Maine Comprehensive Research and Development Evaluation 2006

A Report to the Maine Office of Innovation, Department of Economic and Community Development

SUBMITTED TO:
Maine Office of Innovation
Department of Economic and Community Development
59 State Street Station
Augusta, ME 04333-0059

DEVELOPED BY:
PolicyOne Research, Inc.
201 U.S. Rte 1, #222
Scarborough, Maine 04074

RTI International
Center for Technology Applications
3040 Cornwallis Road
PO Box 12194
Research Triangle Park, NC 27709-2194

February 6, 2007

Contents

List of Tables

List of Figures

1. Executive Summary

Since 1996, Maine has invested a total of $296,755,590 in research and development (R&D). Nearly fifty percent of the total ($147,999,053) went to the state's universities, $82,112,909 (27.7%) to Maine's nonprofit research institutions, and $66,643,628(22.5%) to organizations that support Maine private sector R&D.

In 2001, the Maine legislature enacted 5 MRSA §13122-J and 13122-K, which called for evaluation of Maine's public investment in R&D, the first to be completed in 2001 and every five years thereafter. This is the first year of the second five-year evaluation.

As such, this evaluation was updated to reflect the new goals for R&D in Maine embodied in the 2005 Science and Technology Action Plan for Maine. The overarching goal is that

- Maine's R&D activity will equal $1 billion per year by 2010.

This goal includes five key objectives, listed below.

1. Maine's investments in R&D will stimulate and sustain consistent, competitive growth for Maine's economy.
2. Stimulate a robust R&D enterprise by boosting academic R&D capacity, developing an educated, technically skilled workforce, broadening the impact from the nonprofit research institutions, and increasing private sector R&D activity in key strategic areas important to Maine.
3. Maine's Legislature and key policymakers recognize, advance, and celebrate Maine's R&D investments and strategic priorities.
4. Maine's unique R&D assets and their significance to Maine's economy are used to draw new business and investment to the state of Maine.
5. Foster growth of research-intensive companies through a comprehensive network of services and support.

Using the State's Plan as a guide and with advice and consent from the Maine Office of Innovation, we constructed five questions to be answered by this evaluation, which focus on the R&D-related goals and objectives. They are as follows:

1. Overall, has Maine's public investment in research and development stimulated and sustained consistent, competitive growth in Maine's economy, especially when compared to other states?

2. Has Maine's investment in public and private university R&D led to increased research capacity; the development of an educated, technically skilled workforce; and increased commercialization of university technologies?
3. Are Maine's investments in nonprofit research institutions broadening their impact on Maine's economy?
4. Is Maine fostering the growth of research-intensive companies, increasing private sector R&D activity, and building a technology-based entrepreneurial community?
5. To what extent are these investments increasing the competitiveness of Maine in its key strategic technology and industry areas?

Each of the questions is answered in turn below and in greater detail in **Section 3**.

1.1 Answers to the Five Questions

1. *Overall, has Maine's public investment in research and development stimulated and sustained consistent, competitive growth in Maine's economy, especially when compared to other states?*

It appears that Maine's investment has contributed to consistent growth in Maine's economy, and has increased competitiveness relative to other states. The most important indicator of the impact of Maine's investment in R&D is increase in the quality of life of Maine citizens as measured by income. Maine's per capita income was $30,080 in 2005 compared to the national average of $34,495. The data shows that Maine has been gaining on the other Experimental Program to Stimulate Competitive Research (EPSCoR)[1] states and on the United States as a whole between 1996 and 2005.

The private sector recipients of the state's investments are reporting higher job growth (6.8%) than the average Maine economy (0.5%) and much higher average wages ($38,825), strongly suggesting that they are contributing to this improvement in Maine's overall economic situation. Further, the recipients agree that the assistance they have received from the Maine organizations funded by the R&D funds has been very important to their growth.

Economic growth theory suggests that increases in Maine's production of knowledge (through university, nonprofit research, and industry research) will enhance the competitiveness of Maine's economy. We believe that Maine's production of knowledge

[1] EPSCoR is the acronym for the Experimental Program to Stimulate Competitive Research and is used to denote the states with low levels of federal research funding. The states are: Alabama, Alaska, Arkansas, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, North Dakota, Oklahoma, Puerto Rico, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming.

has grown because Maine residents have been issued patents at a slightly increased rate over the period; Maine has continued to see increases in the past few years when national patent production went down.

There is, however, a serious mismatch between the investment in R&D and the resulting performance. The state has invested roughly 49.87% of new R&D in the universities in the past ten years, bringing the universities up over 160%—to 20% of the total R&D performed in the state. Conversely, while the state has invested 22.5% in industry R&D through private sector-focused programs, industry now performs 53.8% of the state's R&D, down 30%. Maine's nonprofit sector has grown 211% from 1995–2003, while nonprofit research in the United States has gone up only 89%. The net effect of the state's investment has been to increase the academic and nonprofit share, while decreasing industry's share substantially.

The question is, do we care about these allocations? The answer is that we do. While increased R&D is in and of itself a good thing, its real impact on the economy is when the knowledge produced is commercialized. The overwhelming finding from this report is that the academic and nonprofit sectors are not commercializing very much of the new knowledge acquired through the state-funded R&D, while industry is commercializing at a high rate. Therefore, the state's investment is not creating the maximum possible impact.

2. *Has Maine's investment in public and private university R&D led to increased research capacity, the development of an educated, technically skilled workforce, and increased commercialization of university technologies?*

The results indicate that the universities are building their research capacity and contributing to an educated workforce. The state investments have been critical to that outcome. More professors are teaching more science and engineering students; these professors are also writing scholarly articles that are being accepted to peer-reviewed journals, a signal in the academic community of quality of research being performed. These new faculty are also writing large numbers of proposals and winning new federal research grants. Few of these federal grants are earmarked or made through the EPSCoR program, so the faculty members are clearly competitive on a national level.

The specific metrics attributable to state R&D investment reported by the universities in 2006 are as follows:

- 530 enrolled science undergraduates
- 155 science and engineering graduate students
- $2,807,857 in new major research equipment

- 527 research and related support jobs
- 953 scientific peer-reviewed journal articles, book chapters, and books
- 268 new federal research awards totaling $41,089,533
- $7,868,725 in R&D expenditures this year
- 19 disclosures, 10 patents applied for, and 3 patents awarded
- 2 spin-off companies and 6 jobs

While the university results overall are quite positive, those attributable to the state's investment have diminished over time. We believe that this points out the importance of continuing to "prime the pump."

Another concern remains the volume of interaction with Maine industry. Some centers are obviously working extremely well with industry, notably the Advanced Engineered Wood Composites Center (AEWC), and the gains in the composites sector are evidence of the importance of the informal and formal technology transfer that occurs in a collaborative environment. However, overall, the results are underwhelming. The University of Maine, Orono, did not report their number of industry contracts, but the rest of the universities' contracts totaled only seven, for $4.3 million. A look at the academic fields where Maine professors are conducting research reveals another mismatch with Maine's technology community: Environmental technology is a large percentage of university research, especially as compared to the United States and other regions, while life sciences is relatively smaller.

Further, Maine's research universities trail national averages for production of intellectual property (IP) from research, although the reasons behind this result could vary, from the culture within the faculty to insufficient funding for patenting and technology transfer staff.

A third concern is in the production of qualified workers for the research-intensive industry. While the number of science and engineering graduates is up over the past ten years, especially those with Master's degrees or higher, there has also been a drop in enrollments in science and engineering programs over the past five years. The current enrollment is lower than in 1995. Additionally, a large portion of students at the universities are earning degrees in life sciences, but there are few in engineering, mathematics, or computer science, fields of interest to several of Maine's targeted clusters.

Therefore, the answer to the question is that Maine's investment in its universities is increasing research capacity and making progress in the production of an educated workforce, but not as consistently as would be hoped, and the investment is producing disappointing results in terms of commercialization of university technology.

3. *Are Maine's investments in nonprofit research institutions broadening their impact on Maine's economy?*

In 2006, the results attributable to state R&D investments to the nonprofit research institutions included the following:

- $301,992 in new research equipment
- 33 research and support jobs
- 248 scientific, peer-reviewed journal articles, books, and book chapters
- $32,965,792 for 48 new federal research grants (multi-year)
- $73,083,281in expenditures for R&D
- 18 disclosures, 6 patents applied for, and 1 granted
- License income from past agreements totally $136,472
- 1 new spin-off company with 2.5 jobs.

Jackson Laboratory continues to be the largest nonprofit research entity in the state and, with its high ranking among National Institutes of Health (NIH) research institutes (#7 in 2005), brings prestige and federal funding to the state.

Our concern with this sector remains its limited impact on Maine's economy beyond the direct jobs it provides. Since this sector has limited interactions with the private, research-intensive companies in the state (only 42 research projects with Maine companies reported this year for $4.1 million, 4% of total R&D performed this year), the opportunity for informal technology transfer is minimized. Similarly, although the sector has made some improvements in its formal technology transfer capacity in the past few years, its production of intellectual property, licenses, and spin-off companies is extremely limited given the large volume of research being performed.

4. *Is Maine fostering the growth of research-intensive companies, increasing private sector R&D activity, and building a technology-based entrepreneurial community?*

Seven hundred and twelve (712) companies have received assistance from entities funded by the Maine R&D investment in the last five years, and 36.7% have worked with more than one of these stakeholders.

Maine's private sector, represented by the 363 companies that responded to this survey, is growing faster than the rest of the Maine economy, paying wages that are 25% higher and contributing almost $87 million to Maine's economy. These companies receive 80% of the venture capital invested in the state and account for almost 60% of the patents. It is fair to say that Maine's private sector is growing in importance and competitiveness due in some part to Maine's investments in support of R&D.

The firms surveyed indicated a high degree of satisfaction with the services they have received from the stakeholders and also noted that the assistance was important to them. The mean score for importance of assistance received was 3.31 out of 5.00, somewhere between frequently important and very important. The mean score for satisfaction with assistance received was 4.09, somewhere between satisfied and very satisfied. More specifically, over two-thirds of respondents indicated that they were either satisfied or very satisfied.

The respondents reported a net gain of 437 employees, or 6.8% of their workforce, in 2006. (Employment growth in Maine overall in 2006 was 0.5% in 2005.) They had a total of 6,774 employees whom they paid $263,005,517 in wages and salaries. The average wage of these employees, therefore, is $38,825.

The respondents reported $1,439,990,135 in revenue in 2006, an increase of $221,813,149 (18.2 %) over their prior year's revenue. This strong showing suggests that the companies that are availing themselves of the services offered by the stakeholders are growing faster than Maine's economy.

Using an IMPLAN model[2] of the Maine economy, we calculate that the companies generated $53,920,416 of direct impact on the Maine economy, $16,995,416 in indirect impact, and $15,659,028 of induced impact, for a total of $86,574,860 When compared to Maine's public investment of $4,608,476 to support research-intensive companies, this represents a 14 times return.

5. *To what extent are these investments increasing the competitiveness of Maine in its key strategic technology and industry areas?*

The case study shows that the composites sector is a growing area in Maine, reflecting the national and international trends. A large market for civil infrastructure and construction applications is emerging, largely dependent on bio-based composites. This is good news for Maine's composite sector, with its predominant research asset being the AEWC.

Overall, the sectors in Maine, represented by their companies, are making progress as indicated by these metrics. They are all growing faster (both employment and revenues) with higher wages than the average Maine company.

2 See extended discussion of this calculation in Attachment E.

1.2 Recommendations

Overall, Maine's investments have improved the state's position in science and technology. Our recommendations are based on the goals set out in the Science and Technology Plan, best practices in innovation-based economic development, and deficiencies in the current implementation.

1. Maine needs to continue to invest in R&D, and in fact, needs to accelerate its investment in order to (a) meet the goal of $1 billion in R&D by 2010 and (b) improve its relative position in the innovation economy. While the past investments have proven to be fruitful, investments must continue to be made to keep pace with the other states and the rest of the world.

2. Future investments in R&D should include a larger percentage for the programs that support the private sector. Investments in programs that provide technical assistance in commercialization have been shown here, and in other states, to increase the economic impact substantially compared to investment in research capacity alone.

3. Future R&D investments should require more commercialization outcomes from universities and nonprofit-performed R&D. These entities should be encouraged to perform industry-sponsored R&D, to protect IP, and to license IP to in-state companies, both start-ups and established firms. Other commercialization outcomes which are significant include attracting related industry to locate in Maine, contributing to specific workforce training for industry and the development of new products, processes and/or services.

4. The workforce needs of Maine's research-intensive industries should be studied and specific recommendations made for curriculum enhancements at Maine universities and community colleges.

5. The technology transfer capacities of the universities and nonprofit research institutions should be assessed again (a report was done by USM in 2001), issues identified, and actions recommended to increase technology transfer outcomes. Models to consider include shared technology transfer capacity that can support institutions without sufficient R&D to support their own technology transfer staff such as currently provided by the CLI. The provision of adequate staff and patent funds has been demonstrated to be correlated with technology transfer outcomes such as patents, licenses and start-ups.

6. To support the composites sector, we recommend a variety of initiatives that encourage academic and industrial research, intra-sector collaboration, commercialization, and workforce preparation. We recommend that similar types of programs support other critical sectors in Maine's economy.

2. Introduction

In 2001, the Maine legislature enacted 5 MRSA §13122-J and 13122-K, which called for evaluation of Maine's public investment in R&D, the first to be completed in 2001 and every five years thereafter. At that time, the Maine Science and Technology Foundation (MSTF) was charged with establishing outcome measures considered appropriate by public and private practitioners in and outside of the state in the fields of R&D and economic development, and to assess the competitiveness of technology sectors in Maine and the impact of R&D in Maine on the state's economic development. In 2003, MSTF was de-organized by the state and the majority of its responsibilities transferred to the newly created Maine Office of Innovation (MOI) within the state's Department of Economic and Community Development (DECD). Since that time the evaluation process has been the responsibility of MOI[3]. An advisory board, the Maine State Science and Technology Advisory Board, is charged by the state with providing guidance and input on the activities of the MOI, including the evaluation project. The MOI activities are further articulated in and guided by the State Science & Technology Action Plan, the latest of which was developed in 2005 by MOI with oversight from the Science and Technology Advisory Board.

To conduct the R&D Evaluation, including evaluation design, project management, data gathering, analysis, and reporting, MOI has contracted with consultants/analysts. For the initial five-year-evaluation, MOI contracted with PolicyOne Research for project management and data collection and with the Office of Economic Development at the University of North Carolina, Chapel Hill, for analysis and reporting. This arrangement was an extension of the initial team established by MSTF. For FY2006–07,MOI has contracted with PolicyOne Research to manage the evaluation and data collection; PolicyOne has partnered with RTI International[4] for design, analysis and reporting.

[3] See 5 MRSA §13105)

[4] RTI International is a trade name of Research Triangle Institute.

Given that this marks the beginning of a second five-year cycle of evaluation, the MOI and the evaluation designers felt that it would be appropriate to use the experience of the past five years to amend the original evaluation plan[5] where necessary to reflect the current circumstances. Our guiding principles for this review were as follows:

- To maintain, wherever possible, consistency of longitudinal data
- To continue to work toward providing companies with single data collection interactions that comply with both the overall evaluation and the evaluation of the Maine Technology Institute[6]
- To provide MOI, the Maine Science and Technology Advisory Board, state legislators, and the science and technology community with usable, actionable information for policy analysis.

In September 2006, we completed an Evaluation Plan for the new five-year cycle. That plan detailed new questions that are somewhat different than those posed in 2001. One important reason for this is that the MOI published a new strategic plan, "A Science and Technology Action Plan for Maine," in 2005.[7] The objectives in this plan supersede those laid out in 2001. However, we feel that the new questions tie closely with those answered in the previous reports and that little, if any, continuity is lost.

The 2005 Science and Technology Action Plan for Maine includes the following goal:

- Maine's R&D activity will equal $1 billion per year by 2010

This goal includes five key objectives, which are listed below.

1. Maine's investments in R&D will stimulate and sustain consistent, competitive growth for Maine's Economy.
2. Stimulate a robust R&D enterprise by boosting academic R&D capacity, developing an educated, technically skilled workforce, broadening the impact from the nonprofit research institutions, and increasing private sector R&D activity in key strategic areas important to Maine.
3. Maine's Legislature and key policymakers recognize, advance, and celebrate Maine's R&D investments and strategic priorities.
4. Maine's unique R&D assets and their significance to Maine's economy are used to draw new business and investment to the state of Maine.

[5] Luger, Michael I., Feller, Irwin, and Renault, Catherine. 2001, Evaluation of Maine's Public Investment in Research and Development. Chapel Hill, NC: Office of Economic Development.
[6] For a description of MTI's evaluation requirement see MRSA 5 §15302. Maine Technology Institute
[7] A full copy of "A Science and Technology Action Plan for Maine" is available at the Maine Office of Innovation's Website: http://www.maineinnovation.com/

5. Foster growth of research-intensive companies through a comprehensive network of services and support.

Using the State's Plan as a guide we constructed five questions to be answered by this evaluation, which focus on the R&D related goals and objectives. They are as follows:

1. Overall, has Maine's public investment in research and development stimulated and sustained consistent, competitive growth in Maine's economy, especially when compared to other states?
2. Has Maine's investment in public and private university R&D led to increased research capacity, the development of an educated, technically skilled workforce; and increased commercialization of university technologies?
3. Are Maine's investments in nonprofit research institutions broadening their impact on Maine's economy?
4. Is Maine fostering the growth of research-intensive companies, increasing private sector R&D activity, and building a technology-based entrepreneurial community?
5. To what extent are these investments increasing the competitiveness of Maine in its key strategic technology and industry areas?

This report is structured around these five questions.

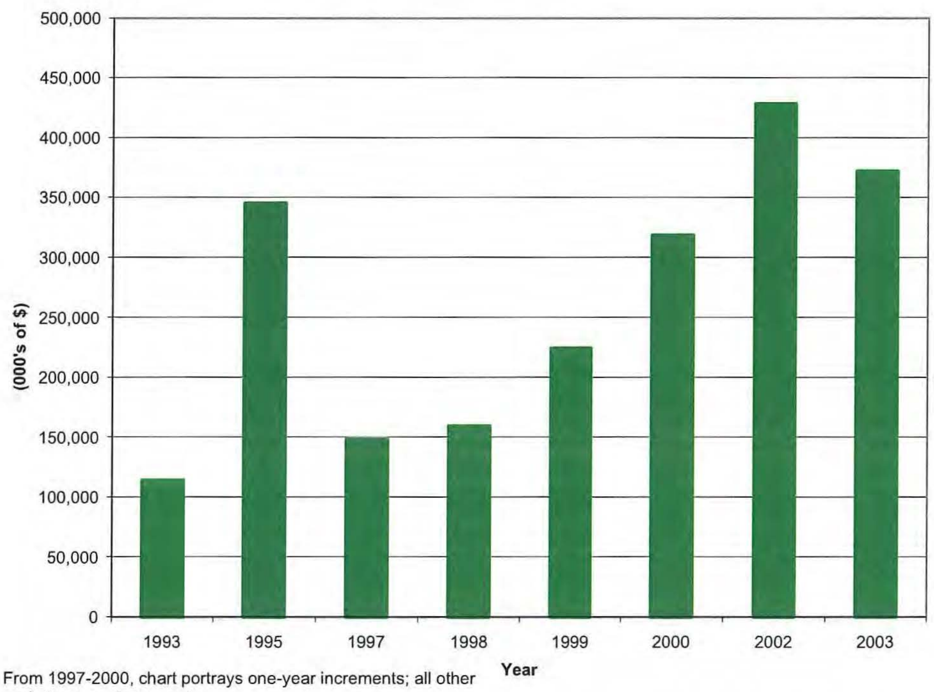
- Findings and Conclusions (**Section 3**)
- Recommendations (**Section 4**)
- Composites Case Study (**Section 5**).
- Private Sector Survey Instrument (**Attachment A**)
- Private Sector Survey Data and Analysis (**Attachment B**)
- R&D Institutions Survey Instrument (**Attachment C**)
- R&D Institutions Survey Data (**Attachment D**)
- IMPLAN Results (**Attachment E**)

3. Findings and Conclusions

This section details the answer to each of the five questions posed by this report and discusses the evidence obtained from the annual private sector survey, the survey of the R&D institutions, the case study on the composites sector, and the 2006 Innovation Index.[8]

The overall goal of reaching $1 billion in R&D activity by 2010 stated in the 2005 Science and Technology Action Plan for Maine is quite a stretch, based upon available information. As noted in the Plan, considerable additional state investment will be required to reach the goal. **Figure 3.1** shows progress toward this goal through 2003, the latest data available. In 2003, Maine has total R&D investment of $372 million, down 13.24% from $428 million in 2002.

Figure 3.1. Total R&D Spending in Maine, 1993–2003



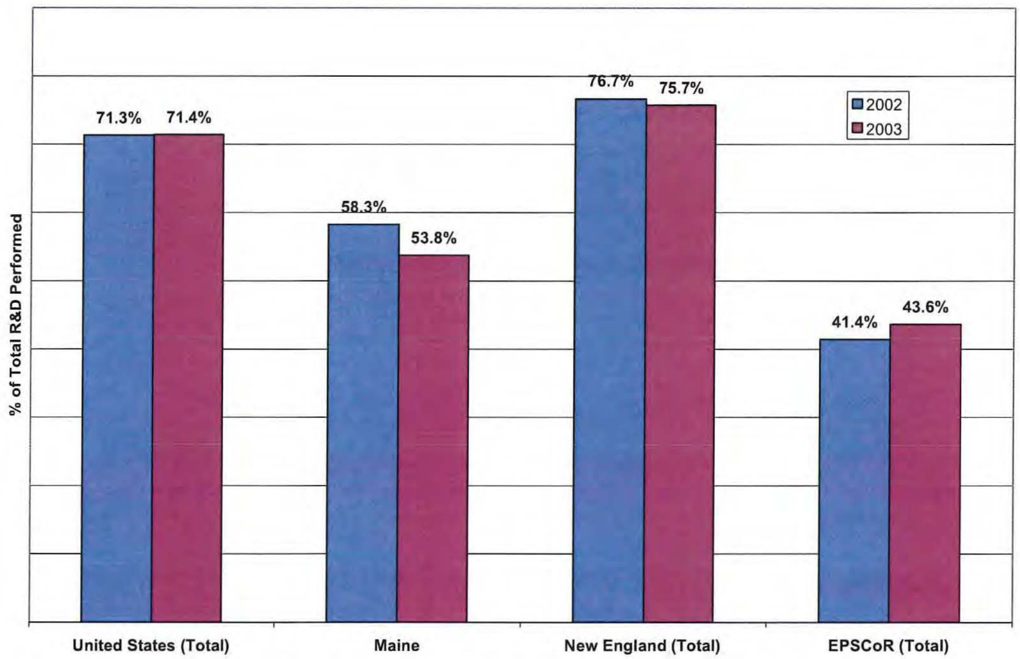
Note: From 1997-2000, chart portrays one-year increments; all other years are in two-year increments.

