high of 30 to 40 million pounds in the early 1990s to 12.9 million pounds in 2000, largely due to overharvesting. The $17.7 million value of the harvest (2000) makes it the fourth most valuable species harvested in Maine, behind lobster, salmon and groundfish. The ecology of the urchin remains poorly understood, and heavy harvesting has produced changes in the natural balance of harvesting areas, leading to shifts in dominant species and a steep decline in urchin abundance. Experimental tank cultivation is under way in Lubec and could be a source for reseeding depleted areas, but whether aquaculture of urchins could be undertaken for commercial production is unknown. A large source of research dollars derived from urchin licenses remains largely untapped.

Support for research and development for aquaculture is critical to the future of the industry, but the role of technologies in the more traditional capture fisheries should not be ignored. For example, applications of information technologies may assume an important role in the management of many of these fisheries, particularly groundfish. Biotechnology applications may be used to monitor food processing for health (such as several IDEXX products do). As policies and programs have developed so far, these fisheries have not been emphasized. However, there may be important cluster and cross-cluster connections in traditional fisheries to which those involved in R&D support and economic development should be alert.

Subclusters

The two major types of aquaculture, finfish (salmon) and shellfish, comprise the major subclusters in this area. As noted, these may be more appropriately considered subclusters of the food cluster in future assessments. Shared interests with Maine's other food industries, including food processing, transportation, marketing and distribution, suggest that these subclusters can best be grouped this way.

Finance

Startup companies face considerable difficulty in obtaining financing, as the success rate for aquaculture ventures, particularly early ventures, has not been good. Banks generally will only consider financing established companies with solid revenue streams, so the hurdles for startup companies are considerable. Given that several years are required before marketable products are available, only established companies or part-time operations with outside income can start new ventures. Startup companies also face competitive pressures with existing firms that inhibit technology transfer to new companies. Grants from MAIC and more recently MTI play an important role in developing new technologies or applications.

"Aquaculture in Maine... has a research infrastructure that exceeds several other, larger industries in the state."

Research and Development Facilities and Organizations

Aquaculture in Maine has a variety of resources and expertise available for research and development and has a research infrastructure that exceeds several other, larger industries in the state. The University of Maine has the newly established Advanced Technology Centers at Walpole, Franklin and Eastport, all targeted toward the industry (shellfish or finfish) that predominates in each locality. These centers are organized with the goal of spurring innovation and entrepreneurial activity, not just research. The University of Maine School of

MARINE TECHNOLOGY & AQUACULTURE

"The small size of Maine's aquaculture industry often means that capacity for product development is limited, particularly for small companies in niche markets."

Marine Science has several faculty members with expertise in fish biology and aquaculture, and fish disease and pathology services are available through the Extension Service. The Department of Marine Resources has several research programs in place for key species. The Beals Island Shellfish Hatchery and the Darling Center in Walpole have strengths in shellfish aquaculture.

Recently, the USDA Aquaculture Research Service (ARS) announced the development of a Cold Water Marine Research Center to be located in Maine. To date, the department has received over $5 million toward the design, engineering and Phase I construction of applied aquaculture research facilities, which will be co-located at the University of Maine in Orono and the Center for Collaborative Aquaculture Research (CCAR) in Franklin. ARS scientists will work in partnership with the University of Maine and industry to solve problems facing the marine aquaculture industry.

While organizations and infrastructure are fairly good, funding for research in the industry has been poor. MAIC struggled for a decade with a yearly budget of $200,000 for both research and operations, an amount dwarfed by national programs in Canada, Norway and other European countries that are direct competitors. Recently, the University of Maine has been successful in capturing research dollars for aquaculture, but research has not received sufficient funding to meet identified industry needs in recent years.

Much of the research and development in aquaculture is highly practical in nature, and Maine clearly benefits from its skilled cadre of aquaculture specialists—more than 20 years in the making—who have both technical skills and an understanding of the requirements for successful commercial ventures. Valuable knowledge also resides in the state's aquaculture biotechnology companies. For example, expertise in fish vaccine development and commercialization is available from Micro Technologies, Inc., in Richmond.