Sources: Total R&D Performed – National Science Foundation/Division of Science Resources Statistics; National Patterns of R&D Resources 2002 & 2004 Data Updates, derived from four NSF surveys: Survey of Industrial R&D; Survey of R&D Expenditures at Universities and Colleges, Survey of Federal Funds for R&D, and Survey of R&D Funding and Performance by Nonprofit Organizations; http://www.nsf.gov/statistics

[8] The private sector survey instrument is included as **Attachment A** and the complete findings as **Attachment B**. The R&D Institutions Survey is included as **Attachment C** and the data in **Attachment D**. The case study is in **Section 5** of this report. The Innovation Index for 2006 is under separate cover.

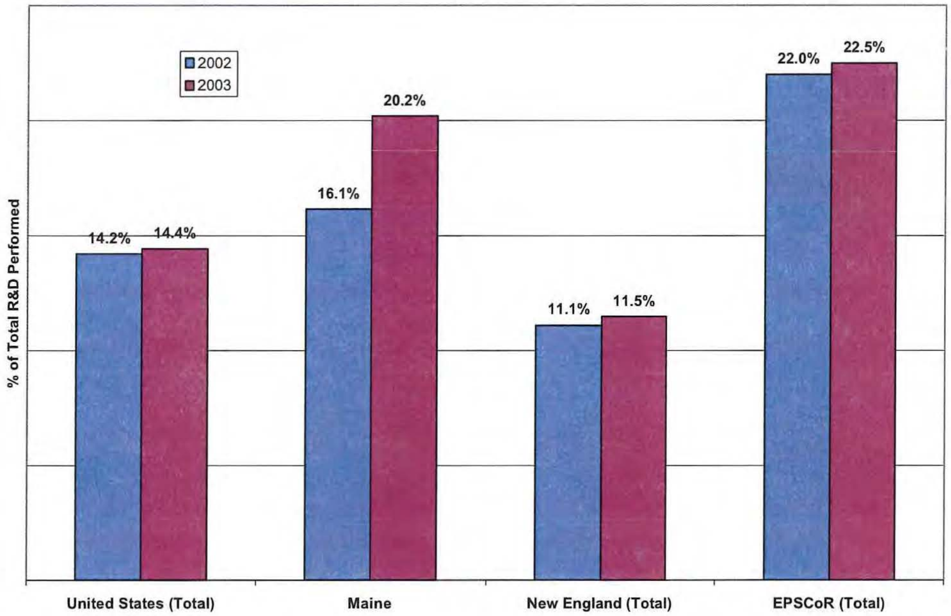
Maine's R&D environment is unusual in that a large portion of the R&D is performed by nonprofit research institutions. **Figures 3.2** through **3.4** show the relative importance of the three types of R&D performers in Maine. Industry has a larger role in the state's R&D than in other EPSCoR states, but lower than the United States and New England as a whole. Academic R&D is a higher percentage and growing, while the nonprofit sector is far more significant in Maine than elsewhere.

Figure 3.2. Industry R&D as a Percent of R&D Performed, 2002 & 2003



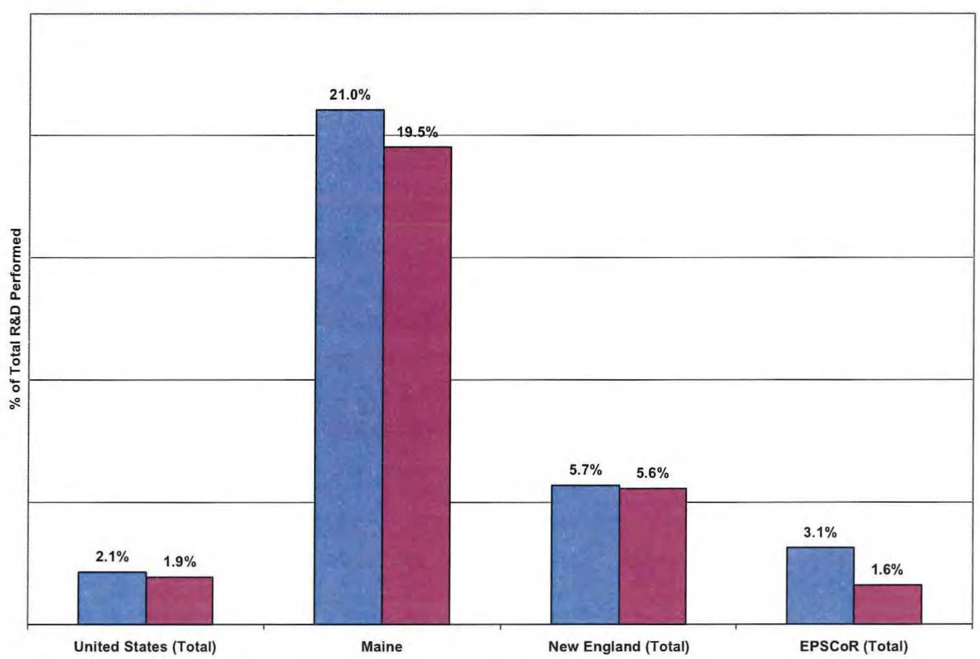
Source: Industry R&D Performed - National Science Foundation/Division of Science Resources Statistics, Survey of Industrial Research and Development: 2001 and 2002, 2002-2003 forthcoming; http://www.nsf.gov/statistics.

Figure 3.3. Academic R&D as a Percent of R&D Performed, 2002 & 2003



Source: National Science Foundation/Division of Science Resources Statistics; Survey of R&D Expenditures at Universities and Colleges 2003 & 2004; http://www.nsf.gov/statistics.

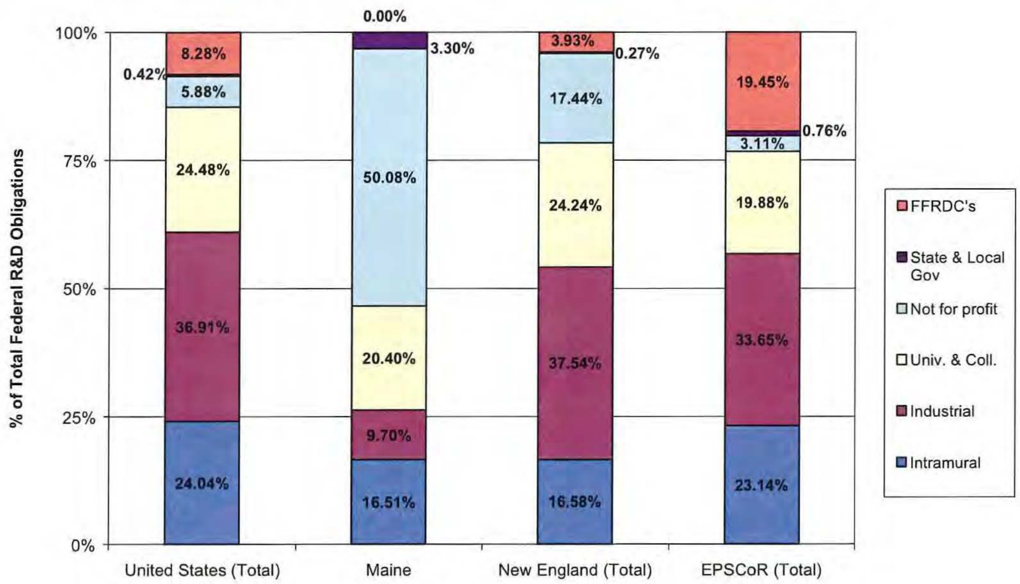
Figure 3.4. Federally Supported Nonprofit R&D as a Percent of R&D Performed, 2002 & 2003



Source: National Science Foundation/Division of Science Resources Statistics, Survey of Federal Funds for Research and Development: Fiscal Years 2002, 2003, 2004, and 2005; http://www.nsf.gov/statistics

Another view of this data is shown in **Figure 3.5**. Here the distribution of federal R&D funds clearly shows the importance of the nonprofit sector to Maine's R&D capacity.

Figure 3.5. Federal Obligations by Performance Sector, 2003



Source: Federal R&D Obligations - National Science Foundation/Division of Science Resources Statistics; Survey of Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005; http://www.nsf.gov/statistics

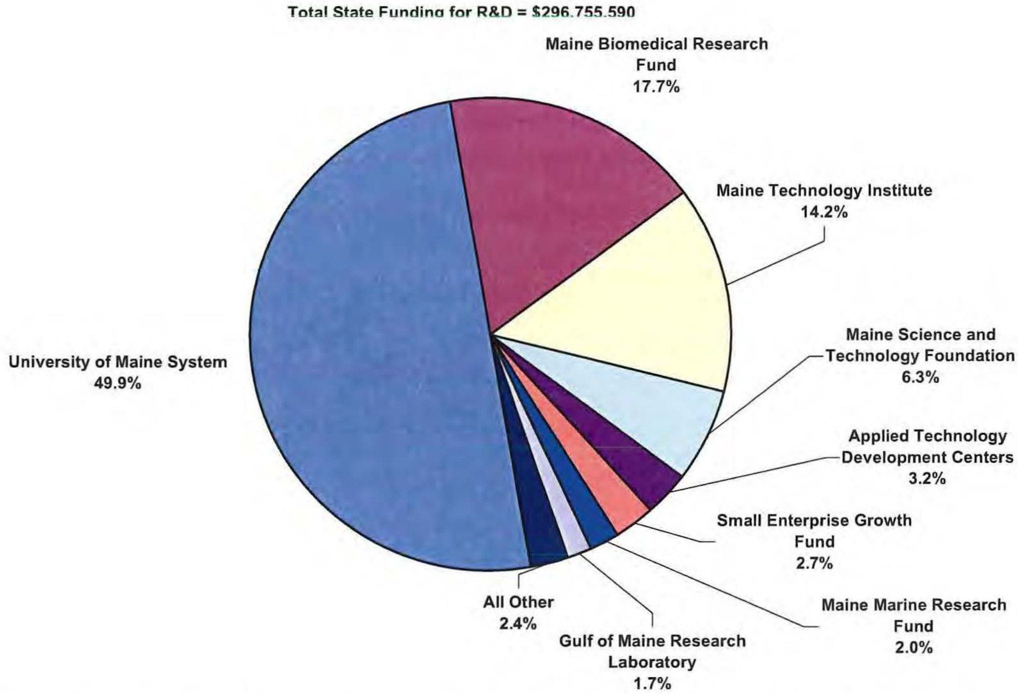
3.1 Maine's Competitive Position

Overall, has Maine's public investment in research and development stimulated and sustained consistent, competitive growth in Maine's economy, especially when compared to other states?

Starting in 1996, Maine has invested a total of $296,755,590 in R&D. **Figure 3.6** shows the distribution of the investments by major program areas. It is interesting to note the serious mismatch between the investment in R&D and the resulting performance. **Table 3.1** shows that while the state has invested 49.87% of new R&D in the universities in the past ten years, the universities are still only 20% of the total R&D performed in the state. Conversely, while the state has invested 22.5% in industry R&D through private sector-focused programs, industry performs 53.8% of the state's R&D.

As a result, Maine's nonprofit sector has grown 211% from 1995–2003, while nonprofit research in the United States has gone up only 89%; the Maine academic community has gained 160% in research performed over the same period, compared with 93% increase for the United States. The choice of allocation of public investment, however, has seen the industrial share in Maine decrease 30% from 1995–2003, while the U.S. industrial share has gone up 50%.

Figure 3.6. Maine's Public Investment in R&D, 1996–2006



Source: PolicyOne Research from data provided by the Maine Legislature, Office of Fiscal & Program Review

Table 3.1. Comparison of Public Investment (1996–2006) and Performance of R&D (2003)

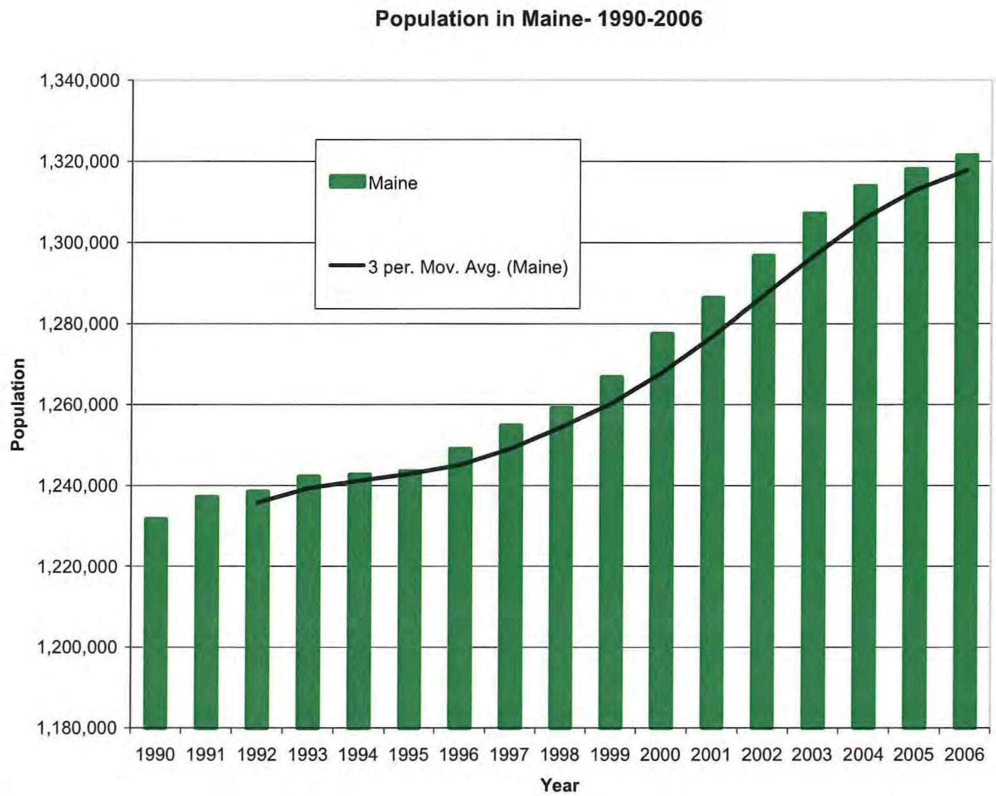
	Percent of Maine Public Investment in R&D 1996-2006	Percent of Performance of R&D, 2003	Maine Percent Change in Performance of R&D, 1995-2003	US Percent Change in Performance of R&D, 1995-2003
Industry	22.5%	53.8%	–30.1%	50.1%
Academia	49.8%	20.2%	160.7%	93.7%
Nonprofit	27.7%	19.5%	211.4%	88.9%

Source: Maine Legislature, Office of Fiscal & Program Review. National Science Foundation/Division of Science Resources Statistics; Survey of R&D Expenditures at Universities and Colleges 2003 & 2004; http://www.nsf.gov/statisticsNational Science Foundation/Division of Science Resources Statistics, Survey of Industrial Research and Development: 2001 and 2002, 2002-2003 forthcoming; http://www.nsf.gov/statistics, National Science Foundation/Division of Science Resources Statistics; Survey of R&D Funding and Performance by Nonprofit Organizations;; http://www.nsf.gov/statistics.

One way to understand the impact of these investments is to compare Maine's overall economic progress compared to the other EPSCoR states and the rest of the United

States. **Figure 3.7** shows the slow but steady growth in Maine's population. Note the inflection point in the graph around 1996. This is coincident with the beginning of the effort to increase investment in Maine's R&D capacity.

Figure 3.7. Population in Maine – 1990–2006

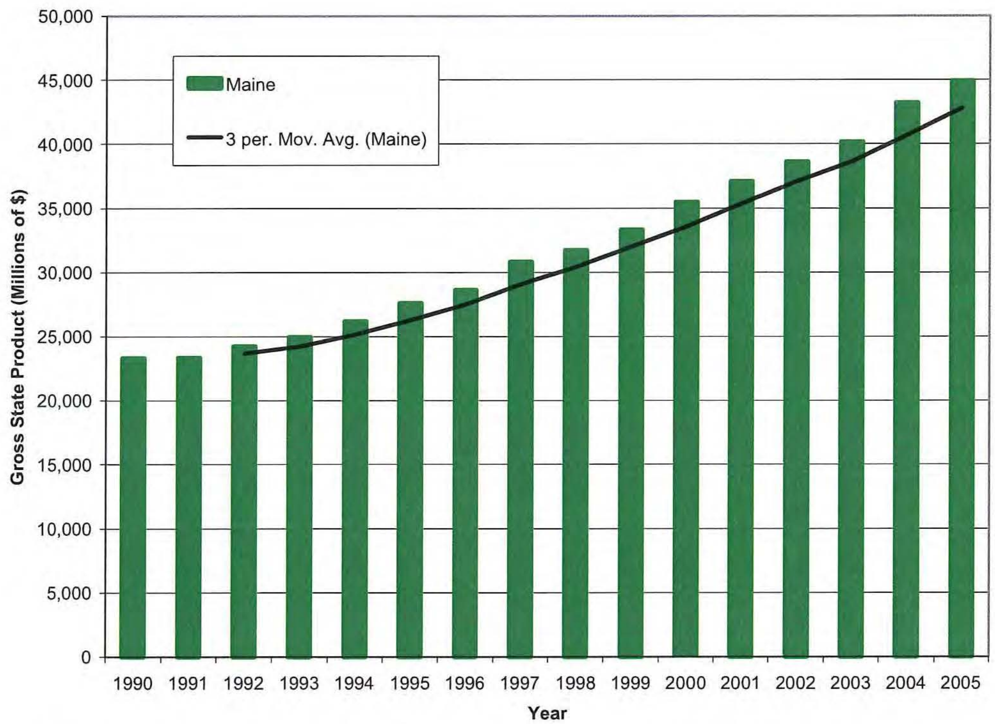


Sources: 1980-1989 - Intercensal Estimates of the Total Resident Population of the States, release date Aug. 1996; 1990-1999 - Table CO-EST2001-12-00 - Time Series of Intercensal State Population Estimates: April 1, 1990 to April 1, 2000; Population Division, U.S. Census Bureau; Release Date: April 11, 2002; July 2000-July 2006 -Table 1: Annual Estimates of the Population for the United States and States, and for Puerto Rico: April 1, 2000 to July 1, 2006 (NST-EST2006-01), Population Division, U.S. Census Bureau, Release Date: December 22, 2006

Similarly, **Figure 3.8** shows the gross state product in Maine for the same time period. The growth is also steady, over 57% in the 1996–05 period, compared to 62.1% in the same period for the United States as a whole and 55.9% for the EPSCoR states. These increases are faster than the growth of the population (5.3% for Maine from 1996–05; 9.81% for the United States and 7.18% for EPSCoR states), suggesting that the economy is showing increased productivity.

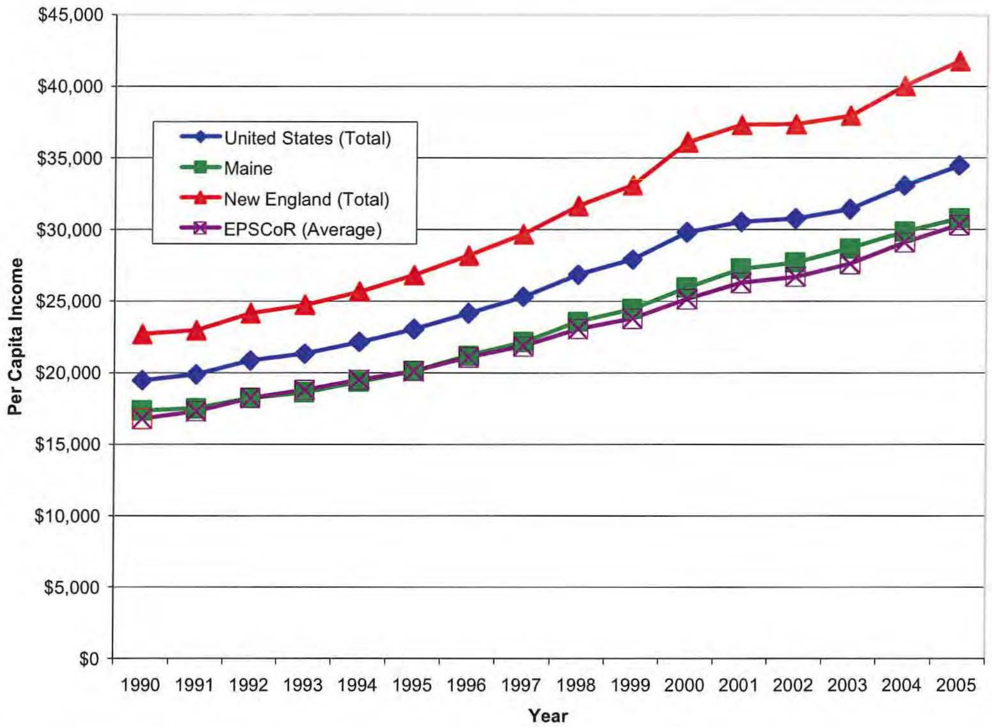
The most important indicator is per capita income, especially given that one goal of investment in R&D is to increase the quality of life of Maine citizens as measured by income. **Figure 3.9** shows per capita income in Maine as compared to the United States, EPSCoR states, and the other New England states. This figure shows that Maine has been gaining on the other EPSCoR states and on the United States as a whole in the 1996–2005 period, although the state is still below the national average of $34,495. Importantly, the change begins in the 1996–97 period and is coincident with the state's R&D investment.