While aquaculture is organized for research and development on the production side, it is less well organized for product processing. Efficiency in processing means that levels of automation must increase, but research on food composition and nutritional characteristics is available from the UM Food Science and Nutrition Department. With nine faculty, 30 graduate students and laboratories for analysis of food composition and characteristics, the department can provide assistance on a range of research questions. Expertise in food processing, packaging and marketing tends to be more industry based, depending on the species and products handled. The small size of Maine's aquaculture industry often means that capacity for product development is limited, particularly for small companies in niche markets.

Trade Associations

The Maine Aquaculture Association (MAA) plays an important role for the industry, advocating for interests of aquaculture companies throughout the state. Recently, MAA was a party in an agreement between salmon farmers and environmentalists on controls for escape of farmed salmon. The Maine Aquaculture Innovation Center, founded in 1988, has been an important source of education, technology transfer and support for new aquaculture ventures. The development of the Northeastern Aquaculture Conference (NAC) has been well received, and the organization plays an important role in fostering the industry. Both MAIC and NAC also serve the industry in government relations and research. Trade associations play a limited role in marketing, particularly for shellfish producers.

Labor

The University of Maine has a well-regarded four-year program in aquaculture, and courses are available at the technical colleges as well. Advanced graduate programs in fisheries science are also available. The Darling Center in Walpole has been, with some ups and downs, a center for teaching and research in aquaculture since the 1970s. There is a committed pool of experienced aquaculturists in the region who have trained or conducted research there in the past. However, with the constraints on growth of the industry in Maine, particularly the difficulty in obtaining lease sites, opportunities for new graduates and entrepreneurs may be much more limited than in the past.

"Good aquaculture sites are highly species specific, with optimum parameters for growth, wintering and access found at a limited number of locations."

Lead Organizations

The Maine aquaculture industry largely grew from small companies into larger ones, and none of the larger organizations have played a significant role to date in spinning off additional firms.

Locational Advantage

Aquaculture clearly is grounded in the geographic advantage of Maine's coast. For salmon aquaculture, there are only a few places in the United States with the combination of fresh and saltwater and protected embayments where salmon aquaculture is possible. These are primarily in Maine and Washington State. Shellfish aquaculture is more widespread but also limited to certain coastal areas. Maine's aquaculture industry has clearly developed detailed knowledge to take advantage of the geographic characteristics available, but development of this knowledge basis is in its infancy. Problems such as infectious salmon anemia and

other potential diseases indicate that intensive sustainable utilization of the coast for aquaculture, particularly for salmon, is still in the future. Thus, continued research and development in aquaculture are essential to making possiblesustaineduseof those geographically favored areas of the coast.

Special Issue: Regulation

The picture for salmon is further muddied by the listing of Atlantic salmon as an endangered species. This has raised the threat of new federal regulatory controls, which further increases uncertainty in the industry. This uncertainty has raised risk to the point that salmon aquaculture in Maine may no longer be economically viable, as multinational companies will look to other production locations that have lower risk and more predictable return on investment. The effects of this for Washington County could be devastating, as much of its fishing and canning industry in the region has, in the last two decades, been replaced by salmon aquaculture.

"Cumbersome leasing procedures and public opposition can discourage even seasoned aquaculture entrepreneurs."

A final issue is leasing. Aquaculture sites must be leased from the state, but there is a significant backlog in lease application approvals, and vigorous local opposition often accompanies applications. Heavy use of waterfront areas in southern Maine has relegated aquaculture to a few areas where aquaculture was established years before, such as the Damariscotta River. Midcoast and downeast Maine are also seeing landowner opposition to both shellfish and finfish operations, and opposition by local environmental groups is a problem. Cumbersome leasing procedures and public opposition can discourage even seasoned aquaculture entrepreneurs, and the leasing procedures and backlog increase risks and uncertainty for commercial operations. The leasing process is under review by the Department of Marine Resources with a view toward reducing backlogs and streamlining permitting. On the freshwater side, the Department of Inland Fisheries and Wildlife plays occasionally conflicting roles for freshwater aquaculture, acting as both regulator and operator of freshwater hatcheries.