Figure 3.8. Gross State Production in Maine – 1990–2005 (millions of current dollars)



Source: Bureau of Economic Analysis, U.S. Department of Commerce, 1980-1996 data; and Accelerated Estimates for 2005 and Revised Estimates for 1997-2004; http://www.bea.gov/bea/regional/gsp.htm; 1997-2005 is based on NAICS while 1980-1996 is based on SIC industry classification

Figure 3.9. Per Capita Income 1990–2005 (actual dollars)



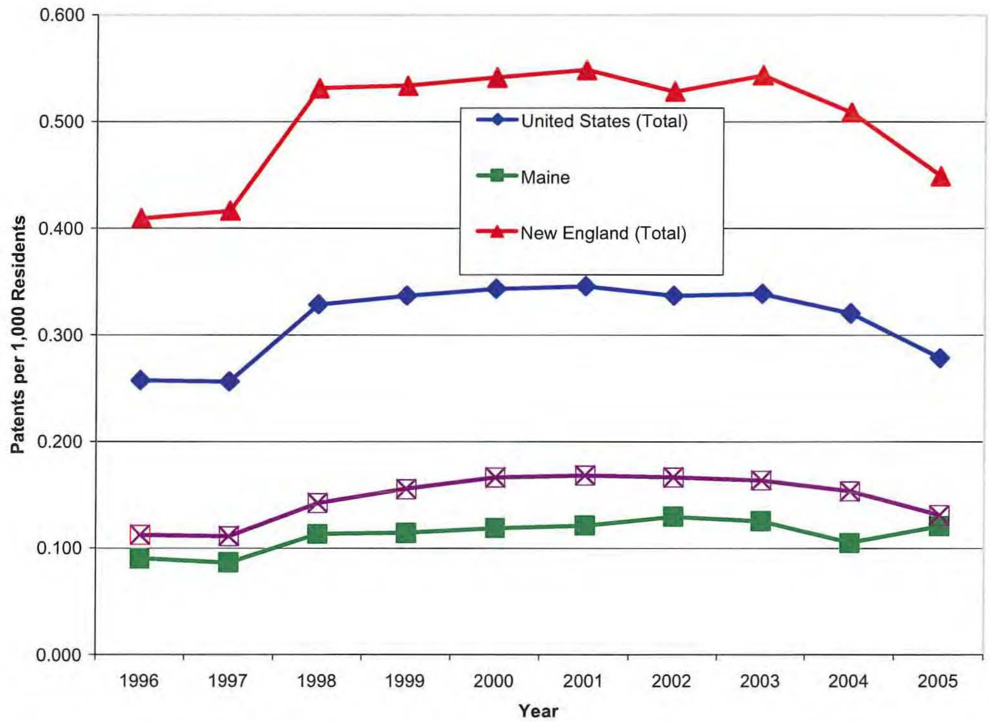
Source: Bureau of Economic Analysis, U.S. Department of Commerce; http://www.bea.gov

Note: All dollar estimates are in current dollars (not adjusted for inflation). 2000–2005 were revised and released September 2006.

Therefore, while we cannot definitively say that the state's investments in R&D have caused these increases, there is evidence that the changes are coincident. Further, as the discussion that follows will detail, the private sector recipients of the state's investments are reporting higher job growth than the average Maine company and much higher average wages, strongly suggesting that they are contributing to the improvement in Maine's overall economic situation. Further, the companies agree that the assistance they have received from the Maine organizations funded by the R&D funds has been very important to their growth.

Economic growth theory suggests that increases in Maine's production of knowledge (through university, nonprofit research, and industry research) will increase the competitiveness of Maine's economy. We believe that Maine's production of knowledge has increased (see **Figure 3.10**). This figure shows that Maine residents have been issued patents at a slightly increased rate over the period and that Maine continued to see increases in the past few years when overall patent production went down. As a point of comparison, in 2005, Mainers were granted 159 patents. In the same year, the universities and nonprofit research institutions reported a total of 4 (2.5%) patents awarded in all fields while the private sector companies who responded to this year's survey (of 2005 activities) reported a total of 90 (56.6%) U.S. patents issued.

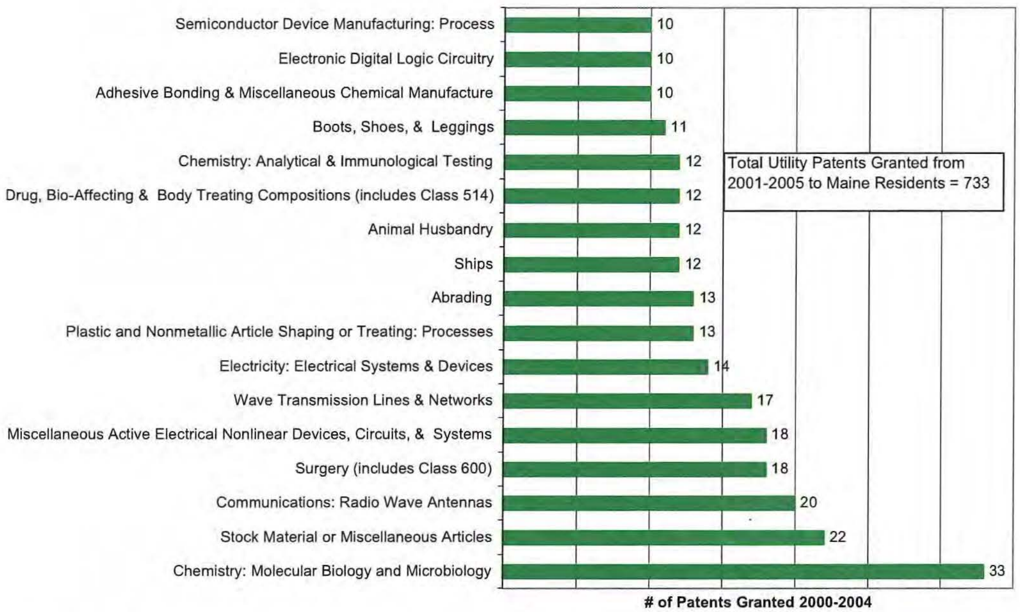
Figure 3.10. Patents Issued per 1,000 Residents in Maine 1996–2005



Source: Patents - Patent Counts by Country/State and Year, All Patents, All Types, January 1, 1977–December 31, 2005; by Calendar Year; US Patent and Trade Mark Office, August 2006; http://www.uspto.gov/

Our understanding of the growth of knowledge in Maine is enhanced by a review of the classes of patents issued in the state in the past four years. As shown in **Figure 3.11**, the number of patents in Chemistry, Molecular Biology and Microbiology (33) far exceed the numbers in any other category.

Figure 3.11. Utility Patents Issued by Technology Class in Maine – 2001–2005



Source: PolicyOne Research from U.S. Patent Office data.

The following sections describe in more detail the contributions of the various parts of the Maine innovation economy.

3.2 Maine's University Research Capacity

Has Maine's investment in public and private university R&D led to increased research capacity, the development of an educated, technically skilled workforce, and increased commercialization of university technologies?

Over the past ten years, Maine has invested heavily in the research capacity of its universities, allocating 49.87% of the total ($147,999,053) since 1996–97, including $14,875,000 in 2005–06.

The universities funded include the following:

- Maine Maritime Academy
- University of Maine, Machias
- University of Maine, Orono
- University of New England
- University of Southern Maine

In 2006, these institutions reported the following outcomes[9] attributable to the state investments:

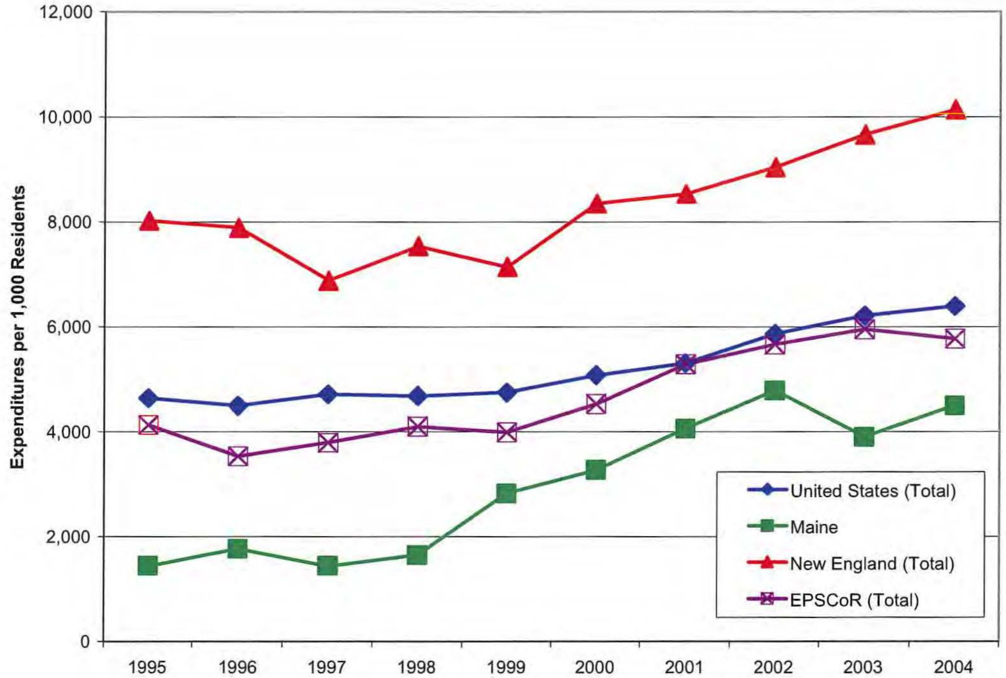
- 530 enrolled science undergraduates
- 155 science and engineering graduate students
- $2,807,857 in new major research equipment
- 527 research and related support jobs
- 953 scientific peer-reviewed journal articles, book chapters and books
- 268 new federal research awards totaling $41,089,533
- $7,868,725 in R&D expenditures this year
- 19 disclosures, 10 patents applied for, and 3 patents awarded
- 2 spin-off companies and 6 jobs

These results indicate that the universities are building their research capacity and contributing to an educated workforce. The state investments have been critical to that outcome. More professors are teaching more science and engineering students; these professors are also writing scholarly articles that are being accepted to peer-reviewed journals, a signal in the academic community of quality of research being performed. These new faculty are also writing large numbers of proposals and winning new federal research grants. Few of these are earmarked or made through the EPSCoR program, so the faculty members are clearly competitive on a national level.

While these are impressive results, they are down substantially from 2002 across the board, although still much higher than in 1996, prior to the current investments. While the university results overall are quite positive, those attributable to the state's investment have diminished over time. We believe that this points out the importance of continuing to "prime the pump." For example, **Figure 3.12** shows that Maine's investment in research equipment is allowing the state to keep pace with other states, but not gaining any ground.

[9] The R&D institution survey and results are included in **Attachments C** and **D**, respectively.

Figure 3.12. Research Equipment Expenditures at Universities & Colleges per 1,000 Residents, 1994–2005

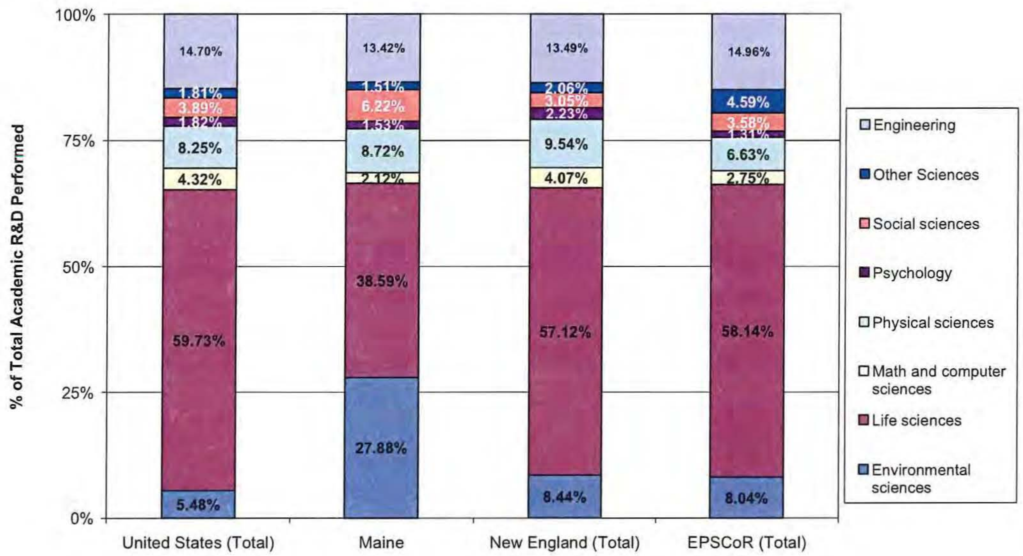


Source: Research Equipment Expenditures - National Science Foundation, WebCASPAR Database System from "Survey of Research and Development Expenditures at Universities and Colleges"; http://webcaspar.nsf.gov.

Another disappointment remains the volume of interaction with Maine industry. Some centers are obviously working extremely well with industry, notably the AEWC, and the gains in the composites space are evidence of the importance of the informal and formal technology transfer that occurs in a collaborative environment. However, overall, the results are underwhelming. The University of Maine, Orono, did not report their number of industry contracts, but the rest of the universities totaled only seven contracts, for $4.3 million of sponsored research.

Another element of this issue relates to the fields of study being pursued by Maine academicians. As shown in **Figure 3.13**, environmental technology is the largest field of study when compared to other states and the United States as a whole, while life sciences is much smaller. This has several implications. One is that there is less opportunity to access federal funds which are more focused on life sciences. On the other hand, increasing national interest in alternative energy may be a boon to Maine. The second implication is that there is less opportunity to interact with the strong nonprofit biomedical sector, calling into doubt the state's ability to build a biomedical cluster.

Figure 3.13. Academic R&D by Field of Study, 2004



Source: University & College R&D Performed - National Science Foundation/Division of Science Resources Statistics; Survey of R&D Expenditures at Universities and Colleges 2004; http://www.nsf.gov/statistics

Further, Maine's research universities trail national averages for production of IP from research. As shown in **Table 3.2**, if the universities followed the averages reported by AUTM[10], the total $81 million in research performed should have generated 45% more disclosures, 2.5 times more patents filed, 4.5 times more licenses, and 3.6 times more license revenue. On the other hand, the Maine universities are producing start-ups at a higher rate than would be predicted, which can also account for the lower license revenue (start-ups take longer to generate royalties).

The Maine universities are relatively new to technology transfer compared to the universities in the AUTM dataset, so they would not be expected to reach the levels listed below yet. These outcomes can also be a symptom of insignificant funding for the technology transfer functions at the institutions, both for patent prosecution and in terms of staff levels. It has been demonstrated that the level of technology transfer outcomes (e.g., patents, licenses and revenues) are directly correlated with the amount of budget allocated to staff and patent expenses.[11]

[10] AUTM Annual Survey: FY 2003.

[11] Donald Siegel, David Waldman and Albert Link.2003. "Assessing the impact of organization practices on the relative productivity of university technology transfer offices: An exploratory study." *Research Policy* 32: 27-43.

Table 3.2. Predicted and Actual Technology Transfer Metrics for Maine Universities

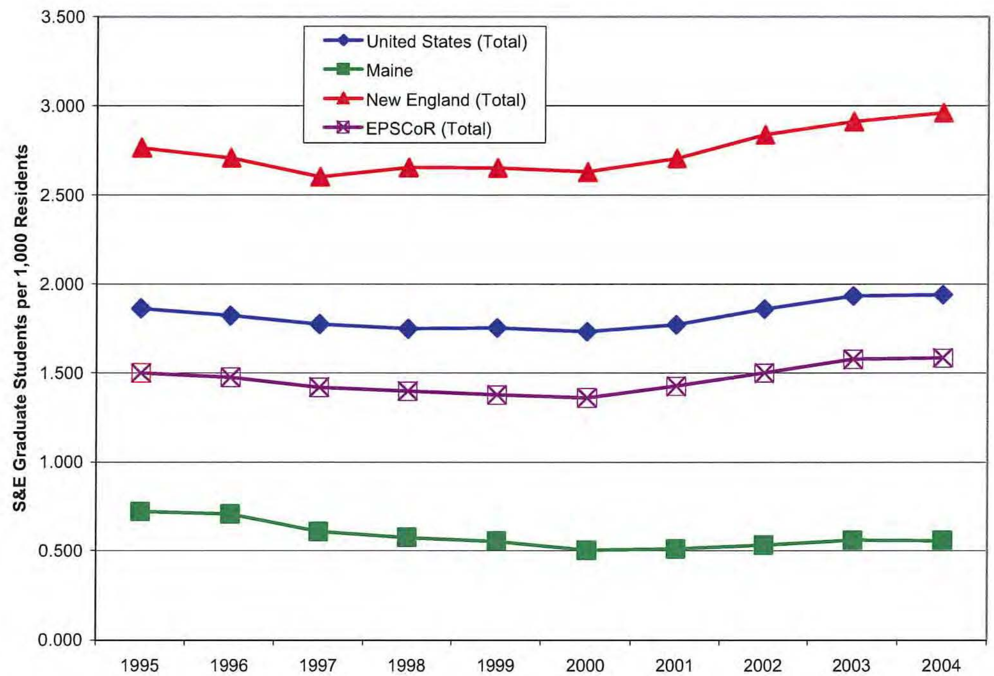
	Average U.S. University	Predicted for Maine	Actual for Maine
Disclosures	$2.54m in sponsored research per disclosure	32 disclosures	22
Patents filed	.86 patents filed per disclosure $2.96m in sponsored research per filed patent	28 patents filed	11
Licenses	$9.03m in sponsored research per license	9 licenses	2
License revenue	$115,153 income per license	$1,036,337 license revenue	$285,000
Start-ups	$100m in sponsored research per start-up	<1 start-up per year	2

We do not have enough data to ascertain whether the Maine universities are contributing the right skills to support the growth of research-intensive companies in the state. We do have a snapshot from one sector, composites (see **Section 5**). Several of Maine's educational institutions are providing courses and majors to support the composites industry. The University of Maine, Orono, continues to graduate small numbers of chemists and civil, mechanical, and environmental engineers. At the University of Southern Maine, the Applied Science, Engineering and Technology program conferred 78 bachelor's degrees and 5 master's degrees in 2004. The Maine Community College System offers a few degrees in fields relevant to composites. The Landing Institute, a private school, plans to offer composites training starting in September 2007. However, at present, very few of their students stay in Maine upon graduation.

Many of the composites companies that we spoke with mentioned workforce development as a key barrier to growth in Maine. The companies discussed how they have to recruit new employees with the right basic skills, sell them on the value of receiving composites training, and then provide the training themselves. Several of the interviewees noted that training being provided by the community college system is not relevant to state-of-the art composites. The Workforce Investment in Regional Economic Development (WIRED) grant received by the state early in 2006 brings great promise in terms of tackling this issue.

Nationally, the issue of adequate skills development through the nation's K–12 and university systems is receiving a lot of attention, especially with respect to science and technology training and preparation. As shown in **Figure 3.14**, Maine's universities are also lagging in the enrollment of science and engineering graduate students. On a per capita basis, enrollment has been flat since 2000 and is actually lower than in 1996.

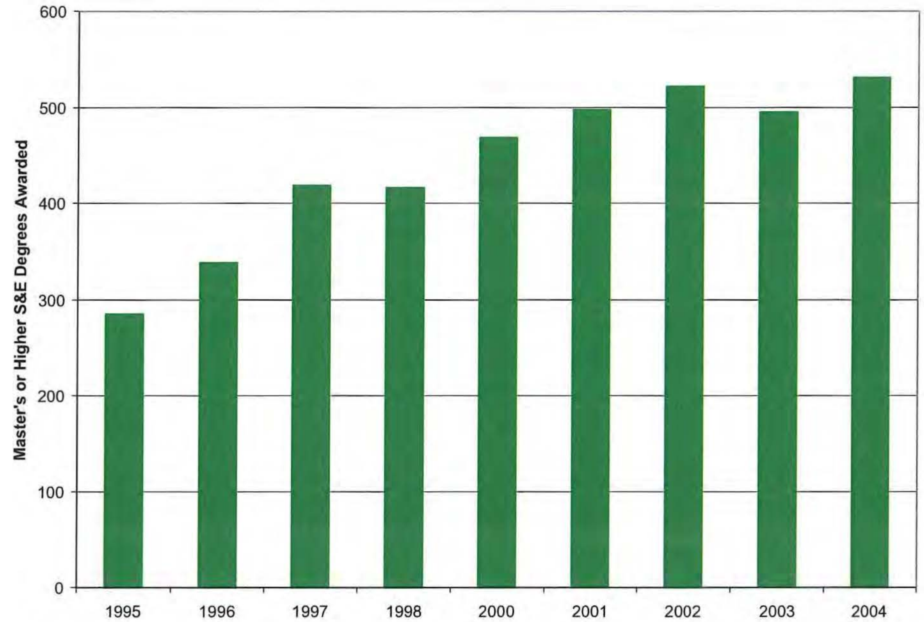
Figure 3.14. Science and Engineering Graduate Enrollments per 1,000 Residents, 1995–2004



Source: S&E Graduate Students - NSF WebCASPAR Database System based on "Survey of Graduate Students and Postdoctorates in Science and Engineering," National Science Foundation and National Institutes of Health; http://webcaspar.nsf.gov

This is critical, because it foreshadows the future number of science and engineering graduates. As shown in **Figure 3.15**, the number of graduates looks strong, especially for master's degrees and higher.

Figure 3.15. Master's or Higher Science & Engineering Degrees Awarded in Maine – 1995–2004



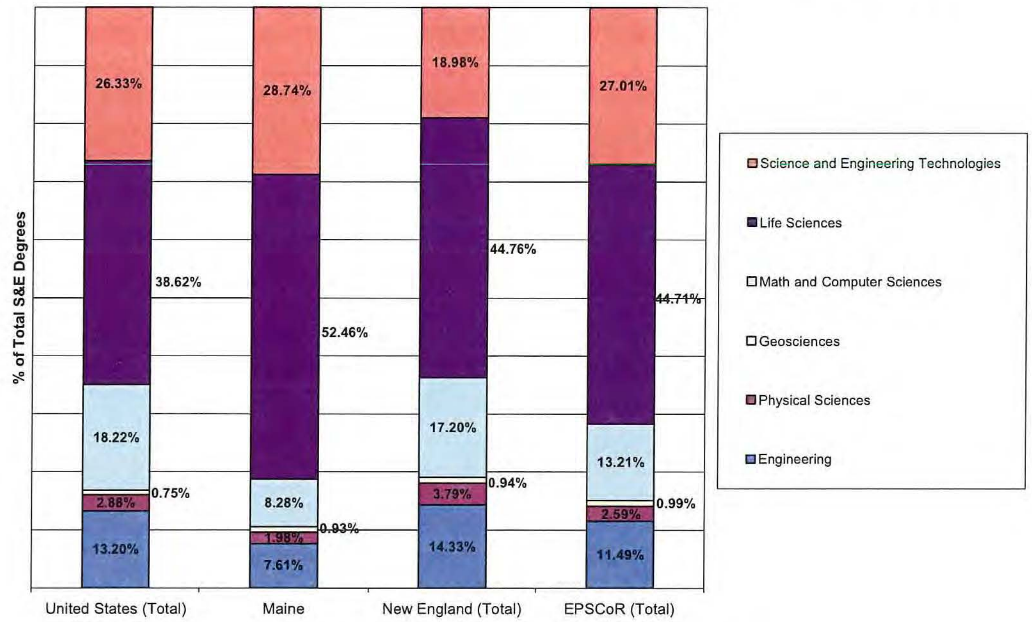
Note: 1999 data is unavailable

Source: S&E Degrees Awarded - Extracted from NSF WebCASPAR Database System, http://webcaspar.nsf.gov, based on the Higher Education General Information Survey and Integrated Post-Secondary Education Data System, National Center for Education Statistics, U.S. Department of Education, www.nces.ed.gov. (Data for 1999 was unavailable.)