TABLE TWENTY
SUMMARY OF CLUSTER CHARACTERISTICS[15]

INNOVATION	Product	2
	Process	2
REGIONAL BUSINESS FUNCTIONS	Research	2
	Development	2
	Production	3
	Marketing	1
ENTREPRENEURSHIP OBJECTIVES	Lifestyle—Growth	2
FUNDING	Self—Outside	2
	Grants—Capital	2
RELATIONSHIPS	Firms—Horizontal	1
	Firms—Vertical	1
	Labor	2
	R&D Facilities & Organizations	2
	Industry Organizations	2
	Lead Organizations	2
LOCATIONAL ADVANTAGE	Geography	2
	Knowledge	2
MARKET POTENTIAL	Mature—Growth Markets	1
	Diversity of Markets	1
	Local Demand	1
	Exports	3
ECONOMIC PERFORMANCE		2

"Recently, the University of Maine has been successful in capturing research dollars for aquaculture, but research has not received sufficient funding to meet identified industry needs in recent years."

[15]See the chapter *Measuring Clusters in Maine* for discussion of factors.

ENVIRONMENTAL TECHNOLOGIES

Introduction

The environmental technology sector in Maine has been viewed as a potentially important growth area that brings with it potentially valuable contributions toward a more sustainable environment and economy. Pollution prevention and innovative technologies have received considerable attention and support from state and federal agencies. Environmental technologies may be divided into service providers, equipment providers and environmental resources. The first two categories are concerned with the control of pollution; environmental resources include water supply utilities and "green" power generators.

"Pollution prevention and innovative technologies have received considerable attention and support from state and federal agencies."

Environmental Services. Includes testing of soil, water and air; collection and treatment of wastewater; collection and disposal of solid and hazardous wastes; cleanup of contaminated sites; engineering; design; and permitting.

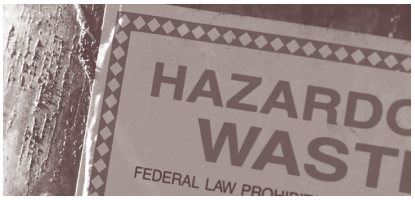
Environmental services is the largest field in Maine and includes several large solid waste disposal companies, a few hazardous waste cleanup firms, a handful of testing labs and a wide array of environmental consulting firms. Some of these businesses, such as Waste Management Inc., and Casella in solid waste disposal, collectively employ over 1,000 people spread across many communities. Environmental services also includes environmental consulting, one of the larger business areas. Maine is estimated to have close to 100 environmental engineering consulting firms around the state employing up to 1,500 people.

Environmental Equipment Providers. Include equipment for collection, treatment and disposal of all kinds of wastes, collection and treatment of water supplies and air pollution control.

This field has a relatively small number of companies in Maine and includes companies such as Kady International, Lapointe Industries and Vortechnics. These companies are often both engineers and manufacturers of equipment, so in serving their clients they work closely with engineering consulting firms or may incorporate their services. The markets tend to be varied, with clients from many industries, but the common goal is pollution control and reduction. Total employment in the field is estimated to be considerably less than in environmental services.

Environmental Resources Management. Includes water utilities; recycling facilities; and "green" power producers, including hydropower, wind and solar.

This field is considerably larger than that of equipment providers. Maine has a number of water utilities, both public and private. Recycling facilities are often included here, although they may be parts of solid waste enterprises or facilities.



"Green" power providers in the state include small hydroelectric dams, as well as wind power facilities, waste-to-energy plants and biomass power facilities. Employment is difficult to estimate due to the diversity of enterprises.

To better understand the current state of the industry in Maine, we conducted interviews with senior management at 17 firms and organizations around the state. The firms that were selected were among the most innovative in their sectors. Interviews focused on the current status of the industry and the importance of innovation both for the company and for the industry in Maine. The following companies and individuals were interviewed:

TABLE TWENTY-ONE
SELECTED MAINE ENVIRONMENTAL TECHNOLOGIES COMPANIES

COMPANY NAME	LOCATION	PROFILE	CONTACT	EMPLOYEES
Boralex	Montreal	Five Maine biomass plants	Jean Roy	100–500
Brims Ness Corp.	S. Portland	Monitors for contaminants	John Merrill	1–4
Casella Waste Systems	Saco	Solid waste and recycling	Jim Hiltner	>500
Center for Env. Enterprise	S. Portland	Incubator for enviro. startups	Phil Helgerson	1–4
Consumers Water Co.	Rockport	Water utility	Judy Kelly	25–49
EER	Portland	Consulting engineers	Mike Crawford	1–4
Endless Energy	New Gloucester	Wind power systems	Harley Lee	1–4
Greenville Steam	Bangor	Wood-fired power generation	Ray Kusche	10–24
Hydro-Photon	Blue Hill	Pocket-size water sterilizers	Miles Maiden	1–4
Intelligent Controls	Saco	Fuel tank leak detection	Alan Lukas	50–99
Kady International	Scarborough	High-speed dispersion mills	Kent Peterson	24–49
Septitech	Gray	Septic systems	Scott Samuelson	10–24
SRD	Orono	Sensor research development	Carl Freeman	10–24
UF Strainrite	Lewiston	Filter systems	Alan Lapoint	50–99
Vortechnics	Portland	Stormwater treatment	Francis Tighe	24–49
Woodard and Curran	Portland	Consulting engineers	Al Curran	100–500
Woods End Research	Mt. Vernon	Compost testing	Will Brinton	5–9

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"Continuing opportunities for market growth lie in overseas markets, particularly in developing countries."

Business Characteristics

1. Environmental Services

The U.S. environmental technologies (ET) industries produced $189.8 billion in revenues in 1998, supporting 1.37 million jobs. Revenues have increased 42 percent since 1993, or an average of 8.4 percent per year (EBJ, 2001). While hazardous waste cleanup and "green" technologies receive much public attention, in fact 70 percent of the industry revenues are in solid waste, recycling and water/wastewater treatment. The U.S. is the single largest ET market in the world, but some segments such as engineering and consulting are mature and highly competitive. Over the last ten years, numerous large companies, including Asea Brown Boveri, GE and others, have entered environmental engineering segments of the business, but have not been successful. Venture capital is scarce to nonexistent in some industry segments.

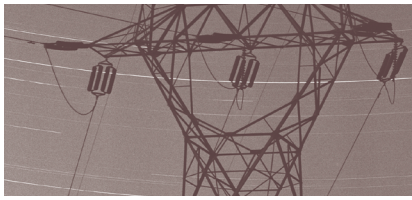
Continuing opportunities for market growth lie in overseas markets, particularly in developing countries in which infrastructure needs are high and markets for ET undeveloped. The global ET market is expected to grow from $484 billion currently to $554 billion by 2005 (EBJ, 2001).

Maine has seen slow but steady growth over the last decade in service areas such as solid waste, recycling and wastewater treatment. Maine's slow rates of population growth and modest infrastructure have minimized demand for these services. Mature solid waste markets dominated by national firms provided opportunities for smaller companies with innovative management, such as Casella Waste Systems, to acquire large portions of the solid waste business in Maine. Casella has also moved successfully into areas, such as composting industrial wastes, that were largely undeveloped in the state.

The Maine Department of Environmental Protection (DEP) provides a regulatory framework in which solid waste companies must operate, and municipalities control many local markets through service contracts. Both DEP and the State Planning Office play key roles in long-range planning for disposal capacity, a role formerly played by the Waste Management Authority. Industry leaders are also heavily engaged in long-term capacity issues, and with time frames of ten to 20 years for development of landfill capacity, the industry must look far ahead. Recycling is heavily integrated into the solid waste market but, as discussed later, operates in different markets.

Environmental Testing. Maine's environmental testing field has seen small biotechnology companies develop innovative new test kits for environmental contaminants. Companies such as Evirologix, Cape Technologies and Beacon Analytical, building on expertise developed in immunodiagnostics, developed quick field tests

for pesticides, dioxins and genetically engineered corn. Others companies such as Woods End Research, developed kits for compost testing that have grown popular in national and international markets.



Environmental Engineering. Environmental engineering consulting firms make up a significant portion of the employment base in the environmental services industry, and some local firms have grown even as larger national firms stumbled. A series of mergers and acquisitions in the early 1990s saw Maine's largest firm, E. C Jordan, taken over by the Swedish-German firm Asea Brown Boveri (ABB), then shed employees in a national wave of contractions, mergers and consolidations. Numerous large companies that entered the business during this period experienced significant losses as excess capacity was squeezed out of the industry.