Another piece of evidence (**Figure 3.16**) about the production of a workforce prepared to support Maine's research-intensive industries is the disciplines in which degrees are awarded. Maine is producing a large number of life sciences graduates, but a small number of engineers, mathematicians, and computer scientists. This is problematic given the strength of the engineering and information technology sectors in the state.

Therefore, the answer to the question is that Maine's investment in its universities is increasing research capacity and making progress in the production of an educated workforce, but not as consistently as would be hoped, and the investment is producing disappointing results in terms of commercialization of university technology.

Figure 3.16. Science & Engineering Degrees by Discipline, 2004



Source: S&E Degrees Awarded - Extracted from NSF WebCASPAR Database System, http://webcaspar.nsf.gov, based on the Higher Education General Information Survey and Integrated Post-Secondary Education Data System, National Center for Education Statistics, U.S. Department of Education, www.nces.ed.gov. (Data for 1999 was unavailable.)

3.3 Maine's Nonprofit Research Institutions

Are Maine's investments in nonprofit research institutions broadening their impact on Maine's economy?

In 2005–06, Maine invested $12,000,000 in the nonprofit research institutions in Maine, $8,000,000 through the Maine Biomedical Research Fund and $4,000,000 through the Maine Marine Research Fund. Since 1996–97, Maine has supported these institutions with a total investment of $82,112,909, or 27.7% of the total investment.

The following institutions received funds:

- Bigelow Laboratory
- Downeast Institute for Applied Marine Research
- Foundation for Blood Research
- Gulf of Maine Research Institute
- Jackson Laboratory
- Maine Institute for Human Genetics and Health

- Maine Medical Center Research Institute
- Mount Desert Island Biological Laboratories
- Wells National Estuarine Research Reserve

In 2006, these institutions reported[12] a significant impact on the State of Maine attributable to the state's investment in the past ten years. This impact included the following:

- $301,992 in new research equipment
- 33 research and support jobs
- 248 scientific, peer-reviewed journal articles, books and book chapters
- $32,965,792 for 48 new federal research grants (multi-year)
- $73,083,281in expenditures for R&D
- 18 disclosures, 6 patents applied for, and 1 granted
- License income from past agreements totaling $136,472
- 1 new spin-off company with 2.5 jobs

Jackson Laboratory continues to be the largest nonprofit research entity in the state and with its high ranking among NIH research institutes (#7 in 2005[13]), brings prestige and federal funding to the state.

Our concern with this sector remains its limited impact on Maine's economy beyond the direct jobs it provides. Since this sector has limited interactions with the private, research-intensive companies in the state (only 42 research projects with Maine companies reported this year for $4.1 million, 4% of total R&D performed this year), the opportunity for informal technology transfer is minimized. Similarly, although the sector has made some improvements in its formal technology transfer capacity in the past few years, its production of IP, licenses, and spin-off companies is extremely limited given the large volume of research being performed. This is shown in **Table 3.3**.

Maine's investment in this sector continues to benefit the institutions involved, but has not made the hoped-for broader impacts on Maine's technology industry.

[12] The R&D institutions survey and results are included in **Attachments C** and **D**, respectively.

[13] http://grants1.nih.gov/grants/award/trends/resins05.htm

Table 3.3. Predicted and Actual Technology Transfer Metrics for Maine Nonprofit Research Laboratories

	Average U.S. University	Predicted for Maine	Actual for Maine
Disclosures	$2.54m in sponsored research per disclosure	28 disclosures	18
Patents filed	.86 patents filed per disclosure $2.96m in sponsored research per filed patent	24 patents filed	6
Licenses	$9.03m in sponsored research per license	8 licenses	0
License revenue	$115,153 income per license	$921,224 license revenue	$136,472
Start-ups	$100m in sponsored research per start-up	<1 start-up per year	1

3.4 Maine's Research-intensive Companies

Is Maine fostering the growth of research-intensive companies, increasing private sector R&D activity, and building a technology-based entrepreneurial community?

Maine's public investment to support research-intensive companies totaled $4,608,476 in 2005-06 and $66,643,628 the past ten years. These investments, 22.5% of the total over the ten years and 18.4% last year, have been made through the following programs:

- Maine Technology Institute (MTI)
- Center for Innovation in Biomedical Technologies (CIBT)
- Center for Law and Innovation (which administers the Maine Patent Program) (CLI [MPP])
- Advanced Technology Development Centers administered by the Department of Economic and Community Development (DECD)
- Finance Authority of Maine (FAME)
- Maine Aquaculture Innovation Center (MAIC)
- Maine Space Grant Consortium (MSGC)
- Small Enterprise Growth Fund (SEGF).

The private sector survey data reveal that Maine continues to support the growth of research-intensive companies through these programs.

Seven hundred and twelve (712) companies have received assistance from one of these entities in the last five years, and 36.7% have worked with more than one of these stakeholders. Fifty-one (51) percent of the companies responded to the annual survey.[14]

As in previous years, the respondent companies are primarily small (65% have less than 10 employees), but not necessarily start-ups (almost 50% were started since 2000, only 8.9% started in the last year). They are close to evenly distributed by sector, ranging from 7.8% in biotechnology to 16.9% precision manufacturing. The companies are located in all counties in Maine, with the predominant number in Southern Maine (39.6%). Most of the companies who responded (58.5%) have annual revenues of less than $500,000.

The firms surveyed indicated a high degree of satisfaction with the services they have received from the stakeholders and also noted that the assistance was important to them. The mean score for importance of assistance received was 3.31 out of 5.00, somewhere between frequently important and very important. The mean score for satisfaction with assistance received was 4.09, somewhere between satisfied and very satisfied. More specifically, over two-thirds of respondents indicated that they were either satisfied or very satisfied.

The respondents reported a net gain of 437 employees or 6.8% of their workforce in 2006. (Employment growth in Maine overall in 2006 was 0.5% in 2005.) They had a total of 6,774 employees whom they paid $263,005,517 in wages and salaries. The average wage of these employees, therefore, is $38,825. This compares favorably with the per capita income for the State of Maine of $30,808.[15] The average wage paid to the recipients of the state's investments has risen 26% in the past two years. It was $31,821 in 2003 and $30,794 in 2004.

The respondents reported $1,439,990,135 in revenue in 2006, an increase of $221,813,149 (18.2%) over their prior year's revenue. This strong showing suggests that the companies availing themselves of the services offered by the stakeholders are growing faster than Maine's economy.

The companies that responded to the survey reported 437 new employees. Using an IMPLAN model[16] of the Maine economy, we calculate that the companies generated $53,920,416 of direct impact on the Maine economy, $16,995,416 in indirect impact, and $15,659,028 of induced impact, for a total of $86,574,860. When compared to Maine's public investment to support research-intensive companies of $4,608,476, this represents a 14 times return.

[14] The survey instrument itself and complete findings from the survey are included in **Attachments A** and **B**, respectively.

[15] Source: Bureau of Economic Analysis, U.S. Department of Commerce; http://www.bea.gov

[16] See extended discussion of this calculation in Attachment E.

Nearly half (46.9%) of the respondents earn a majority (50% or more) of their revenue from the sale of products and services while 64.5 % reported at least some revenue from R&D. Companies with 100% of their revenue from R&D composed 8.7% of the respondents. In 2003, the respondent companies were mostly all R&D or all products and services; now they are more evenly balanced, potentially indicating a maturing of the R&D companies as they commercialize their products and a revitalization of product and services companies with new R&D.

Another measure of the viability of the research-intensive sector in Maine is the ability of the companies to attract new capital, either debt or equity. Seventy-nine of the respondents to this year's survey received a total of $ 33,167,704 of debt financing, 83.9% from banks. In comparison, in 2003, 51 companies obtained slightly over $40 million of debt financing; in 2004 the numbers were dramatically lower.

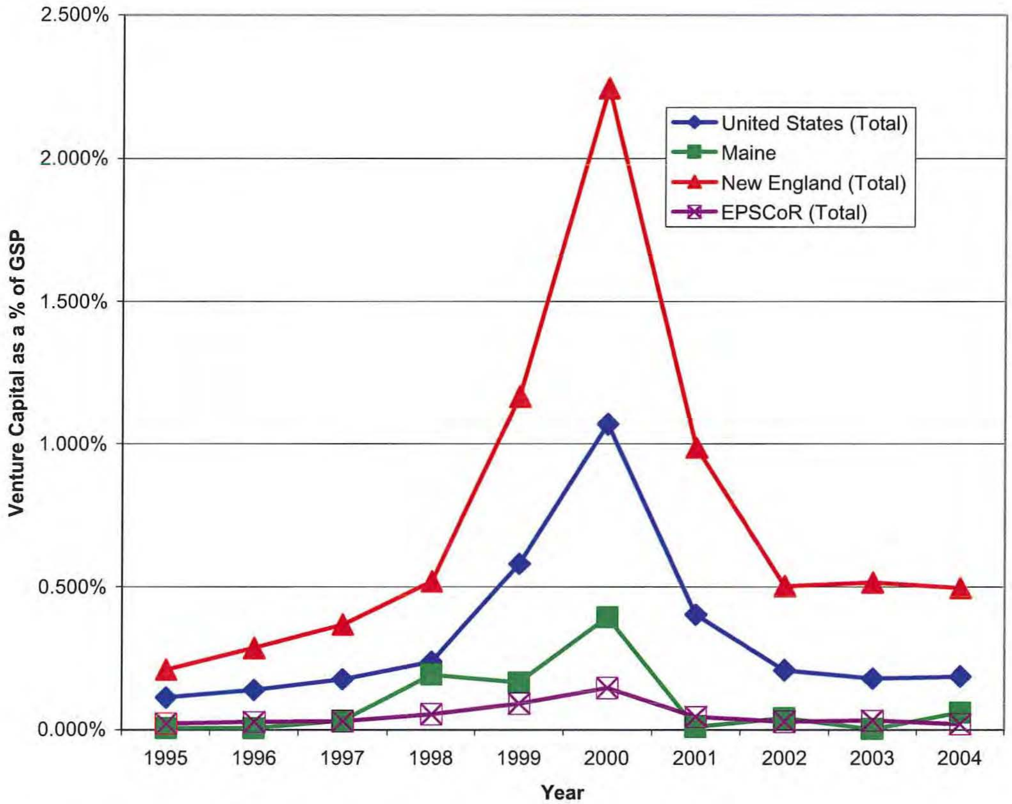
Fifty-three of the respondents also received $31,989,743 in equity financing in 2006, almost 55% from venture capital sources. Interestingly, 20% came from "other" sources than venture capital, state venture funds, angels, or friends and family. In 2003, 56 companies raised almost $60 million in equity, with $35.5 million from venture capital firms. In contrast, only 19 companies raised venture capital in 2004, totaling less than $10 million.

When compared to national and EPSCoR venture capital investments, it is clear that Maine is among the states that fare poorly, but is no worse than its peers. As shown in **Figure 3.17**, all states experienced a huge spike in venture investment in 1999–2000 and a sharp drop thereafter. The one interesting note is that Maine's innovative energy and environmental technology companies are receiving the lion's share (79%) of venture dollars while nationally biotechnology is much stronger. The respondents to the survey received $31 million of the $38 million in venture capital invested in the state.

Federal grants to the respondent companies, another measure of R&D activity, were much lower than in the past with only 16 SBIR or STTR awards worth $6,045,087 reported. In comparison, 27 companies had awards in 2003 worth $6.3 million. Maine has made progress in this area since before the introduction of MTI's SBIR assistance programs in 1998, but it appears that the net value to the state has leveled off and perhaps narrowed in terms of firms affected. This would suggest a constant rate of return for Maine's investment in this program.

When viewed in comparison with national SBIR/STTR trends, Maine is performing very well. **Figure 3.18** shows that Maine's share of SBIR/STTR funds as a percent of gross state product has increased since the MTI programs began in 1998 and grew past the U.S. average in 2004. Respondents to the survey accounted for 63% of the total awards.

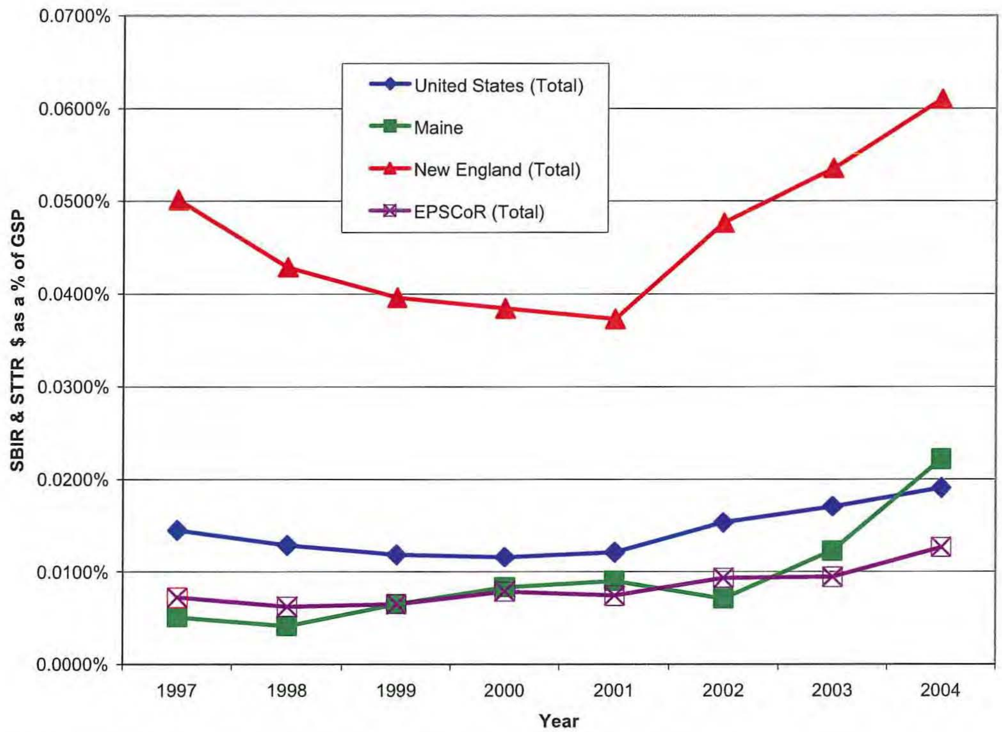
Figure 3.17. Venture Capital Invested as a Percent of Gross State Product – 1995–2004



Source: Venture Capital - MoneyTree Venture Capital Profiles by State; based on PricewaterhouseCooper/Venture Economics/National Venture Capital Association Surveys; http://www.ventureeconomics.com/vec/stats/2006q1/0MAINMENU.html; Data Current as of April 2006

The firms that responded to the survey are producing and protecting their intellectual property. Thirty-three percent of the respondents report that they plan to file or have filed patent protection for the innovations developed through state funding. Thirty four companies reported that they were granted a total of 90 U.S. patents in 2006. Another 37 foreign patents were granted to the respondent companies this year. Forty-four of the companies surveyed had filed for trademark protection in 2006; 27 have registered copyrights. Two companies have used other forms of IP protection. Sixty-six of the responding companies reported that they have licensed or intend to license their IP. As noted in **Section 3.1**, respondents to the survey accounted for 56.6% of the patents issued in Maine in 2005.

Figure 3.18. Total SBIR and STTR $ as a Percent of Gross State Product – 1997–2004



Source: U.S. Small Business Administration, www.sba.gov/SBIR

Maine's private sector, represented by the 369companies that responded to this survey, is growing faster than the rest of the Maine economy, paying wages that are 25% higher and contributing almost $87 million to Maine's economy. It receives 80% of the venture capital invested in the state and accounts for almost 60% of the patents. It is fair to say that Maine's private sector is growing in importance and competitiveness due in some part to Maine's investments in support of R&D.

3.5 Competitiveness of Maine's Strategic Technology Industries

To what extent are these investments increasing the competitiveness of Maine in its key strategic technology and industry areas?

We have two sets of data to answer this question. One is a case study of the Advanced Materials and Composites sector (see **Section 5**), and the other set includes the sector-specific responses to the annual survey.

The case study shows that the composites sector is a growing area in Maine, reflecting the national and international trends. A large market for civil infrastructure and construction applications is emerging, largely dependent on bio-based composites. This is good news for Maine's composites sector, with its predominant research asset being the AEWC Center. The Center has grown substantially in stature and capacity in the four years since we originally reviewed it.[17] AEWC sees several strategic thrusts, including bio-extraction/advanced wood composites; renewable, recyclable materials in construction; advanced composites for marine and boatbuilding applications; composites for security, safety, and military applications; and advanced composites for renewable energy production. These areas are a good match for the industry in Maine and with broader industry trends.

The sector is availing itself of the opportunities available from MTI and the other stakeholders: Companies representing themselves as being in the industry were over 10% of the total. These forty companies reported employment gains of 40 on a base of over 2,600, and revenue gains in 2006 of over $50,000,000 for a total of $443,333,310. The revenue gains were the second largest by percentage (after Marine Technologies and Aquaculture). The composites respondents were able to raise over $6 million in new debt in 2006 but almost no equity. This is a reasonable finding given the product-based nature of the companies in the sector. The composites companies as a whole are not as R&D-focused as companies in some of the other sectors; they were granted eight patents last year and received only $1,025,000 in SBIR/STTR financing.

There are two challenges that the composites sector faces in Maine. One is workforce development. Maine is producing a fraction of the composites industry workers required to support existing employment levels. The Department of Labor's WIRED initiative investment in Maine is expected to help with the workforce issues, but it is too early in the project to assess results.

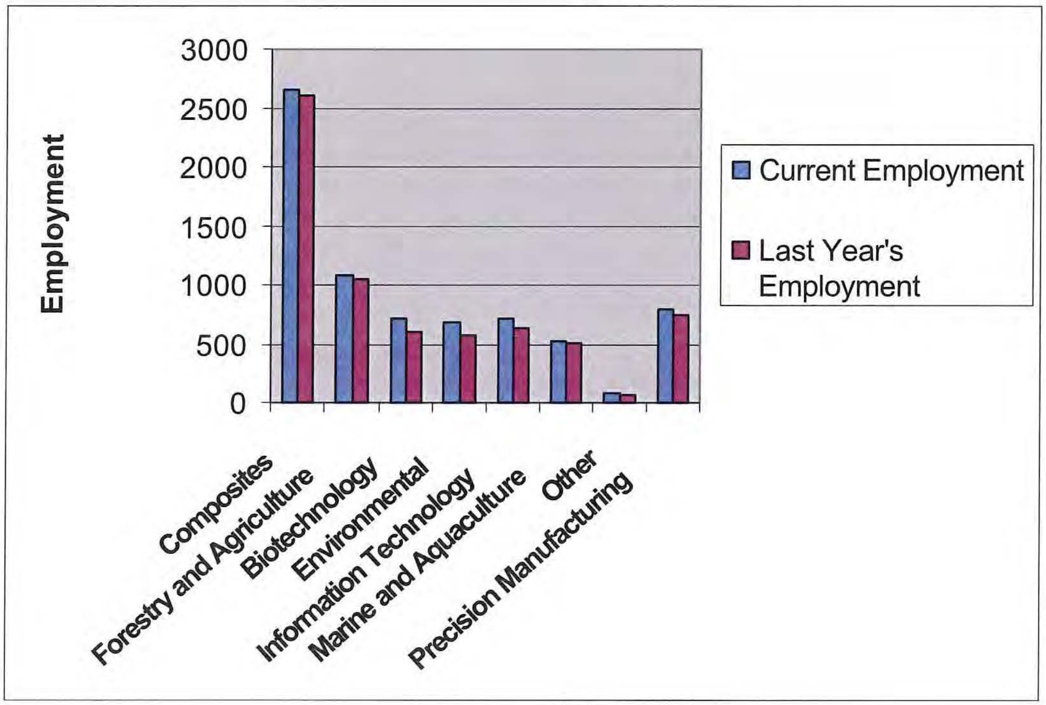
The WIRED grant may also help with the issue of industry support organizations for composites, which is the second major challenge area the industry faces. The Maine Composite Alliance is the most relevant trade association, comprising most of the firms and organizations mentioned in this report. The 2002 MSTF Cluster study mentioned that industry association efforts were weak in composites and this appears to still be the case. Since strong clusters are inclusive of companies, a strong supply network, end users, and research organizations as well as professional services organizations, an industry association is a critical element to a maturing and well-functioning cluster.

[17] See Luger, M.I., Feller, I, and Renault, C. 2001. *Evaluation of Maine's Public Investments in Research and Development*, Chapel Hill, NC: Office of Economic Development, University of North Carolina.

In terms of the other strategic industry clusters, we provide here a snapshot of their relative strengths based on the respondents to the annual survey. Biotechnology, environmental technology, and information technologies had the largest gains in employment in 2006. This is shown in **Figure 3.19**.

Revenue gains among respondents were strongest where employment gains were weakest. Advanced Materials and Composites and Agriculture and Marine and Aquaculture experienced revenue gains of 21.3% and 38.3% respectively. This is illustrated in **Figure 3.20**.

Figure 3.19. Employment by Respondents by Industry Sector



Source: RTI calculations based on respondents to 2006 annual survey. Employment totals add up to more than the actual total because some companies were coded in more than one sector.