As with expansion-and-contraction cycles in other industries, the consolidation and subsequent shrinkage of large companies such as ABB produced numerous small local startup firms that subsequently grew significantly. Many engineering professionals drawn to Maine during boom years in the late 1980s remained and formed a strong pool of talent. Firms based in southern Maine found access to southern New England markets, and the lower costs for salaries and housing in Maine provided an important advantage. Firms such as Woodard and Curran grew rapidly from 100 to 400 employees, expanding into markets throughout the East. Expansion into international markets proved challenging, requiring deep financial resources and management more typical of large national firms. The most successful companies developed strong competencies in local markets and were able to expand these niches outside of Maine.

There are considerable differences between companies in different environmental services fields, such as environmental testing, engineering consulting and solid waste disposal. In addition to serving different markets, companies differ in business practices, organization and services. Testing and engineering are heavily knowledge based, while solid waste disposal is technology and land based. Needs for labor differ greatly, with higher education required in engineering disciplines than in solid waste.

"Testing and engineering are heavily knowledge based, while solid waste disposal is technology and land based."

2. Environmental Equipment

This sector is much smaller than environmental services. Some small companies such as Vortechnics, H.I.L. Technologies and Septitech have developed new, local markets in stormwater control and small wastewater treatment systems, but development of much larger markets outside Maine is a key to growth. While these companies manufacture products for the market, they are also environmental engineering companies and have strong ties to the engineering industry in Maine. Other companies such as Lapoint Industries are primarily manufacturers and have developed a national market in filtration and environmental cleanup products.

"Wind power and solar power are early in their development with a high degree of innovation."

Maine also has a few entrepreneurial ventures in sensor development related to the environment. A program in sensor technology at the University of Maine has served as a nucleus for the development of two companies, but to date neither has perfected the technology or produced any commercial products. A third company, located at the Center for Environmental Enterprise incubator in South Portland, has begun precommercial development of its sensor technology. The success of these ventures has, to a great degree, hinged on the large number of potential applications for sensors in industrial and military applications and the availability of grant funding through NSF, SBIR, DOE, MTI and other sources.

3. Environmental Resource Management

This is a diverse field with a wide range of products, from energy and water to recycling. Provision of power and water creates similarities among companies in that they provide needed public services and work through the utility infrastructure under utility contracts. However, the different sources for power (hydro, wind, wood) used by the companies lead to different resource issues. These companies are also consumers of the services of engineering firms.

"Green" Power Production. While small power producers are included in this sector, the markets they serve ally them closely with larger power producers that use conventional fuels. Unlike fossil fuel power plants, wind power and hydropower face unique resource constraints, such as wind conditions, reservoir management and fishery impacts, that differentiate them from conventional power producers. While hydropower is stable and relies on older technology, wind power and solar power are early in their development with a high degree of innovation. Wind power, which has had several false starts in Maine, has become a major means of generating power in other parts of the country. FPL, which owns generating stations formerly owned by Central Maine Power (CMP), has moved aggressively in this field. FPL is constructing large wind farms in Texas and the Midwest with generating capacities of 200 megawatts or more per site. This technology could have broad applications in Maine, and small companies such as Endless Energy are developing wind power projects here and in Vermont.

Biomass power generation, another important energy source in Maine, faces significant obstacles as fuel prices rise and contract electricity prices drop. This sector, an important part of the forest products industry, is covered in more detail in Forest Products.

Waste-to-energy facilities represent perhaps the most successful "green" power ventures in Maine. These facilities are located in or near urban centers and were built mostly in the late 1980s, when solid waste disposal costs were rising and

landfill capacity appeared limited. As with biomass plants, these facilities provide an important function in disposing of waste material while simultaneously producing power. No new biomass or waste-to-energy facilities are planned.

4. Recycling

The recycling industry is integrated into solid waste services for collection of material but operates in markets for recyclables that are fundamentally different from solid waste. Recycling collection is strongly driven by markets for recyclables, which are generally regional or national in scope and are limited by end uses for recycled materials and the location and distribution of processing facilities. Municipalities typically define the extent of local collection activities, generally without regard to marketability of recycled materials. This aspect of the market forces subsidization of collection, sorting and processing of materials, a cost usually justified by the avoided cost of landfills. Limited markets, transportation costs and high handling costs act as barriers to industry expansion.