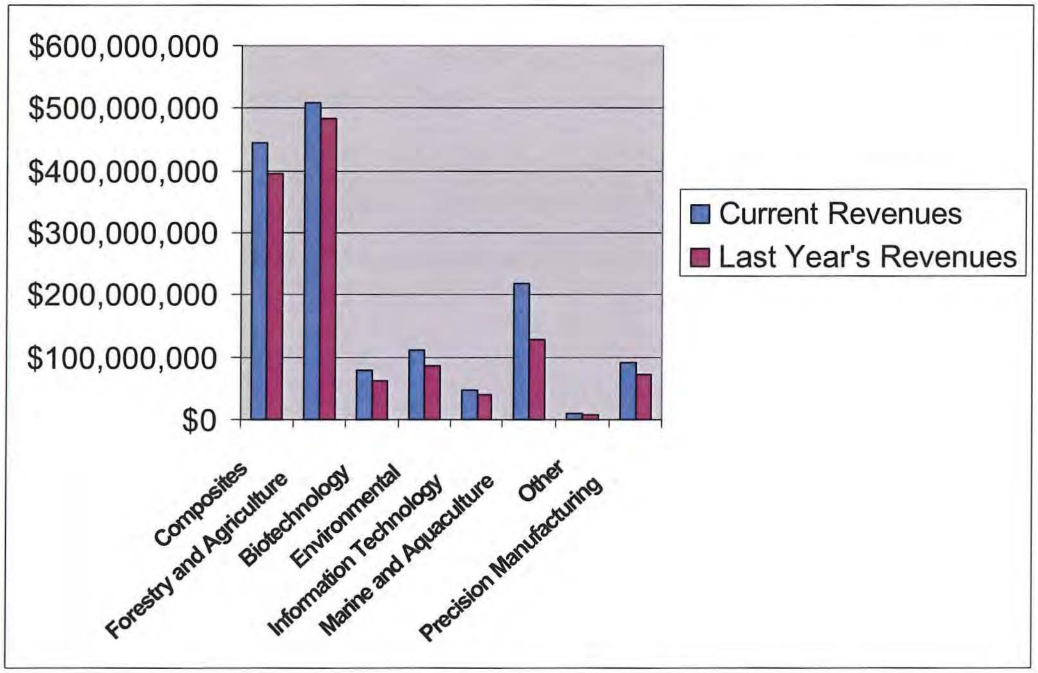
Information technology respondents raised the largest amount of debt capital, totaling $17 million, almost 60% of all the debt raised. On the other hand, a single company raised $15 million in venture capital, skewing the totals because they are in two sectors. Without this one deal, the equity capital picture is skewed toward biotechnology companies who raised $7,686,000 in total.

Not surprisingly, biotechnology, environmental technology, and marine and aquaculture have the highest number of new patents granted in 2006 since their technologies are most patentable. Information technology companies reported the most copyrights.

Information technology companies did the best on federal R&D financing in the form of SBIR/STTR awards. They received over $3.4 million in 2006.

Overall, the sectors in Maine, represented by their companies, are making progress as indicated by these metrics. They are all growing faster (both employment and revenues) with higher wages than the average Maine company.

Figure 3.20. Revenue Gains by Respondents by Industry Sector



Source: RTI calculations based on respondents to 2006 annual survey. Employment totals add up to more than the actual total because some companies were coded in more than one sector.

4. Recommendations

Overall, Maine's investments have improved the state's position in science and technology. Our recommendations are based on the goals set out in the Science and Technology Plan, best practices in innovation-based economic development, and deficiencies in the current implementation.

1. Maine needs to continue to invest in R&D, and in fact, needs to accelerate its investment in order to (a) meet the goal of $1 billion in R&D by 2010 and (b) improve its relative position in the innovation economy. While the past investments have proven to be fruitful, investments must continue to be made to keep pace with the other states and the rest of the world.
2. Future investments in R&D should include a larger percentage for the programs that support the private sector. This should reverse the trend of decreasing industry performance of R&D and increase all the indicators of commercialization of new knowledge. Further, investments in programs that provide technical assistance in commercialization have been shown here, and in other states, to increase the economic impact substantially compared to investment in research capacity alone.
3. Future R&D investments should require more commercialization outcomes from universities and nonprofit-performed R&D. These entities should be encouraged to perform industry-sponsored R&D, to protect IP, and to license IP to in-state companies, both start-ups and established firms. Other commercialization outcomes which are significant include attracting related industry to locate in Maine, contributing to specific workforce training for industry and the development of new products, processes and/or services.
4. The workforce needs of Maine's research-intensive industries should be studied and specific recommendations made for curriculum enhancements at Maine universities and community colleges.
5. The technology transfer capacities of the universities and nonprofit research institutions should be assessed again (a report was done by USM in 2001), issues identified, and actions recommended to increase technology transfer outcomes. Models to consider include shared technology transfer capacity that can support institutions without sufficient R&D to support their own technology transfer staff such as currently provided by the CLI. The provision of adequate staff and patent funds has been demonstrated to be correlated with technology transfer outcomes such as patents, licenses and start-ups.

6. To support the composites sector, we recommend the following:

   a. Continue to fund the AEWC, with a focus on providing the matching funds needed for the organization to win large federal grants and contracts. These federal funds will support the development of the research infrastructure that supports the entire sector.

   b. Identify methods, perhaps within MTI, to encourage Maine companies and AEWC to work together to a greater extent. This collaboration will help bring new technologies into Maine companies, train students who may stay in Maine, and strengthen the innovation flow from the university into the economy.

   c. Support the Composites Technology Center so that full-time managers can be hired for both the Sanford and Greenville incubators. Move the focus from filling up the buildings to creating successful composite companies that will grow in Maine. Alternatively, hire subject matter experts to support start-up composites companies regardless of which incubator they reside in.

   d. Provide support for the Composite Alliance to plan for the sustainability of their organization. This may be best accomplished through the merger of the organization with another one such as the Maine Marine Trade Association. This would allow the organization to reach a scale that would support full-time staff and activities such as "e" below.

   e. Follow the model of other Maine sectors such as biotechnology and boatbuilding and market the advanced technology being developed at Maine composite companies nationally and internationally. Take a "Composites in Maine" booth, and companies, to national and international composites shows; use these to recruit new companies to the area to build capabilities.

   f. Provide similar types of programs to support other critical sectors in Maine's economy.

5. Composites Case Study

5.1 Executive Summary

"Composite technologies are used in a wide variety of applications, resulting in a highly fragmented and regionally oriented industry," stated one of our interviewees, nicely summing up the challenges of supporting this sector in Maine. Based on interviews with nine companies and support organizations, this case study updates the earlier work done by the University of Southern Maine.

We find that composites technology is still a growing area (around 7% a year), with a total market approaching $50 billion annually. Maine's largest segments, boatbuilding and marine infrastructure and construction materials, mirror the markets nationally and internationally.

According to the Advanced Composite Manufacturers Association, composite suppliers are actively developing new products for the civil infrastructure, considered by many to be the largest potential market for fiber-reinforced polymer (FRP) composites. In addition, construction applications are also expected to grow because of the influence of bio-based composite materials.

As noted in the earlier cluster report, the Advanced Engineering Wood Composites (AEWC) Center at the University of Maine is the dominant innovation asset in this technology sector. We find that the AEWC has grown substantially in capacity and stature in the intervening four years. And, our analysis reveals a significant level of research being done by industry, much of it supported by the Maine Technology Institute (MTI).

Going forward, AEWC sees several strategic thrusts including bio-extraction/advanced wood composites; renewable, recyclable materials in construction; advanced composites for marine and boatbuilding applications; composites for security, safety, and military applications; and advanced composites for renewable energy production. We note that these research themes are well matched with the national and international trends in the composites market.

A large challenge for the composites technology sector is workforce development. Maine is producing a fraction of the composites industry workers required to support existing employment levels. Few students at any level of education are exposed to composites as a career option, and employers are faced with having to recruit and train workers themselves.

The Department of Labor's Workforce Innovation Regional Economic Development (WIRED) initiative investment in Maine is expected to help with the workforce issues, but it is too early in the project to assess results. The WIRED grant may also help with the issue of industry support organizations for composites. The Maine Composite Alliance is the most relevant trade association, comprising most of the firms and organizations mentioned in this report. The 2002 MSTF Cluster study mentioned that industry association efforts were weak in composites, and this appears to still be the case.

5.2 Introduction

The Evaluation of Maine's Public Investments in R&D poses five key questions, four of which have been addressed. The fifth question is: *To what extent are these investments increasing the competitiveness of Maine in its key strategic technology and industry areas*? To answer this question, the evaluation team will conduct a series of case studies, focusing on a single technology area each year. This year, the case study is focused on advanced materials, specifically composites.

In 2002, the University of Southern Maine completed a study entitled, *Assessing Maine's Technology Clusters.*[18] Their analysis of the Advanced Materials cluster concluded that the sector was bifurcated between different types of materials. In one area, composites using man-made fibers, the study stated, "Maine has developed strong products with a high degree of research and development, particularly in boatbuilding." In the other area, composites built upon both natural and man-made fibers, such as composite wood products, the study reported, "the sector is still at an early stage of evolution. Early research has demonstrated technical feasibility … but this has not been fully demonstrated in the market." The divisions also limit communications between organizations and "may limit future development of the technologies involved."

The objective of this case study is to assess the progress being made in the competitiveness of the advanced materials sector in Maine, specifically composites, since the earlier report was written. The timing is fortuitous, as Maine has just become the recipient of a $15 million, three-year Department of Labor grant under the WIRED initiative. Educational and training programs, marketing, and research and development within Maine's boatbuilding, composites, and marine industries will be the main focus.

This case will look at the industries supported by composites technology and the associated research community. The case is by nature impressionistic, as the scope does not encompass a full evaluation of the progress in this technology sector. However, we

[18] Colgan, C.S., Baker, C, Butterfield, N. and Cote, M. 2002. *Assessing Maine's Technology Clusters*. Portland, ME: Maine Science and Technology Foundation.

believe that this case captures the important elements of the innovative composites community in Maine.

This report involves four separate elements: national and international market trends, the research environment, specific companies in Maine, and Maine's composites-enabled workforce. Using a combination of the four analyses, we will assess the improvements in competitive position made to date and make recommendations to enable future progress.

5.3 Composite Technology Overview

5.3.1 Composite Technology Defined

In the broadest definition, a composite material is one in which two or more materials that are different are combined to form a single structure with an identifiable interface. Concrete is a composite, as are a range of other metal and ceramic type composites. The most commonly used interpretation of composites, however, and that which is most relevant to the Maine composites industry, is where a "composite" includes a polymer as the matrix material, and which contains a fiber reinforcing agent—or in other words, an FRP composite.

Polymer matrix materials are either thermoplastic polymer, including polyvinyl chloride, polypropylene, polyamide, polyesters, or polycarbonate; or thermoset polymer, such as polyester, vinyl ester, epoxy, or phenolic. Thermoset polymer composites are by far the most commonly used matrix material today. For the reinforcing agent, fiberglass is certainly the most commonly used, with carbon and aramid (Kevlar) fibers typically used in composites where greater strength, stiffness, or lighter weight are needed. Fiber reinforcements can be used in various forms, including woven fabrics, chopped fiber mats, unidirectional filaments, or prepregs (fiber structures pre-impregnated with polymer resins). FRP composites may also contain fillers, additives, or core materials to affect cost or performance characteristics. Commonly used composite manufacturing methods include pultrusion, resin transfer molding (RTM), vacuum assisted resin transfer molding (VARTM), compression molding, filament winding, and hand lay-up.

FRPs in themselves are quite varied, ranging from high-volume, low-tech products such as chopped glass composite that might be used in making a storage tank, for example, to highly engineered, multi-layer, carbon fiber-based composites, heat-cured under pressure, that are used in demanding marine or aerospace applications.

5.3.2 Applications of Composite Technology

Composites were first used in the 1940s for defense applications. In the 1950s and '60s, composites grew into other applications, with marine use being the dominant market during that time. In the 1970s, automotive applications became the dominant market, as it remains today. The primary advantages driving the use of composites include high strength, stiffness, and toughness as well as lighter weight, durability, and often lower cost. Composites are generally used in structural applications. Major markets today are automotive, marine, construction, aerospace, appliance, consumer (sporting goods), wind energy, corrosion (pipes, tanks), and electrical/electronics applications.

The American Composite Manufacturers Association[19] reports that the composite manufacturing industry includes over 100,000 employees with revenues on the order of $15 billion per year. On a weight basis, transportation is the largest market at 32%, construction markets at 20%, corrosion-resistant markets at 12%, and marine and electrical both at 10%—for an estimated 4 billion pounds in the United States in 2004. With suppliers and composite applications included, the total market is on the order of $50 billion per year. Advanced composites, those based on carbon and aramid fibers as well as selected types of polyethylene or glass fibers, account for a relatively small percentage by volume of the total composites market. By value however, advanced composites represent a much more substantial portion of the market.

As a comparison, the global recreational boating industry was estimated to be $24 billion in 2005, with the United States representing a major market segment. Global growth is expected to be on the order of 7% per year through 2010 and, most recently, European markets have been growing fastest. FRP is the dominant construction material for recreational boats, with aluminum, steel, or wood used only in niche segments.[20]

The majority of fiberglass boats are manufactured currently using open mold processes. However, pressure from environmental regulators is driving change. By August 2004, U.S.-based boat builders were required to further control their air emissions and to increase control on pollutants according to Environmental Protection Agency (EPA) regulations. As a result, closed mold processes are becoming more common.[21]

Over the next several years, wind energy, transportation, and construction are expected to be the dominant markets driving growth in the use of composite materials. Some niche applications such as thermoplastic composite applications, infrastructure applications, military and defense applications, industrial rollers, fuel cells, and others are also expected to show healthy growth.[22]

[19] http://www.acmanet.org/professionals/2005-Composites-Industry Statistics.pdf#search=%22composites%20industry%20statistics%22

[20] Opportunity Assessment for Composites in Global Boating Industry 2005-2010, December 2005 (http://www.e-composites.com/marketmarinecomp.asp)

[21] http://www.e-composites.com/marketmarinecomp.asp

[22] Global Composites Market 2004 – 2010: Opportunities, Market and Technologies, February 2005, http://www.acmashow.org/home.cfm.

According to the Advanced Composite Manufacturers Association, composite suppliers are actively developing new products for the civil infrastructure, considered by many to be the largest potential market for FRP composites. Concrete repair and reinforcement, bridge deck repair and new installation, composite-hybrid technology (the marriage of composites with concrete, wood, and steel), marine piling, and pier upgrade programs are some of the applications currently being explored.[23]

Biobased composite materials are expected to play an increasingly important role in a number of applications. The interest in and potential of these emerging materials is discussed in the review paper, "Biobased Structural Composite Materials for Housing and Infrastructure Applications: Opportunities and Challenges."[24] Researchers at Oak Ridge National Laboratories and elsewhere are attempting to drive down the costs of advanced composite materials, including carbon fiber materials, for example. Oak Ridge is exploring the use of lignins from pulp and paper waste streams as a raw material for carbon fiber production.[25]

5.4 Maine's Innovation Assets in Composites

As noted in the earlier cluster report, the AEWC Center at the University of Maine is the dominant innovation asset in this technology sector. However, our analysis reveals a significant level of research being done by industry, much of it supported by MTI.

5.4.1 Advanced Engineered Wood Composites Center

The AEWC Center at the University of Maine, Orono, is the primary academic entity involved in composites research in Maine. Started in 1997 with a $3 million National Science Foundation (NSF) Experimental Program to Stimulate Competitive Research (EPSCoR) grant and a $1 million match from the State of Maine, AEWC has grown to a world-class research center with a 38-member staff, 23 graduate students, 63 undergraduate students, and close to $6 million in sponsored research.

Table 5.1 shows the evolution of AEWC along a number of key measures of research capacity.

After the initial start-up period, the average proposal size increased from $242,627 in FY2002 to $660,835 in FY2005, a 2.7 times improvement. The average award increased 2.4 times from FY2000 to FY2004 before decreasing to $392,333 per award in FY2005. This is still up 1.8 times from the beginning of the center.

---

23 http://www.mdacomposites.org/mda/overview.html

24 http://www.pathnet.org/si.asp?id=1076#search=%22chopped%20glass%20fiber%20composites%20applications%22

25 http://pubs.acs.org/cen/coverstory/8235/8235composites.html

Since 1997, the Center has raised $46.85 million, $35.4 million dedicated for research. Using standards derived from an analysis of overall data reported annually to the Association of University Technology Managers (AUTM), the eight patents issued to Center staff and fifteen patent applications pending is reasonable.[26] AEWC's nine start-ups compared very favorably to the AUTM averages, which would have predicted no start-ups so far.

The Center has moved from being built on set-aside funds to a significant level of funding, primarily from competitive federal proposals, indicating a high level of technical competence. In addition, the Center is supporting a large number of undergraduate and graduate students from a wide array of departments (mechanical engineering, civil engineering, forestry management, environmental engineering, electrical engineering, chemical engineering, wood science, forestry, business, and art), demonstrating a dedication to training the next generation of composite engineers. The level of publications in peer-reviewed journals is also consistently high, as is the level of presentations made to academic and practitioner audiences. This also demonstrates the quality of the work being done and the influence of the Center in certain key technologies.

AEWC has worked with some important start-up companies in Maine, including Maine Marine Manufacturing (see Boatbuilding **Section 5.5.1** below), and Harbor Technologies (see **Section 5.5.2** below).

[26] Averages from the AUTM U.S. Licensing Survey: FY 2004 (www.autm.net) are shown in **Table 3.2**. AEWC has an average over its entire history of $1,539,130 per patent application and $4,425,000 per patent issued. Therefore, on patents filed, the Center has done very well, but lack of progress on its patent applications over the past two years is skewing its outcomes for patents issued. On the other hand, given that the Center has had approximately $30 million in sponsored research, its record of nine startups is extraordinary.

Table 5.1. AEWC Metrics July 1, 1999 – June 30, 2006[27]

	July 1, 1999 – June 30, 2000	July 1, 2000 – June 30, 2001	July 1, 2001 – June 30, 2002	July 1, 2002 – June 30, 2003	July 1, 2003 – June 30, 2004	July 1, 2004 – June 30, 2005	DRAFT July 1, 2005 – June 30, 2006	Total[28]
Proposals, #	30	20	19	19	14	14	10	126
Proposals, $	$9,220,792	$8,543,826	$4,609,917	$6,433,377	$6,609,366	$9,251,695	$11,611,538	$56,280,511
Awards, #	18	18	16	10	7	12	5	86
Awards, $	$3,888,645	$4,261,525	$3,917,813	$3,814,555	$3,613,166	$4,707,999	$5,761,138[29]	$29,964,841
Industrial projects, $		$139,846	$169,068	$280,237	$328,246	$259,662	$404,820	$1,581,879
Industrial projects, #		45		37	28	34	32	176
ME companies	3	3	8	14	15	1	9	53
Undergrad students	29	52	96	86	75	68	63	n/a
Graduate students	40	12	16	20	24	25	23	n/a
# Peer publications[30]	29	18	20	42	43	28	18	198
Patents awarded/total	1/1	2/3	1/4	4/4	1/8	0/8	0/8	8
Patents pending	1	3	4	2	4	8	5; 2 being filed	n/a
# staff	24	23	31	32	36	30	38	n/a
Start-ups	0	0	0	1	6	1	1	9

Note that our totals for proposals only count the ones submitted in the year of the report; their numbers often include proposals submitted (and counted in a previous year, if they are awarded in the current year).

[27] Data compiled by RTI International from AEWC Annual Reports.

28 Numbers of students and staff are not totaled as many individuals have been there for multiple years.

29 This includes $1.8 million for DOL WIRED grant.

30 Not counting proceedings and publications in press or only accepted, but not published.

AEWC has been awarded eight patents and has fifteen pending. A list of their patents is included in **Table 5.2.**

Table 5.2. Patents Issued to the AEWC, University of Maine

Patent Title	Inventor(s)	Award Date	Number
Prestressing System for Wood Structures and Elements	Dagher, H.J., Abdel-Magrid, B.	January 9, 2001	6,170,209
Resin Starved Panel Application for Glulam Beams	Dagher, H.J., Abdel-Magrid, B., Shaler, S.M.	August 28, 2001	6,281,148
Modular Fiber Reinforced Polymer Composite Structural Panel System	Lopez-Anido, R., Hota, G. V. S..	October 30, 2001	6,309,732
Modular Fiber Reinforced Polymer Composite Deck System	Lopez-Anido, R., Hota, G. V. S.	September 24, 2002	6,455,131
Building Construction Configuration	Dagher, H.J.	December 10, 2002	6,490,834
Wood Composite Panels for Disaster-Resistant Construction	Dagher, H.J., Davids, W.G.	April 2003	European Patent
Modular Fiber Reinforced Polymer Composite Deck System	Lopez-Anido, R., Hota, G.V.S., Barbero, E.J.	April 8, 2003	6,544,624
Wood Composite Panels for Disaster-Resistant Construction	Dagher, H.J., Davids, W.G.	March 2, 2004	6,699,575

Source: AEWC Annual Reports and US Patent Office, www.uspto.gov.

The AEWC aims to have a balance of several types of research. They wish to have approximately 50% basic research and 50% engineering or applied research. A small percentage of the total budget of the AEWC, around $400,000 per year, comes from small engineering projects for industry. These projects, about one-third of which come from Maine companies, allow the Center to provide invaluable practical assistance to industry and practical experience for University of Maine students. The AEWC has also funded development work at Maine composite companies in support of federal projects being conducted at AEWC, and this offers another example of how the Center is supporting composite innovation in the state.

Going forward, the Center sees several strategic thrusts. While these are still in draft form, they are indicative of the thinking of the center's senior leadership.

- Bio-extraction/advanced wood composites. This is a family of advanced wood-based composites, such as oriented strand lumber, in which bio-extraction becomes an additional objective of the manufacturing process. Bio-based resins, chemicals, nanomaterials, or fuels are extracted prior to manufacturing the wood-based composites.

- Renewable, recyclable materials in construction. These include extruded structural composites using bio-polymers and bio-fillers, or recycled materials. Such materials can represent next-generation wood-plastic composites.
- Advanced composites for marine and boatbuilding applications. This research focuses on advanced high-speed boat designs for improved wave impact, fuel, and vibration response in commercial and defense-related applications.
- Composites for security, safety, and military applications. These include blast, ballistic, and hurricane-resistant building construction using hybrid wood/non-wood composites and tamper-resistant materials for security applications.
- Advanced composites for renewable energy production, including, for example, next-generation windmill blades and composites for tidal or wave energy generation.

We note that these research themes are well matched with the national and international trends in the composites market.