Markets for recyclables have grown significantly, but the supply of material is large and prices remain low. Newsprint is the only area in which Maine has excess processing capacity, with the newsprint recycling facility at Great Northern Paper using 130,000 tons per year, while the state produces only 60,000 tons. Recycled materials offer excellent opportunities for innovation, primarily in the substitution of recycled materials for virgin materials. The growth of the plastic lumber industry is closely tied to the availability of recycled plastic feedstock, and recycled PET plastic shows up in carpets and other domestic products.

"Recycled materials offer excellent opportunities for innovation, primarily in the substitution of recycled materials for virgin materials."

While Maine lacks local markets that use recycled glass or metal, the growth of the composting industry in Maine has been helped by the range of organic materials, including fish and agricultural wastes, sawdust, leaves and wastewater biosolids, that are available locally. Proximity to major markets in southern New England has been a significant asset and has allowed development of premium product lines for suburban markets.

Subclusters

The environmental services group is probably the most significant subcluster in this area. It appears to be the most competitive from an export perspective. The various waste disposal and treatment technologies under development in Maine may form a subcluster, if additional commercially successful development in the field takes place.

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Finance

Innovative environmental technology companies report good access to grant funding at the state and national levels, although persistence is required. Federal agencies such as EPA have funded a variety of programs to provide information about grants and contracts and have provided funding through regional initiatives for research and development. Companies report that grants from MTI, DOE and EPA, as well as SBIR, are particularly useful. CEI and FAME have also provided financing and capital for several companies in the sector.

"Environmental tests developed by several Maine biotechnology companies are an area of growth...

Innovation

Despite the small size and diverse nature of this industry in Maine, companies here are innovative in a number of areas. Environmental tests developed by several Maine biotechnology companies are an area of growth, and sensor development by local R&D firms for environmental contaminants has considerable promise. Vortechnics of Portland is developing a strong niche in stormwater control technology, while Septitech of Gray has received EPA recognition for its innovative septic systems. Correct Deck and Gates Formed Fiber are making innovative products for the building and automotive industries using recycled plastics. Endless Energy plans to have operational wind farms in Maine in the next few years. Woods End Research and Coast of Maine, Inc., undertake innovative research and product development in composting, while Casella Waste Systems has been successful in composting industrial and wastewater treatment byproducts.

This sector is constrained limited local markets for its products, which forces companies to look out of state for markets large enough to support company growth. Considerable effort has been invested by the U.S. Environmental Protection Agency in providing information on federal grants and contracts for environmental technologies and, with agencies such as DEP, promoting a series of conferences for environmental technology and pollution prevention.

The potential for growth in environmental technologies was examined in some detail in the early 1990s (CEI, 1994). Several areas were identified as good growth candidates including environmental testing, pollution control equipment, sensors and composting. Several new companies have developed in these fields, and additional growth can be expected as new products are developed and markets expand. This growth has been balanced by the disappearance of a number of small environmental technology firms. While insufficient data are available to address this question, it is clear that the industry as a whole has not grown significantly in the last few years.

The brightest area remains a small subcluster in the environmental engineering field. Local strengths have developed in environmental engineering, stormwater control and environmental testing, and these companies are now national competitors. The growth and contraction of this field resulted in numerous smaller companies being spun off that are now important companies in the field. Successful companies in engineering fields in Maine have found local markets that later allowed them to move to regional or national markets.

In contrast, Maine's environmental technology industries are still too small and too diverse to function as a cluster. There is a great deal of support for these firms, including associations, incubators, education and finance, but so far there has not been sufficient growth. The sector has potential, if the support that has been initiated for R&D and incubators can be maintained.

Environmental resource management firms comprise an important group within Maine, but their services are confined to Maine itself and are not traded outside of Maine. While a combination of solid waste and water pollution control organizations exists within Maine, these firms have not yet developed technologies or services that can be sold outside the state; thus, their economic development potential is limited.

In sum, Maine's environmental industries are strongest in engineering and consulting, where there has been growth and where regional and national markets are served. Environmental technologies remains a small but promising sector, while environmental resource management organizations serve primarily Maine markets. With the exception of environmental engineering, none of the three subgroups in this sector has yet found a sufficiently clear market role that can demonstrate either strong interconnections among firms and organizations within Maine or strong growth potential from which such connections could be formed. There is potential both for additional connections and for market growth, but until one or both of these occur, the direction of environmental technologies in Maine will not be clear enough to allow the field to be characterized as a cluster of competitive advantage.

Research and Development Facilities and Organizations

Environmental technology is the only industry in Maine that has had an operational business incubator for the last five years. The Center for Environmental Enterprise at Southern Maine Technical College has served several startup companies in the field, including firms involved in sensor research and environmental software applications. It has also been a pilot program for incubators now being developed for Maine's other strategic industries.

...and sensor development by local R&D firms for environmental contaminants has considerable promise."

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"The brightest area remains a small subcluster in the environmental engineering field."

Trade Associations

The solid waste industry in Maine is predominantly controlled by large companies that are effective in advocating for their interests and thus lacks a statewide trade association. National organizations form an effective voice for solid waste issues in Washington, providing information and advocacy. The Maine Resource Recovery Association advocates for the state's waste-to-energy facilities. Recycling organizations and Web-based materials exchanges have been promoted in Maine by DEP, the State Planning Office, MMEP and EPA as a way to link municipalities with markets but with limited success. Compost products have no local association.

The environmental engineering industry in Maine has Consulting Engineers of Maine, a professional association, plus several associations focused on water and wastewater issues. Most consulting firms are effective marketers of their own services, so assistance in this area is not needed. Services such as the Energy and Environment (E2) Business Center provide information, directories and guidance on federal and state grant programs for innovative enterprises in energy and environmental technology. The E2 Center, with assistance from MMEP, DOE and EPA, is also active in organizing local conferences on solid waste, energy use and pollution prevention.

Within the field of "green" power generation, Independent Energy Producers of Maine acts as an important voice in the legislature and before the Maine Public Utilities Commission on issues relating to deregulation and small generator interests. Operators of biomass, hydropower and wind power installations also have national organizations that can be useful in promoting understanding of new technologies.

Labor

Labor does not generally appear to be a constraint for this sector. Maine's institutions of higher education provide a range of degrees and training in the environmental disciplines, and these programs produce significant numbers of graduates. Engineering firms report few problems in attracting qualified personnel from within and outside the state. Maine's quality of life remains a major attraction for professionals in the field. However, manufacturing companies employing lower wage workers do report difficulty in attracting and holding employees.

Lead Organizations

Lead organizations have appeared in the engineering segment of this sector but not in the technology or resource management sectors. These organizations are primarily the state's larger engineering companies, which have produced spinoffs and provided a market for smaller companies on a subcontract basis.

Locational Advantage

Maine's longstanding tradition of tough environmental policies designed to protect its uniquely rich environmental resources has clearly been an example of what Harvard professor Michael Porter has described as the beneficial side of regulation: high standards, applied locally, provide a basis on which firms can develop the management structures, products and services that will serve them when they move outside the state. This has paid off for the environmental engineering field, which has developed its own substantial knowledge base in Maine and could yet be a source of advantage for environmental technologies and resource management.

"Waste-to-energy facilities represent perhaps the most successful 'green' power ventures in Maine."

TABLE TWENTY-TWO
SUMMARY OF CLUSTER CHARACTERISTICS[16]

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	Process	1
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	R&D Facilities & Organizations	1
	Industry Organizations	1
	Lead Organizations	1
LOCATIONAL ADVANTAGE	Geography	2
	Knowledge	2
MARKET POTENTIAL	Mature—Growth Markets	2
	Diversity of Markets	1
	Local Demand	2
	Exports	1
ECONOMIC PERFORMANCE		NA

[16]See the chapter *Measuring Clusters in Maine* for discussion of factors.

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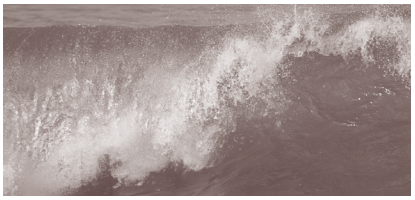

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- Measuring and assessing Maine's public investments in research and development and their impact on the state's economy;
- Serving as a public information resource by maintaining Maine's science and technology clearinghouse, www.mainescience.org;
- Convening science and technology stakeholders and fostering collaboration among organizations;
- Identifying new opportunities for science- and technology-related activities;
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