5.4.2 Other Sources of Innovation in Maine

Maine has a finite level of R&D based innovation in the composites area, limited to the research activities at the AEWC and in a handful of companies.

One big player, General Dynamics Bath Iron Works (BIW), has participated in a variety of research projects sponsored by the U.S. Navy and focused on composites, but appears to have closed their lab. In 2000, the Office of Naval Research awarded BIW $9.2 million to design an advanced propulsion system for a demonstration vessel. The propulsion motor was to be housed in a pod fabricated with advanced composite materials designed by AEWC.[31] It appears that this award built upon earlier work by Michael McClain and Bruce Jackson on the use of composites on Navy vessels.[32] A few years later, Bruce Jackson again presented at a national conference, this time on the development of marine composite to steel joints.[33] This work appears to still be important.

BIW is implementing new technology for composite-to-steel adhesive joints for the DD(X), the Navy's next-generation multi-role surface combatant. This technology, which was developed with a large team of researchers from across the country, was the focus of a 2005 Department of Defense Manufacturing Technology Achievement Award.[34] In

[31] BIW press release, July 2, 2000. http://www.gdbiw.com/news_and_events/pressrelases/2000_archive/2000_07_02_01..htm.

[32]. A technical paper entitled General Repair Considerations for Composites Aboard Surface Ships was delivered by Michael McClain and Bruce Jackson from BIW at the 33rd meeting of the Society for the Advancement of Material and Process Engineering, November 2001. http://www.sampe.com/store/paper.sapx?pid=2166

[33] Proceedings of ShipTech 2004, http://www.nsrp.org/st2004/st2004.html.

[34] See www.dodmantech.com/index.asp.

contrast, BIW is one of two teams competing for the final Littoral Combat Ship (LCS).[35] The BIW team is offering a trimaran design that is based on a steel hull. Designs from two other companies that employed composites were not chosen for the final round of the competition.

Another marine design cluster of innovation is the team of Hodgdon Yachts, AEWC, and a Hodgdon spin-off, Maine Marine Manufacturing. This team has moved from a concept for a composite-hulled high-speed craft for special operations for the Navy to a contract to build a prototype. The team re-engineered the hull to maximize performance and then researched a variety of composite materials to match the Navy's requirements. There is also a marine infrastructure cluster of innovation with AEWC, Harbor Technologies, and Kenway.

In the field of construction products, Correct Building Products is an innovator in Maine, with two patents awarded. Riley Benoit has a patent on an oriented strand board (OSB) stud. Several companies are using textile-based reinforcements to increase composite performance. These companies include TexTech and Baychar Holdings. Other recent composite patent awards were made to Maine companies Hydrophilix, Fairchild, Pioneer Plastics Corporation, and Saint Gobain (formerly Brunswick Technology Inc.). About ten individual inventors are working on products based on composites as diverse as multi-hull watercraft, skis, shoes, and golf equipment.

5.5 Maine's Industry that Uses Composite Technology

In Maine, the users of composite technology are split among a number of applications including boatbuilding, marine infrastructure, and building products. Each application area is described below.

5.5.1 Boat Building

Maine's boatbuilding industry reportedly generates approximately $650 million annually, with nearly 450 companies making up the industry.[36] State and industry plans hope to grow this market to over $1 billion in the next ten years.[37] Composites are being used in a wide variety of boatbuilding applications in Maine from recreational to military customers.

The recreational boat builders—Hodgdon, Hinckley, Sabre, Kenway (Maritime Skiffs), and Lyman-Morse, for instance—are all using composites to some degree. All except Kenway are building high-end customized yachts that include a substantial amount of

[35] http://www.defenseindustrydaily.com/2006/06/the-usas-new-littoral-combat-ships-updated
[36] www.mainebuiltboats.com
[37] http://www.aewc.umaine.edu/News/govbal.pdf

composite materials. The major innovation here is the use of resin infusion in closed mold processes. Traditional open molding of composite parts is known to emit styrene at levels above current standards. Compared to the older technologies, resin infusion processes, in particular vacuum infusion, provide a means to significantly reduce emissions in the workplace. This is a major benefit since the EPA is tightening their enforcement of compliance with volatile organic compound (VOC) emission limits. In 2004, the EPA found that over 34% of large boat manufacturing and repair facilities had violated at least one environmental requirement in the last two years.[38] In addition, this process yields stronger and higher performance boats.

Hodgdon has developed its own proprietary process as a specific example of innovation, and it features a cold-molded structure with infused carbon fiber hull plating. This allows the flexibility to adapt to the hull form as needed for design purposes, while the cored carbon skin ensures that the boats will be light, yet stiff and responsive.

We note, however, that while the vacuum infusion process is new to Maine and boatbuilding in general, it is not cutting edge technology, as it is also being employed by composite manufacturers all over the world. Therefore, the use of this technology by Maine recreational boat builders merely allows them to maintain their competitive position.

In terms of shipbuilding, it appears that General Dynamics Bath Iron Works has been involved with the use of composites on Navy ships. We note, however, that BIW is not currently involved with the Maine Composites Alliance although they have worked with AEWC in some phases of their research. According to AEWC, BIW closed their composites lab this year.

In between these two well-known Maine boatbuilding sectors is a promising new project called the Mark V.1 Special Operations Craft. A $13 million, four-year contract has been awarded to the joint venture between Maine Marine Manufacturing, Hodgdon Yachts, and AEWC to develop a new, versatile, high-performance combatant craft for the Navy, primarily special operations personnel such as SEAL combat swimmers. To date, the project has included an innovative hull design as well as the incorporation of new composite laminates that greatly increase the performance characteristics of the craft. "The primary goal is to use specialized composite materials in the hull and elsewhere that can absorb the shock created by high-speed travel across the water's surface. By dampening the effect of the boat's repeated impacts as it skims across the waves, the new materials can help to protect the crew from back, neck, and joint injuries."[39]

[38] http://www.compositesworld.com/ct/issues/2004/October/579/1, accessed September 12, 2006.
[39] http://www.umaine.edu/news/article.asp?id_no=388, accessed September 12, 2006.

In August 2006, the team announced that it had successfully completed the infusion of the composite hull for the U.S. Navy's Mark V.1 demonstrator sea craft. The infusion is a major milestone in the project. With the infusion of the MK V.1 hull complete, Maine Marine is on track to complete the construction, outfitting, and delivery of the craft to the Navy by late 2007.[40] This is an exciting development for Maine as it significantly broadens the potential market for boatbuilding, getting Maine manufacturers into a new multi-million dollar market for combatant ships, and also opens the door into other larger commercial, high-speed vessels.

5.5.2 Marine Infrastructure

Building upon Maine's marine expertise and AEWC's expertise in composites in civil infrastructure, several companies, led by Harbor Technologies, are now manufacturing pilings, docks, and marine walls made of advanced composite materials. Composites are increasingly the material of choice for these applications because they are environmentally friendly and offer significant performance improvements. Traditional materials such as wood, steel, and steel-reinforced concrete deteriorate (rot or corrode), creating both environmental and structural problems. Composites are resistant to such deterioration, and also offer additional advantages of easier installation and the elimination of toxic coatings or chemicals used to improve corrosion performance of the more traditional materials.

Harbor Technologies, now located in the Brunswick Industrial Park, was founded by Martin Grimnes who was the founder, CEO, and Chairman of Brunswick Technologies (BTI), a leading manufacturer of composite reinforcements. BTI was purchased by Saint-Gobain in 2000 and is still operating in Maine.

5.5.3 Building Products

Another sector of Maine's industry that is using composite materials is building products. Correct Building Products, for instance, offers decking, railings, dimensional composite lumber, and accessories. These products are all made from 60% recycled hardwood sawdust and 40% polypropylene. Their products are an excellent example of the use of a waste material (sawdust) in composites. Correct Building Products has been very successful and was named to the Inc. 500 list of fastest-growing companies in 2005.

Building products, and especially dimensional lumber, is a growing area of research for AEWC. Their innovative projects for the military—developing lightweight, easy-to-install and easy-to-maintain structures, from reinforced tents to bridge trusses and (potentially) airplane hangars—are taking the technology to the next step.

[40] http://boothbayregister.maine.com/2006-08-31/u_s_navy_demonstrator.html, accessed September 12, 2006.

5.5.4 Other

Kenway Corporation is moving toward a product line that is heavily dependent upon composites with a focus on coal power plants and wastewater treatment plants, both slated to undergo major retrofitting and upgrading. Composites are often a preferred material for these types of products, and federal commitments for billions of dollars should support a 10- to 15-year market expansion.

5.5.5 Industry Resources

The composites sector is supported by a number of resources, some state-supported and others privately funded. As one of the state's seven targeted technology sectors, composite materials technology is one of the sectors supported by the Maine Technology Institute (MTI) and of the Advanced Technology Development Centers (ATDC) program. Although the ATDC incubators are no longer limited to the technology originally identified with each location, there are two incubators that are related to the composites sector. The Composite Technology Center is a 501(c)(3) that manages both the Sanford and Greenville incubators. Both are managed by Gordon Davis on a part-time basis.

On the private side are three relevant organizations. Maine Built Boats (www.mainebuiltboats.org) is an organization focused on building the brand recognition for the recreational boat builders in Maine. Many of their members are also members of the Maine Marine Trade Association (www.mmta.org), which represents all the interests related to recreational boating, including boat builders, repair yards, marina, architectural firms, sail makers, and dealerships.

The Maine Composite Alliance is the most directly relevant trade association, comprising most of the firms and organizations mentioned in this report. While the organization has been around for many years, it has been relatively inactive. With the advent of the WIRED initiative, there has been resurgence in this organization and new management. The challenge is that the Alliance is largely made up of small firms and is managed by members rather than a permanent, dedicated staff. The 2002 MSTF Cluster study mentioned that industry association efforts were weak in composites, and this appears to still be the case.

5.6 Maine's Composite Workforce

Many of the companies that we spoke with mentioned workforce development as a key barrier to growth in Maine. The companies discussed how they have to recruit new employees with the right basic skills, sell them on the value of receiving composites training, and then provide the training themselves. Several of the interviewees noted that training being provided by the community college system is not relevant to state-of-the-art composites, and is of little value. Some suggested that Maine look to the American Composite Manufacturers Association as a source for training programs.

The WIRED grant received by the state earlier in 2006 brings great promise in terms of tackling this issue. See **Section 5.6.3** below.

5.6.1 Composite Workforce Needs

The composite industry crosses several industries and therefore can include an array of specific occupations and skills. There are a few key occupations for this industry. They are mechanical engineers, material scientists, chemists, material testers, tool makers, and services such as computer-aided design/computer-aided manufacturing (CAD/CAM) designers, as well as the skilled technicians.

Table 5.3 shows the occupation descriptions from The Bureau of Labor Statistics outlining the skill requirements and education programs Maine should use as a benchmark for considering its workforce training efforts.

Table 5.3. Composite Occupation Requirements

Occupation	Degree Requirements	Skill Sets
Mechanical Engineer	A bachelor's degree in engineering is required for almost all entry-level engineering jobs. Graduate training is essential for engineering faculty positions and many research and development programs. Many engineers obtain graduate degrees in engineering or business administration to learn new technology and broaden their education.	Testing skills for tools, engines, machines, and other mechanical devices is key. They should be creative, inquisitive, analytical, detail-oriented, able to work as part of a team, and able to communicate well, both orally and in writing.
Chemist and Materials Scientist	A bachelor's degree in chemistry or a related discipline is the minimum educational requirement; however, many research jobs require a master's degree, or more often a PhD. Required courses in analytical, inorganic, organic, and physical chemistry, biological sciences; mathematics; physics; and computer science are good course offerings. Specific courses should include atmospheric chemistry, water chemistry, soil chemistry, and energy. Courses in statistics are useful.	Hand work in building scientific apparatus, performing laboratory experiments, and computer modeling skills are a must. Perseverance, curiosity, and the ability to concentrate on detail and to work independently are essential. Understanding other disciplines, including business and marketing or economics, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships, fellowships, or work-study programs in industry, also is useful.
Materials Engineer	A bachelor's degree is required for most entry-level jobs.	Most materials engineers specialize in a particular material.

Occupation	Degree Requirements	Skill Sets
Tool Maker	Most tool makers train for 4 or 5 years in apprenticeships or postsecondary programs; employers typically recommend apprenticeship training. They are among the most highly skilled workers in manufacturing.	Precision measuring for instruments and familiarity with the machining properties, such as hardness and heat tolerance, of a wide variety of common metals, alloys, plastics, ceramics, and other composite materials. As a result, tool makers are knowledgeable in machining operations, mathematics, and blueprint reading. Tool makers often are considered highly specialized machinists. Strong knowledge of CAD/CAM programs is essential. Precision measuring and a high degree of patience and attention to detail is required. Persons should be mechanically inclined, be able to work independently, have strong mathematical skills, and be capable of doing work that requires concentration and physical effort.
Engineering Technician	Most employers prefer to hire someone with at least a 2-year associate degree in engineering technology. Although employers usually do not require certification, it may provide jobseekers a competitive advantage.	Prospective engineering technicians should take as many high school science and math courses as possible to prepare for postsecondary programs in engineering technology. Most 2-year associate degree programs accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology require college algebra and trigonometry and one or two basic science courses. Creative problem solving and design work is useful. Good communication skills and the ability to work well with others also are important.
Painting and Coating Worker	Most workers acquire their skills on the job. The completion of high school generally is not required, but is advantageous. Additional instruction is offered at many community colleges and vocational or technical schools. Such programs enhance one's employment and promotion prospects.	Training in chemicals, paints, or equipment; safety and quality tips; product knowledge, equipment, and general business practices. Skills in the intricacies of mixing and applying different types of paint.

The Maine Department of Labor's occupational projections show limited or slightly negative growth in these occupations. However, these projections are based upon an extrapolation of past experience, largely related to declines in the paper industry, and do not necessarily capture positive changes that might occur based on changes in technology. The projections are shown in **Table 5.4**.

Table 5.4. Projections for Selected Composite Occupations, 2002–2012

Occupational Title	2002 Estimated Employment	2012 Projected Employment	Total 2002–2012 Employment Change	Annual Avg. Percent Change	Total Percent Change
Mechanical Engineers	710	686	–24	–0.3	–3.4
Chemists	158	153	–5		
Materials Scientists	***	***	***		
Civil Engineers	1,134	1,135	1	0	0.1
Tool and Die Makers	184	161	–23	–1.3	–12.5
Civil Engineering Technicians	520	523	3	0.1	0.6
Mechanical Engineering Technicians	71	67	–4	-0.6	–5.6
Painting, Coating, and Decorating Workers	163	164	1	0.1	0.6

Source: Maine Department of Labor, Labor Market Information Services. Asterisks indicate confidential data.

5.6.2 Education and Training for Composite Workers in Maine

Several of Maine's educational institutions are providing courses and majors to support the composites industry. As shown in **Table 5.5**, the University of Maine, Orono, continues to graduate small numbers of chemists and civil, mechanical, and environmental engineers. At the University of Southern Maine, the Applied Science, Engineering and Technology program conferred 78 bachelor's degrees and 5 master's degrees in 2004.[41]

The Maine Community College System[42] offers a few degrees in fields relevant to composites. At Central Maine Community College in Auburn, architectural and civil engineering technician, building construction technician, and mechanical engineering technician courses are offered. Civil engineering technician and building construction technician courses are also offered at Eastern Maine Community College in Banger while computer-aided design and pulp and paper technology are offered at Kennebec Valley Community College in Fairfield. A boatbuilding curriculum is offered at the Calais

[41] http://usm.maine.edu.books/book2004/FactBook2004.pdf.
[42] http://www.mtcs.net/

campus of Washington County Community College and computer-aided design is offered at York City Community College in Wells.

The Landing School,[43] a private full-time vocational school, plans to offer composites training starting in September 2007. However, at present, very few of their students stay in Maine upon graduation.

Table 5.5. Engineering Degrees Conferred by University of Maine, Orono, 2001–2005

Degree	2001	2002	2003	2004	2005
Chemistry					
BS	4	4	3	1	2
MS	4	2	0	0	2
PhD	3	1	5	2	2
Civil & Environmental Engineering					
BS	26	30	19	33	30
MS	13	8	12	7	10
PhD	2	0	1	0	0
Mechanical Engineering					
BS	41	20	27	37	25
MS	2	4	6	6	3
PhD	0	0	1	1	0

Source: http://www.maine.edu/pdf/deg05.pdf

5.6.3 WIRED Initiative

Maine's North Star Alliance is an industry-focused economic development initiative that includes business leaders, R&D providers, educational institutions, and workforce development organizations centers in Maine that make up or support the marine trades and those that use advanced composite materials comprising boatbuilding, marine/waterfront infrastructure, marine service and repair, building products, sporting goods, and ballistic armor. The Initiative is strategically partnered with Maine Composites Alliance, Maine Built Boats, and the Maine Marine Trade Association. The Alliance has been made possible through funding received from the U.S. Department of Labor Workforce Innovation in Regional Economic Development Initiative.

[43] http://www.thelandingschool.org/

The goals of the Alliance WIRED Project are as follows:

- Create high quality, skilled jobs that support the competitiveness of the targeted industries, the income of Maine workers, and a return for the public investment.
- Expand current markets and develop new ones so that the boatbuilding, composites, and marine trade industries achieve global industry leadership.
- Transform and build upon the capacity of the public system to nimbly and flexibly support competitive boatbuilding, composites, and marine trade industries that are looking to expand capacity, create and/or improve their workforce, and/or take their technology to the next level.
- Through advanced training opportunities, build on the willingness, ability, and skill sets of both the current and future workforce.
- Ensure that the economic development delivery model is sustainable and can be replicated for other targeted industries and regions.
- Catalyze innovation through research, development, and workforce preparedness that will sustain and improve the global competitiveness of Maine's boatbuilding, composites, and marine trades industries.

Four "pillars" of activity support these goals:

- Workforce Development
- Research and Development
- Outreach and Development
- Capitalization and Infrastructure Development

The Workforce Development pillar will undertake a number of activities, including the following:

- Hire industry workforce/economic development liaisons.
- Use Skills Transferability Analyses in business attraction/expansion efforts.
- Leverage customized training targeted to specific employer needs.
- Design new and expanded curricula through MACS. (?)
- Establish a K–12 program to introduce the industry.
- Reconfigure the apprenticeship model.
- Support training for future S&T workforce.

In addition, the Alliance has teamed with Southern Maine Community College on a $2 million grant to establish a composites training facility in the Brunswick community.

The recently announced North Star Alliance Technology Fund is available to eligible companies and nonprofit organizations in Maine's boatbuilding, composite materials, and related marine trade industries that win MTI seed grants, development awards, and cluster enhancement awards. Fund resources can be used for a co-investment of up to 75% of an eligible MTI awardee's seed grant, development award, or cluster enhancement award. The goal of the Fund is to further the development and commercialization of new technologies in these industries, thus boosting the competitiveness and growth of Maine companies in these sectors and creating quality jobs for Maine people.

Although the WIRED initiative is in its early stages, it has succeeded in focusing on the industry's needs and more defined networks are beginning to develop. It offers promise for addressing some of the workforce development needs of the industry.

5.7 Findings

Compared to four years ago, the composites picture in Maine has changed for the better. The breadth of innovation assets with experience in this technology has expanded. AEWC has grown to be a very strong player nationally and internationally, and has increased its interactions with Maine industry. Several small companies in Maine are taking advantage of AEWC resources to design, test, and evaluate new products. Other companies are developing their own, in-house capabilities. One loss appears to be composites capability at Bath Iron Works.

Furthermore, the work being done at AEWC and contemplated for the future match very well to the rapid growth areas in the marketplace. Work in advanced wood composites, composites based on bio-materials, advanced marine applications, and renewable energy applications are all very promising. A challenge for Maine, however, is that very few of the companies using composites are working in these new, high-value-added applications. Those who are doing this advanced work are being well supported by MTI and, to some extent, by the incubator system.

Many of Maine's companies that are working with composite technologies, such as the recreational boatbuilders, are generally not using the most advanced technologies, although they are making some strides in advanced molding techniques. This sector would be better served by the state if their workforce needs were better supported. There is hope that the WIRED initiative will make progress on this issue. However, the exceedingly low production of chemists and engineers with the appropriate training in composites, as well as the few technician training opportunities geared to this technology area will continue to pose a challenge to the growth of this technology area.

The Maine Composites Alliance, while an excellent example of a private-sector-driven trade organization, could be more effective if it had full-time staff.

Attachment A

Private Sector Survey Instrument

2006 Private Sector Maine R&D Evaluation Report - SAMPLE SURVEY

2. Indicate the type of entity/individual you are responding for.

- [x] Corporation
- [ ] Partnership
- [ ] LLC
- [ ] Sole Proprietorship
- [ ] Not a business but an individual

Check one that best applies. If 'Not a business but an individual', go to Question #36

3. Is your company/business still in business today? ☐ Yes ☐ No

Note: In answering the questions that follow, "your company/business" refers to your business organization, whether sole proprietorship, corporation, or other.
If 'Yes', go to Question #6

4. What year did your company go out of business? ☐

Indicate calendar year

5. As a result of your state funded award(s) or assistance, has your company produced proprietary or potentially proprietary intellectual property? ☐ Yes ☐ No

After answering the above question, go to Question #55

6. In the last completed fiscal year, has your company

a) Been acquired? ☐ Yes ☐ No

b) Purchased other companies? ☐ Yes ☐ No

c) Had an Initial Public Offering (IPO)? ☐ Yes ☐ No

d) Had other change in organizational structure. If so explain:

7. Where is your company's headquarters located?

a) City ☐

b) County ☐

c) State/Province ☐

d) Country ☐

8. Does your company operate in any locations beyond your headquarters?

☐ Yes ☐ No

If 'No', go to Question #12

9. How many locations/establishments/places of business does your company currently have in Maine? ☐

10. How many locations/establishments/places of business does your company currently have outside of Maine, but in the U.S.?

11. How many locations/establishments/places of business does your company currently have outside the U.S.?

12. What year was your company first organized?

Note: Use the year of incorporation, partnership, formation, or a comparable year. Requires 4 digits for year.

13. Employees, Wages, and Salaries:

a) How many employees did your company have last month, including the owner (include yourself if individual or sole proprietorship)?

b) How many employees did your company have twelve months ago, including the owner (include yourself if individual or sole proprietorship)?

c) What was the total dollar value of wages and salaries paid to your employees (excluding the employer share of benefits) in the last full fiscal year?

14. What were your company's total revenues in the last completed fiscal year from all sources including research grants?

a) What is the approximate dollar amount of revenues from the sales of products or services?

b) What is the approximate dollar amount of revenues from grants and contracts?

c) What is the approximate dollar amount of revenues from all other sources?

d) What were your company's total revenues in the year **prior to** the last completed fiscal year?

Note: The total of (a), (b), and (c) should approximately equal the dollar amount of your total revenues in the last completed fiscal year.

15. What is the approximate dollar value that your company expended on R&D in the last completed fiscal year?

16. How much corporate income tax did your company pay to the State of Maine for the last tax year?

Note: Please enter '0' if you did not pay any Maine corporate income taxes in the last tax year.

17. Did your company claim any Maine R&D Tax Credits in the last completed tax year?

☐ Yes ☐ No

18. What percentage of your company's sales for your last completed fiscal year were made to customers

a) In Maine?

b) Outside of Maine, but in the U.S.?

c) Outside of the U.S.?

Note: Please enter a number between 0 and 100 with no percent sign. The total of a)-c) should equal 100. Estimate as closely as possible.

19. Did you receive any new debt financing in the last completed fiscal year?

☐ Yes ☐ No

If 'No', go to Question #21

20. Please indicate the dollar amount from each source of all new debt financing you received in the last completed fiscal year.

a) Bank

b) Small Business Administration Guaranteed Loans

c) Friends and Family

d) Other

Note: Please enter 0 for those categories from which you did not receive any financing.

21. Did you receive any new equity funding in the last completed fiscal year?

☐ Yes ☐ No

If 'No', go to Question #24

22. Please indicate the dollar amount from each source of all new equity financing you have received in the last completed fiscal year.

a) Venture Capital Firms

b) State Seed Capital Funds (e.g., Small Enterprise Growth Fund)

c) Angel Investors

d) Friends and Family

e) Other

Note: Please enter 0 for those categories in which you did not receive any financing.

24. In the last completed fiscal year, did you receive any Federal grants for R&D (for example SBIR, STTR, etc.)? ☐ Yes ☐ No

If 'No', go to Question #36

25. In the last completed fiscal year, did you receive a Federal R&D grant from the NIST Advanced Technology Program (ATP)? ☐ Yes ☐ No *If 'No', go to Question #27*

26. What was the total award amount for your NIST ATP grant(s)?

27. In the last completed fiscal year, did you receive a Federal R&D grant from the Small Business Innovation Research (SBIR) Program, either Phase I or II? ☐ Yes ☐ No

If 'No', go to Question #29

28. What was the total award amount for your SBIR Phase I and II grant(s)?

29. In the last completed fiscal year, did you receive a Federal R&D grant from the Small Business Technology Transfer Research (STTR) Program? ☐ Yes ☐ No

If 'No', go to Question #36

30. What was the total award amount for your STTR grant(s)?

36. For discoveries related to any of the above project(s), did you or do you plan to file for patent protection in the U.S. or abroad?

☐ Yes

☐ No

☐ Not sure

If 'No', go to Question #41
If 'Not sure', go to Question #41

37. For discoveries related to any of the above project(s), did you or do you plan to file for U.S. patent protection?

☐ No

☐ Intend to file

☐ Have filed

☐ Patent granted

☐ Not sure

If 'No', go to Question #39
If 'Not sure', go to Question #39

38. How many U.S. patents for discoveries related to the above project(s):

a) Have been filed?

b) Do you intend to file?

c) Have been granted?

Note: The sum of (a), (b), and (c) must be greater than zero but if none in a category then enter "0" for that category.

39. For discoveries related to any of the above project(s), did you or do you plan to file for foreign patent protection?

- [ ] No
- [ ] Intend to file
- [ ] Have filed
- [ ] Not sure

If 'No', go to Question #41
If 'Not sure', go to Question #41

40. How many foreign patents related to the above project(s):

a) Have been filed? [ ]

b) Do you intend to file? [ ]

c) Have been granted? [ ]

Note: The sum of (a), (b), and (c) must be greater than zero but if none in a category then enter "0" for that category.

41. Did you or do you plan to protect your intellectual property from any of the above project(s) using trade secrets?

- [ ] Yes
- [ ] No
- [ ] Not sure

42. Did you or do you plan to register your intellectual property from any of the above project(s) by copyright?

- [ ] No
- [ ] Have registered
- [ ] Intend to register
- [ ] Not sure

43. Did you or do you plan to enter into a licensing agreement for the production or use of the technology from any of the above project(s)?

- [ ] Yes
- [ ] No
- [ ] Not sure

If 'No', go to Question #45
If 'Not sure', go to Question #45

44. Are the licensees located in Maine?

- None are
- All are
- Some are
- Not sure

45. Did you or do you plan to register any trademarks related to any of the above project(s)?

- No
- Yes, filed, not yet registered
- Yes, registered
- Yes, intend to file within 12 months
- Not sure

46. Did you or do you plan to utilize any other form of intellectual property protection (such as Plants Rights) for any of the above project(s)(other than patent, trade secrets, copyrights, licensing, and trademarks)?

- No
- Have filed
- Intend to file
- Not sure

51. With respect to your research and development activities, using the scale where 1="completely unimportant" to 5="critically important", please indicate the importance of the services offered by each of the following organizations. If you do not use the services offered by a listed organization, please select "0".

	0	1	2	3	4	5
a) Any campus of the University of Maine System (UMS)	☐	☐	☐	☐	☐	☐
b) Any other educational institution in Maine	☐	☐	☐	☐	☐	☐
c) Any non-profit research institution in Maine	☐	☐	☐	☐	☐	☐
d) Trade associations in Maine	☐	☐	☐	☐	☐	☐
e) Other Maine firms in your industry	☐	☐	☐	☐	☐	☐
f) Maine Technology Institute (MTI)	☐	☐	☐	☐	☐	☐

g) Maine Manufacturing Extension Partnership (MEP)	☐	☐	☐	☐	☐	☐
h) Maine's Applied Technology Development Centers (ATDC)	☐	☐	☐	☐	☐	☐
i) Maine Patent Program (MPP)	☐	☐	☐	☐	☐	☐
j) Maine Small Business Development Centers (MSBDC)	☐	☐	☐	☐	☐	☐
k) Maine Procurement Technical Assistance Center	☐	☐	☐	☐	☐	☐
l) Educational or research institutions, outside Maine	☐	☐	☐	☐	☐	☐
m) Other firms in your industry, outside Maine	☐	☐	☐	☐	☐	☐
n) Trade associations outside Maine	☐	☐	☐	☐	☐	☐

52. Did you license any technology from any of the MAINE sources mentioned in the previous question, as a result of your interactions? ☐ Yes ☐ No

53. Considering all of the State R&D assistance you received in the last completed fiscal year, how important has this assistance been?

☐ Critically important

☐ Very important

☐ Frequently important

☐ Occasionally important

☐ Not important

54. Considering all of the State R&D assistance you received in the last completed fiscal year, how satisfied have you been?

☐ Very satisfied

☐ Satisfied

☐ Somewhat satisfied

☐ Unsatisfied

☐ Very unsatisfied

55. If you have additional comments, please enter them here.

Attachment B

Data from Private Sector Survey

Findings from Private Sector Surveys, 2006[44]

1. Survey Response

The total number of companies/entities surveyed is 712. 369 companies/entities have responded for a response rate of 51.8%.

2. Maine R&D Program Affiliation

The 712 total entities surveyed represented 872 programs and the 369 total respondents to the survey represented 526 programs. Entities can receive assistance from multiple programs. The sample is biased toward MTI clients.

	All Respondents		All Surveyed	
State R&D Programs	**Number**	**Percent**	**Number**	**Percent**
ATDC	62	11.8	91	10.4
CIBT	1	0.2	1	0.1
MAIC	9	1.7	20	2.3
EPSCOR	1	0.2	1	0.1
MPP	137	26.1	369	42.3
MSCTCP	51	9.7	94	10.8
MSGF	0	0	2	0.2
SEGF	1	1.3	8	0.9
MTI	258	49.1	286	32.8
Total	526	100.0	872	100.0

The sample population and the actual population are statistically different; $\chi 2 = 66.5$; df = 8; at a= 0.001.

3. Company Headquarters

Of the 319 companies who responded to the question, 310 or 97% are headquartered in Maine. Among those, 245 reported having just one location for their company. The remaining 74 companies reported having operations in multiple locations in Maine.

Seven companies are headquartered in the U.S., but outside of Maine. The other states represented are AL, CT, MA, NC, OH, and VA.

Two companies reported being headquartered outside of the U.S. – one located in Canada and one in the United Kingdom.

[44] Data reported herein are only for the questions which were asked of all respondents. Data for questions which were asked of only MTI clients are reported in the MTI evaluation report. For this reason, question numbers in this section do not correspond directly to question numbers in the survey itself.

4. Geographic Breakdown

County Breakdown	All Respondents	
	Number	**Percent**
No Address	53	14.4
Androscoggin	13	3.5
Aroostook	14	3.8
Cumberland	118	32.0
Franklin	5	1.4
Hancock	11	3.0
Kennebec	15	4.1
Knox	13	3.5
Lincoln	14	3.8
Oxford	6	1.6
Penobscot	38	10.3
Piscataquis	2	0.5
Sagadahoc	12	3.3
Somerset	6	1.6
Waldo	5	1.4
Washington	9	2.4
York	28	7.6
Other State	7	1.9
Total	369	100.0

Regional Breakdown	All Respondents	
	Number	**Percent**
No Address	53	14.4
Central	72	19.5
Eastern	20	5.4
North	14	3.8
South	146	39.6
Western	57	15.4
Other State	7	1.9
Total	369	100.0

Central region: Androscoggin, Kennebec, Know, Lincoln, Sagadahoc, and Waldo
Eastern region: Hancock and Washington
North region: Aroostook
South region: Cumberland and York
Western region: Franklin, Oxford, Penobscot, Piscataquis, and Somerset

5. Industry Breakdown

Industry Sector	All Respondents		All Surveyed	
	Number	Percent	Number	Percent
Advanced Materials and Composites	40	10.1	48	6.5
Advanced Technologies for Forestry and Agriculture	37	9.3	49	6.6
Biotechnology	31	7.8	35	4.7
Environmental Technology	39	9.8	49	6.6
Information Technology	65	16.4	98	13.2
Marine Technology	52	13.1	79	10.6
Precision Manufacturing	67	16.9	77	10.4
Other Sector or Unknown	66	16.6	309	41.5
Total	397	100.0	744	100.0

The 712 total entities surveyed represented 744 sector instances; the 369 total respondents to the survey represented 397 sector instances; entities can be classified within more than one industry sector. Sectors were assigned by the research team based on information provided by the entities, website research, project categories, etc.

6. Restructuring Events

During the last fiscal year, six responding companies were acquired; four purchased other companies; two offered an IPO; and thirty others reported some sort of change in their organizational structure.

7. Year Organized

Years	All Respondents	
	Number	Percent
Pre-1980	18	4.9
1980-1984	19	5.1
1985-1989	22	6.0
1990-1994	29	7.9
1995-1999	53	14.4
2000-2004	141	38.2
2005-2006	33	8.9
Organize in the Future	2	0.5
Not Coded	52	14.1
Total	369	100.0

8. Number of Employees (including employer)

Number of Employees	All Respondents Number	Percent
1-10	241	65.3
11-20	30	8.1
21-30	8	2.2
31-40	10	2.7
41-50	4	1.1
51-100	11	3.0
100-499	10	2.7
500+	3	0.8
Not Coded	52	14.1
Total	369	100.0

Total number of employees this year: 6,774
Total number of employees last year: 6,337
Change in employment: 6.8 % / 437 employees

9. Wages

Total wages and salaries paid this year: $263,005,517
Total wages and salaries paid last year: $188,796,630
Change in total wage and salary: 39.3 % / $74,208,887

Average wage and salary per employee this year: $38,825
Average wage and salary per employee last year: $29,792
Change in average wage and salary per employee: 30.3 % / $9,033

10. Revenues

Company Revenues	All Respondents Number of Companies	Percent
$0	66	17.9
$1 – 49,999	68	18.4
$50,000 – 99,999	21	5.7
$100,000 – 499,999	61	16.5
$500,000 – 999,999	18	4.9
$1 million – 4,999,999	38	10.3
$5 million +	31	8.4
Not Coded	66	17.9
Total	369	100.0

Company revenues earned this year: $1,439,990,135
Company revenues earned last year: $1,218,176,986
Change in company revenue: 18.2 % / $221,813,149

Revenue per employee this year:	$212,576
Revenue per employee last year:	$192,232
Change in revenue per employee:	10.5 % / $20,344

11. Sources of Revenue

	All Respondents	
Revenues	Dollars	Percent of Total
Sales of Products and Services	$1,152,431,769	91.7
Grants and Contract	52,124,779	4.1
All other Sources	52,647,306	4.2
Total	$1,257,203,854	100.0

(Less than total revenue because some respondents didn't answer this question.)

12. R&D Expenditures

The respondents spent $42,370,128 in R&D in the reporting period.

13. Corporate Income Tax Paid

The respondents paid $979,136 in Maine corporate income tax.

14. Tax Credits Claimed

	All Respondents	
Maine R&D Tax Credits Claimed?	Number	Percent of Total
Yes	21	5.7
No	281	76.1
N/A	67	18.2
Total	369	100.0

15. Where are Your Customers?

	All Respondents	
Percent of Sales in Maine	Number	Percent of Total
0-10	185	50.1
11-25	22	6.0
26-50	13	3.5
51-75	13	3.5
76-100	69	18.7
N/A	66	18.2
Total	369	100.0

	All Respondents	
Percent of Sales Outside of Maine, In US	Number	Percent of Total
0-10	152	4.1
11-25	22	59.6
26-50	18	4.9
51-75	30	8.1
76-100	79	21.7
N/A	68	18.2
Total	369	100.0

	All Respondents	
Percent of Sales outside of US	Number	Percent of Total
0-10	269	72.9
11-25	17	4.6
26-50	12	3.3
51-75	1	0.3
76-100	5	1.4
N/A	65	17.6
Total	369	100.0

16. Debt Financing

66 companies or 17.8% (66 out of 369) accessed new debt financing during their most recently completed fiscal year.

	All Respondents		
Sources	**Number of Transactions**	**Dollars of New Debt**	**Percent of Total New Debt**
Bank	43	$ 27,849,809	83.9
SBA loans	2	$ 640,000	1.9
Friends and family	19	$ 1,995,443	6.0
Other	15	$ 2,682,452	8.2
Total	79*	$ 33,167,704	100

*Total adds to more than 66 companies because there were multiple transactions at some companies.

17. Equity Financing

41 companies or 11.1% (41 out of 369) accessed new equity financing during their most recently completed fiscal year.

	All Respondents		
Sources	**Number of Transactions**	**Dollars of New Equity**	**Percent of Total New Equity**
Venture capital	6	$ 17,550,000	54.9
State seed funds	4	$ 905,000	2.8
Angel investors	13	$ 5,613,000	17.5
Friends and family	12	$ 1,530,450	4.8
Other	18	$ 6,391,293	20.0
Total	53*	$ 31,989,743	100

*Total adds to more than 41 companies since there were multiple transactions at some companies.

18. Federal Awards

22 or 5.9% (22 out of 369) of respondents received some type of federal award during their most recently completed fiscal year.

	All Respondents	
Federal Award	**Number of Awards**	**Total $ of Awards**
Advanced Technology Program	0	$0
SBIR Phase I or Phase II	15	$5,945,087
STTR	1	$100,000
Total	16	$6,045,087

19. Intellectual Property

Copyrights:
Have you registered or do you intend to register for a copyright?

Copyright Registration	All Respondents Number of Companies	Percent
Have Registered	27	7.3
Intend to Register	41	11.1
No	178	48.2
Not Sure	87	23.6
Not Coded	36	9.8
Total	369	100.0

Licenses:
Have you entered or do you plan to enter into a licensing agreement?

Licensing Agreements	All Respondents Number of Companies	Percent
No	146	39.6
Not Sure	121	32.7
Yes	66	17.9
Not Coded	36	9.8
Total	369	100.0

License Locations	Number of Companies	Percent (out of 369)
All in Maine	2	0.5
Some in Maine	22	6.0
None in Maine	28	7.6
Not Sure	14	3.8
Total	66	17.9

Patents:
Did you or do you plan to file for patent protection for any of your discoveries?

Responses	All Respondents Number	Percent
No	157	42.5
Not Sure	53	14.4
Yes	123	33.3
Not Coded	36	9.8
Total	369	100.0

Filed for U.S. patent protection:

U.S. Patent Protection	Number of Companies	Percent (out of 369)
Have Filed	56	15.2
Intend to File	33	8.9
Granted	34	9.2
Total	123	33.3

U.S. Patent Protection	Number of Patents
Filed	201
Intend to File	110
Granted	90

Filed for foreign patent protection:

Foreign Patent Protection	Number of Companies	Percent (out of 369)
Have Filed	43	11.6
Intend to File	21	5.7
Granted	0	0.0
No/Not Sure	59	16.0
Total	123	33.3

Foreign Patent Protection	Number of Patents
Filed	166
Intend to File	111
Granted	37

Trademarks:
Have you registered or do you intend to register for a trademark?

	All Respondents	
Trademark Registration	Number of Companies	Percent
Yes, Registered	44	11.9
Filed not Registered	13	3.5
Intend to File	44	11.9
No	132	35.8
Not Sure	100	27.1
Not Coded	36	9.8
Total	369	100.0

Trade Secrets:
Do you use or intend to use trade secrets?

Trade Secret Usage	All Respondents	
	Number of Companies	**Percent**
No	143	38.7
Not Sure	93	25.2
Yes	97	26.3
Not Coded	36	9.8
Total	369	100.0

Other Intellectual Property:
Do you intend to utilize other forms of intellectual property?

Utilization of other Intellectual Property	All Respondents	
	Number of Companies	**Percent**
Have Filed	2	0.5
Intend to File	7	1.9
No	211	57.2
Not Sure	113	30.6
Not Coded	36	9.8
Total	369	100.0

20. Support Organizations

Nearly 70% of total respondents received some level of support from MTI during the survey period and over half of those recipients found that assistance to be "most critical" in their success. Moreover, MTI received the highest mean score at 4.09.

This table shows the support organizations that were used and a ranking of how important the services were to the participating companies (1–least critical, 5–most critical).

	All Respondents						
		Degree of Importance					
Support Organization	**Didn't Use**	**1**	**2**	**3**	**4**	**5**	**Mean Score**
MTI	78	16	14	37	52	136	4.09
ATDC	223	18	22	24	19	27	3.14
Other firms outside Maine	130	14	36	51	50	52	3.44
Maine Patent Program	163	24	25	28	28	65	3.5
Other Maine Firms	160	25	41	42	37	28	3.01
UMaine System	139	25	26	41	36	66	3.47
Educational/Research outside Maine	185	17	31	41	26	33	3.18
Trade Associations outside Maine	174	24	33	46	29	27	3.01
SBDC	178	24	27	39	33	32	3.14
Market Development Center	249	17	18	21	16	12	2.86
Nonprofit Research Institutes	214	30	18	36	17	18	2.79
MEP	200	23	25	30	26	29	3.10
Maine Trade Associations	176	37	29	45	28	18	2.75
Other Educational Institutions	212	22	29	31	17	22	2.9

21. Licensing from Maine Support Entity

Six (1.6%) of the respondents licensed a technology from a Maine source such as a university or non-profit research laboratory

22. <u>Importance of Assistance</u>

The mean score for importance of assistance received was 3.31, somewhere between frequently important and very important.

How important?	All Respondents Number of companies	Percent (out of 369)
Critically important (5)	114	30.9
Very important (4)	67	18.2
Frequently important (3)	40	10.8
Occasionally important (2)	35	9.5
Not important (1)	77	20.9
Not Coded	36	9.8
Total	369	100.0

23. <u>Satisfaction with Assistance</u>

The mean score for satisfaction with assistance received was 4.09, somewhere between satisfied and very satisfied. More specifically, over two-thirds of respondents indicated that they were either satisfied or very satisfied.

How satisfied?	All Respondents Number of companies	Percent (out of 369)
Very satisfied (5)	153	41.5
Satisfied (4)	99	26.8
Somewhat satisfied (3)	55	14.9
Unsatisfied (2)	12	3.3
Very unsatisfied (1)	14	3.8
Not Coded	36	9.8
Total	369	100.0

Attachment C

R&D Institution Survey

2006 SURVEY FOR RESEARCH INSTITUTION RECIPIENTS OF MAINE STATE R&D FUNDING

For the Evaluation of Maine's Investments in Research and Development Conducted for the Maine Office of Innovation

1. Name of Research Institution: ____ ____
2. Name of Person Completing Survey: _____
   Position:__ ____
   Phone:_____ ______________________________
   Email:_____
3. Date of Response: _____

GENERAL INSTRUCTIONS:

If your fiscal year is other than July 1 to June 30, please indicate at the top of page 5 your fiscal year starting and ending dates and use the most recent year for which you have complete data in place of FY06.

On the left side, enter the total amount for each category for your institution in FY06.

On the right hand side, list only the FY06 amounts attributable to the state R&D funding sources listed below. For instance, if state R&D funding was used to hire a faculty member, all his/her activity would count, even if that person is now funded by other sources. If a building or laboratory was built with the R&D funding, all activity in the building would count. The possible sources of state R&D funding for research institutions that are relevant for this evaluation are:

- State Research and Development Bonds
- Funding from the State for Capital Improvements to Support Research
- EPSCoR State Matching Funds for DOE, NSF, or NASA
- Maine Economic Improvement Fund
- Maine Technology Institute
- Maine Biomedical Research Fund
- Marine Research Funds, Marine Technology Fund, and Marine Connectivity Funds
- Maine Aquaculture Innovation Center
- Center for Innovation in Biomedical Technology
- Maine Space Grant Consortium Prior to 2004
- Research Challenge Grants
- Strategic Technology Initiative

Answer by taking into account specific programs, research activities, personnel, buildings and equipment funding by these sources. Where necessary, estimate as best as possible.

The answers to all questions will be kept confidential and will only be reported in the aggregate. If you have a question, please contact Catherine Renault, RTI International, (919) 485-5655 or crenault@rti.org.

Please return this survey to Catherine Renault, RTI International, PO Box 12194, Miami 2, Research Triangle Park, NC 27709-1294, by fax to (919) 541-6221, or by email to crenault@rti.org.

SPECIFIC INSTRUCTIONS:

Question 4: Institutional Capacity

If you are an accredited educational institution, enter the number of students enrolled, degrees conferred, and total number of degree programs in **4 A-D**. Note that **4D** refers to undergraduates. This should be the official headcount for Fall Semester.

The total square footage available for research and development should be entered in **4G**. This is defined as research laboratories, controlled environment space such as clean or white rooms; technical support space such as carpentry and machine shops; space for laboratory animals, such as animal production colonies, holding rooms, isolation and germ-free rooms; faculty and staff offices to the extent that they are used for research; department libraries, to the extent that they are used for research; fixed equipment, such as fume hoods and benches; single pieces of non-fixed equipment each costing at least $1 million, such as MRI equipment; and leased space. It does not include: space that is designated as federally funded research and development centers (FFRDCs); space used by faculty but not administered by the institution; and space administered by the institution but leased to others for their use. Square footage is measured from the inside faces of walls.

The current value of facilities and fixed equipment should be the depreciated value of these assets. Enter in **4H**. However, **4I** requests only the total value of all major moveable research equipment purchased this year. Major is defined as having a purchase price of >$50,000 for each item.

In **4J**, enter the number of positions (headcount) you have in each of these categories. Faculty include tenured and tenure-track professors. Research (non-tenure track) faculty includes other senior scientists that are principal investigators. Professional refers to those exempt employees directly engaged in research and development activities. Students would include any research and development positions held by undergraduate or graduate students. Classified employees include technicians, clerical and administrative positions that are paid hourly and/or subject to overtime.

Question 5: Research and Development Outcomes

5A, Publications, refers to all articles, books and reports published in the reporting period. If the research supporting the publications was done substantially at your institution, e.g., during a summer, or by an adjunct faculty member, you should include it.

5B, Research Proposals, counts all extramural research proposals officially submitted by your institution. Proposals made by individuals associated with your institution on their own behalf are not included. Maine institutions mean any institution headquartered or chartered in Maine, or with substantial operations in Maine. The Maine campus of an institution headquartered elsewhere would be a Maine institution.

For value, enter the face value of the proposal, the total value of all costs for all years proposed, including option years.

5C, Research Awards, asks about the contracts awarded to the institution during the year. The start date of the contract does not have to be in the year. Include all costs including overhead.

- For **5C1**, enter the total value of the award, including all costs for all years, including option years.
- For **5C2**, enter the number of awards and their total value of awards under the EPSCoR program.
- In **5C3**, earmarked means that the award was the result of a legislative action by the U.S. Congress where an agency was directed to support a specific institution or project with a specific amount of funding. Do not include formula grants for land grant institutions, or funding for national programs such as Agricultural Extension, Manufacturing Extension, Sea Grant, etc.
- Under **5C4**, should include all expenditures at your institution for R&D in FY06. In the second section, break these expenditures out by the type of organization that gave you the contract. If you have a subcontract from a company that has federal contracts, enter this as industry.
- **5C5** should include all grants, contracts and subcontracts awarded to your institution by industry. Industry is defined as for-profit organizations (corporations, partnerships, sole proprietorships, etc). This does not include not-for-profit entities such as educational institutions, elements of state, federal or local government or foundations. Enter the total, face value of the contract, including all costs for all years, including option years. Please include subcontracts from companies that have Federal contracts – the intent of this question is to ascertain the level of interaction between research institutions and industry, not the source of that funding.
- In **5C6**, Maine company is defined as a company headquartered in Maine or with substantial operations in Maine. (BIW is a Maine company, although it is owned by a company outside of Maine.)
- In **5C7**, on the left, enter all foundation grants and gifts related to research and development. On the right, enter only those foundation grants and gifts enabled by the state R&D support. Include both conditional and unconditional amounts. Enter the full amount of the grant or gift, including all costs for all years.

Intellectual Property, Question **5D**. Count the number of items in each category. For **5D8**, Show the total license income received in the fiscal year, including royalties and cashed-in equity.

Spin-off Companies, **5E**. Please indicate the number of new companies formed based on intellectual property licensed from your institution. Date of incorporation should be within this fiscal year. Include the number of jobs in these companies at spin-off. (Future growth in these companies will be captured in the private company survey.)

4. Institutional Capacity

Your fiscal year, if different: ____July 1________, 2005to _June 30_______, 2006

FY 06	***Total for your institution***	***Attributable to State R&D Funding***
a. Number (headcount) of enrolled science and engineering graduate students in Fall semester.	0	0
b. Number of science and engineering graduate degrees conferred.	0	0
c. deleted.		
d. Number (headcount) undergraduate students enrolled in science and engineering majors in Fall semester.	492	0
e. Number of undergraduate students science and engineering degrees conferred.	125	0
f. deleted		
g. Total R&D space	Sq ft	Sq ft
h. Current, depreciated, value of facilities and fixed equipment	$	$
i. Major (purchase price >$50,000) research equipment purchased this year.	$	$
j. Number of positions supported (headcount) • Faculty • Research Staff (non faculty) • Professional staff • Students • Classified personnel (e.g., technicians, clerical)	 __ ________________ ________________ ________________ ________________	 ________________ ________________ ________________ ________________ ________________

5. Research and Development Outcomes

FY 06	***Total for your institution***	***Attributable to State R&D Funding***
A. Publications		
1. Number of scientific peer-reviewed journal articles published.		
2. Number of scientific peer-reviewed book chapters published.		
3. Number of scientific peer-reviewed books published.		
4. Number of other scientific papers published.		
5. Number of other scientific papers not published (e.g. research reports for industry).		
B. Research Proposals		
1a. Number extramural research proposals submitted.		
1b. Dollars Requested on these proposals (face value)	$	$
2a. Number of these proposals submitted jointly with other Maine institutions only		
2b. Dollar Value of these proposals (face value)	$	$
3a. Number of these proposals submitted jointly with non-Maine institutions only		
3b. Dollar Value of these proposals (face value)	$	$
4a. Number of these proposals submitted jointly with both Maine and non-Maine institutions.		

4b. Dollar Value of these proposals (face value)	$	$
C. Research Awards		
1a. Number of new Federal research grants, contracts, subcontracts awarded (total value for all costs and all years)		
1b. Dollar value of these awards (face value)	$	$
2a. Number of these awarded under EPSCoR		
2b. Dollar value of these awards (total value for all costs and all years)	$	$
3a. Number of these awards that were earmarked (total value for all costs and all years)		
3b. Dollar value of these awards (face value)	$	$
4a. Total expenditures for research and development for FY06	$	$
4b: Sources of funds for R&D expenditures:	Federal: $ State: $ Industry: $ Individuals and Foundations:$	Federal: $ State: $ Industry: $ Individuals and Foundations:$
5a. Number of industrial research grants, contracts and subcontracts awarded		
5b. Value of these awards (total value for all costs and all years)	$	$
6a. Number of these industrial research grants, contracts and subcontracts awarded by Maine companies		

6b. Value of these awards (total value for all costs and all years)	$	$
7a. Number of new foundation grants and/or gifts for research		
7b. Value of these grants and/or gifts (total value for all costs and all years)	$	$
D. Intellectual Property		
1. Number of disclosures made.		
2. Number of patents applied for.		
3. Number of patents awarded.		
4. Number of copyrights obtained.		
5. Number of plant variety protection rights obtained.		
6. Number of licensing agreements signed this year.		
7. Number of licensing agreements signed this year with Maine companies.		
8. License income received this year.		
E. Spin-off Companies		
1. Number of new companies formed.		
2. Number of jobs in these companies at spin-off.		

6. Additional Information

Please feel free to add any additional information that you feel we may need to fully appreciate the contributions of your institution to economic development in Maine in the past year. This can be attached documents, e.g., annual report, or free-form narrative below. Take as much space as you need:

Attachment D

R&D Institutions Survey Data 2002–2006

2006 Combined University and Nonprofit Results

	2006 Total for all Institutions	2006 Attributable to State R&D Funding
Institutional Capacity		
a. Number (FTE) of enrolled science and engineering graduate students	2,736	530
b. Number of science and engineering graduate degrees awarded	171	155
c. Number of degree programs (Question deleted in 2006)	0	0
d. Number (FTE) of undergraduate students enrolled in science and engineering majors	5,944	2,675
e. Number (FTE) of undergraduate students participating in science and engineering programs	901	535
f. Number (FTE) of graduate students participating in science and engineering programs (Question deleted in 2006)	0	0
g. R&D space	1,443,156	1,140,085
h. Current, depreciated value of facilities and fixed equipment	$484,625,305	$234,501,661
i. Major (purchase price >$50,000) research equipment purchased this year	$9,669,231	$3,109,849
j. Number of positions FTE	608	560
Faculty	636	13
Non-faculty PIs	498	19
Technical and professional staff	1,073	42
Students	254	42
Support personnel	1,653	29
Administrative	0	0
Total FTEs	0	0
Research and Development Outcomes		
A. Publications		
1. Number of scientific peer-reviewed journal articles published	1,194	1,036
2. Number of scientific peer-reviewed book chapters published	139	128
3. Number of scientific peer-reviewed books published	41	37
4. Number of other papers published	732	714
5. Number of other papers not published (e.g., research reports for industry)	962	948
B. Research Proposals		
1a. Number of peer-reviewed and/or competitive research proposals submitted	1,197	239
1b. Dollar Value	$410,348,521	$127,268,694
2a Number of these proposals submitted jointly with other main institutions	66	27
2b. Dollar Value	$25,730,084	$15,069,126
3a. Number of these proposals submitted jointly with non-Maine institutions only	67	49
3b. Dollar Value	$33,731,582	$28,197,270
4a. Number of these proposal submitted jointly with both Maine and non-Maine institutions	55	52
4b. Dollar Value	$30,135,347	$28,199,597

	2006 Total for all Institutions	2006 Attributable to State R&D Funding
C. Research Awards		
1a. Number of new federal research grants, contracts, subcontracts	505	316
1b. Dollar Value	$122,610,119	$74,055,325
2a. Number of these awarded under EPSCoR	1	1
2b. Dollar Value	$4,300,000	$4,300,000
3a. Number of these that were earmarked	29	20
3b. Dollar Value	$12,208,422	$8,114,241
4a. Total expenditures for R&D in the fiscal year	$140,941,253	$77,034,280
4b. Federal sources of funds for R&D expenditures	$116,225,705	$67,274,062
State sources of funds for R&D expenditures	$3,964,532	$1,806,612
Industry sources of funds for R&D expenditures	$989,015	$330,596
Individual and foundation sources of funds for R&D expenditures	$12,683,397	$8,110,375
5a. Number of industrial research grants, contracts and subcontracts awarded	49	6
5b. Dollar Value	$8,454,951	$5,693,476
6a. Number of these industrial research contracts awarded by Maine companies	14	4
6b. Dollar Value	$557,669	$170,826
7a. Number of new foundation grants and gifts	171	92
7b. Dollar Value	$18,674,755	$10,279,844
D. Intellectual Property		
1. Number of disclosures made	45	37
2. Number of patents applied for	17	16
3. Number of patents awarded	5	4
4. Number of copyrights obtained	1	0
5. Number of plant breeder's rights obtained	0	0
6. Number of licensing agreements signed	5	4
7. Number of licensing agreements signed with Maine companies	2	2
8. License income received this year	$491,972	$421,472
E. Spin-off Companies		
1. Number of new companies formed	3	3
2. Number of jobs in these companies at spin-off	9	9

Cautions:

Numbers attributable to State R&D Funding in 2002 survey may not be accurate.

Ten entities responded to FY 2003 survey; five responded to FY 2002.

UMaine, Jackson Labs, University Southern Maine, Maine Maritime, MMCRI, Foundation for Blood Research, MDIBL, UMaine Machias, Wells, UNE Osteopathic Medicine

FY 2004 respondents: Bigelow, Maine Medical Centers, University Southern Maine, Wells, University of New England, U Maine Orono, U Maine Machias, Jackson Lab, MDIBL, Maine Maritime, Gulf of Maine, Downeast Institute, FBR

Questions change significantly from 2002–2006

The figure was headcount, changed to FTEs

University Survey Results, 2002–2006

	2006 Total Attributable to State Funding	2005 Total Attributable to State Funding	2002 Total Attributable to State Funding	2005–2006 Percent Change for Universities	2002–2006 Percent Change for Universities
Institutional Capacity					
a. Number (headcount) of enrolled science and engineering graduate students in fall semester	530	0	1,056		-50%
b. Number of science and engineering graduate degrees conferred	155	0	209		-26%
c. DELETED (Number of degree programs)					
d. Number (headcount) undergraduate students enrolled in science and engineering majors in fall semester	2,675	0	7,258		-63%
e. Number of undergraduate students science and engineering degrees conferred	535	0			
f. DELETED (Number [FTE] of graduate students participating in science and engineering programs)					
g. Total R&D space	1,067,836	33,000	606,258	3,136%	76%
h. Current, depreciated, value of facilities and fixed equipment	$218,605,846	$0	$121,251,600		80%
i. Major (purchase price >$50,000) research equipment purchased this year	$2,807,857	$52,000	$16,074,033	5,300%	-83%
j. Number of positions FTE	527				
Faculty	13	8	432	63%	-97%
Research staff (non-faculty)	0	0	23		-100%
Professional staff	16	11	352	45%	-95%
Students	20	15	198	33%	-90%
Classified personnel	2	3	207	-33%	-99%
Research and Development Outcomes					
A. Publications					
1. Number of scientific peer-reviewed journal articles published	798	1	527	79,700%	51%
2. Number of scientific peer-reviewed book chapters published	119	1	30	11,800%	297%
3. Number of scientific peer-reviewed books published	36	0	64		-44%
4. Number of other scientific papers published	653	0	332		97%
5. Number of other scientific papers not published (e.g., research reports for industry)	927	0	768		21%
B. Research Proposals					
1a. Number of extramural research proposal submitted	51	40	574	28%	-91%
1b. Dollars requested	$20,121,229	$23,327,249	$130,232,919	-14%	-85%
2a. Number of these proposals submitted jointly with other Maine institutions	7	5	43	40%	-84%
2b. Dollar Value	$7,054,933	$3,568,078	$9,943,894	98%	-29%
3a. Number of these proposals submitted jointly with non-Maine institutions only	10	7	66	43%	-85%
3b. Dollar Value	$7,898,786	$2,411,651	$10,482,110	228%	-25%
4a. Number of these proposal submitted jointly with both Maine and non-Maine institutions	2	1	0	100%	
4b. Dollar Value	$1,676,366	$7,486,697	$0	-78%	

	2006 Total Attributable to State Funding	2005 Total Attributable to State Funding	2002 Total Attributable to State Funding	2005–2006 Percent Change for Universities	2002–2006 Percent Change for Universities
C. Research Awards					
1a. Number of new federal research grants, contracts, subcontracts (total value for all costs and years)	268	11	429	2,336%	-38%
1b. Dollar Value	$41,089,533	$37,311,371	$44,879,959	10%	-8%
2a. Number of these awarded under EPSCoR	1	3	6	-67%	-83%
2b. Dollar Value	$2,300,000	$2,856,081	$2,278,125	-19%	1%
3a. Number of these that were earmarked	19	19	0	0%	
3b. Dollar Value	$7,868,725	$8,570,836	$0	-8%	
4a. Total expenditures for research and development for FY06	$3,950,999				
4b. Sources of funds for R&D expenditures: Federal	$2,699,906				
State	$446,909				
Industry	$0				
Individuals and foundations	$804,184				
5a. Number of industrial research grants, contracts and subcontracts awarded	0	240	0	-100%	
5b.Dollar Value	$3,757,734	$3,736,208	$1,916,817	1%	96%
6a. Number of these industrial research contracts awarded by Maine companies	0	109	0	-100%	
6b. Dollar Value	$0	$878,025	$0	-100%	
7a. Number of new foundation grants and gifts	57	1	2	5,600%	2750%
7b. Dollar Value	$2,321,942	$1,519,193		53%	
D. Intellectual Property					
1. Number of disclosures made	19	17	$6	12%	217%
2. Number of patents applied for	10	9	4	11%	150%
3. Number of patents awarded	3	3		0%	
4. Number of copyrights obtained	0	0	0		
5. Number of plant breeder's rights obtained	0	0	0		
6. Number of licensing agreements signed	2	2	0	0%	
7. Number of licensing agreements signed with Maine companies	2	1	0	100%	
8. License income received this year	$285,000	$110,000	$0	159%	
E. Spin-off Companies					
1. Number of new companies formed	2	2	0	0%	
2. Number of jobs in these companies at spin-off	6	6	0	0%	
Gray areas = no data or data question has changed significantly					
Questions shift over time, so cannot analyze over time					

Nonprofit Institutions Survey Results, 2002–2006

	2006 Total Nonprofit Institutions	2005 Total Nonprofit Institutions	2002 Total Nonprofit Institutions	2005–2006 Percent Change for Nonprofits	2002–2006 Percent Change for Nonprofits
Institutional Capacity					
a. Number (headcount) of enrolled science and engineering graduate students in fall Semester	0	0	3		-100%
b. Number of science and engineering graduate degrees conferred	0	0	0		
c. DELETED (Number of degree programs)	0				
d. Number (headcount) undergraduate students enrolled in science and engineering majors in fall semester	133	0	0		
e. Number of undergraduate students science and engineering degrees conferred	19	103		-82%	
f. DELETED (Number [FTE] of graduate students participating in science and engineering programs)	0				
g. Total R&D space	354,335	289,800	203,882	22%	74%
h. Current, depreciated, value of facilities and fixed equipment	$180,690,425	$151,503,199	$150,360,110	19%	20%
i. Major (purchase price >$50,000) research equipment purchased this year	$6,861,374	$1,687,041	$4,798,467	307%	43%
j. Number of positions FTE	81		0		
Faculty	60	55	58	8%	3%
Research staff (non-faculty)	479	151		217%	
Professional staff	361	1,062	897	-66%	-60%
Students	120	85	3	42%	3900%
Classified personnel	707	290	257	143%	175%
Research and Development Outcomes					
A. Publications					
1. Number of scientific peer-reviewed journal articles published	334	308	222	8%	50%
2. Number of scientific peer-reviewed book chapters published	16	22	20	-27%	-20%
3. Number of scientific peer-reviewed books published	3	3	0	0%	
4. Number of other scientific papers published	77	93	1	-17%	7600%
5. Number of other scientific papers not published (e.g., research reports for industry)	24	12	2	100%	1100%

	2006 Total Nonprofit Institutions	2005 Total Nonprofit Institutions	2002 Total Nonprofit Institutions	2005–2006 Percent Change for Nonprofits	2002–2006 Percent Change for Nonprofits
B. Research Proposals					
1a. Number of extramural research proposal submitted	338	317	134	7%	152%
1b. Dollars requested	$182,368,973	$211,823,162	$106,590,869	-14%	71%
2a. Number of these proposals submitted jointly with other Maine institutions	27	23	6	17%	350%
2b. Dollar Value	$11,961,116	$17,870,403	$2,170,689	-33%	451%
3a. Number of these proposals submitted jointly with non-Maine institutions only	44	50	22	-12%	100%
3b. Dollar Value	$22,855,275	$31,358,667	$11,559,016	-27%	98%
4a. Number of these proposals submitted jointly with both Maine and non-Maine institutions	51	65	24	-22%	113%
4b. Dollar Value	$26,926,106	$34,822,397	$13,093,005	-23%	106%
C. Research Awards					
1a. Number of new federal research grants, contracts, subcontracts (total value for all costs and years)	81	65	64	25%	27%
1b. Dollar Value	$40,869,436	$69,514,731	$66,049,383	-41%	-38%
2a. Number of these awarded under EPSCoR	0	0	1		-100%
2b. Dollar Value	$2,000,000	$0	$600,000		233%
3a. Number of these that were earmarked	2	2	5	0%	-60%
3b. Dollar Value	$2,245,516	$1,585,015	$3,851,260	42%	-42%
4a. Total expenditures for research and development for FY06	$94,372,486				
4b. Sources of funds for R&D expenditures: Federal	$77,827,420	$72,853,750		7%	
State	$1,466,652				
Industry	$663,190				
Individuals and foundations	$8,517,583				
5a. Number of industrial research grants, contracts and subcontracts awarded	42	11	33	282%	27%
5b. Dollar Value	$4,138,477	$1,596,162	$2,176,807	159%	90%
6a. Number of these industrial research contracts awarded by Maine companies	10	5	0	100%	
6b. Dollar Value	$179,826	$388,067	$0	-54%	
7a. Number of new foundation grants and gifts	86	59	11	46%	682%
7b. Dollar Value	$13,008,472	$7,579,103	$1,140,484	72%	1041%

	2006 Total Nonprofit Institutions	2005 Total Nonprofit Institutions	2002 Total Nonprofit Institutions	2005–2006 Percent Change for Nonprofits	2002–2006 Percent Change for Nonprofits
D. Intellectual Property					
1. Number of disclosures made	23	21	6	10%	283%
2. Number of patents applied for	6	9	4	-33%	50%
3. Number of patents awarded	2	1		100%	
4. Number of copyrights obtained	1	1	1	0%	0%
5. Number of plant breeder's rights obtained	0	0	0		
6. Number of licensing agreements signed	3	2	2	50%	50%
7. Number of licensing agreements signed with Maine companies	0	0	0		
8. License income received this year	$206,972	$347,762	$150,000	-40%	38%
E. Spin-off Companies					
1. Number of new companies formed	1	1	0	0%	
2. Number of jobs in these companies at spin-off	2.5	1.5	0	67%	
Gray areas = no data, or data question has changed significantly					
Questions shift over time, so cannot analyze over time					

University Results Attributable to State Investment, 2002–2006

	2006 Total Attributable to State Funding	2005 Total Attributable to State Funding	2002 Total Attributable to State Funding	2005–2006 Percent Change for Universities	2002–2006 Percent change for Universities
Institutional Capacity					
a. Number (headcount) of enrolled science and engineering graduate students in fall semester	530	0	1,056		-50%
b. Number of science and engineering graduate degrees conferred	155	0	209		-26%
c. DELETED (Number of degree programs)					
d. Number (headcount) undergraduate students enrolled in science and engineering majors in fall semester	2,675	0	7,258		-63%
e. Number of undergraduate students science and engineering degrees conferred	535	0			
f. DELETED (Number [FTE] of graduate students participating in science and engineering programs)					
g. Total R&D space	1,067,836	33,000	606,258	3,136%	76%
h. Current, depreciated, value of facilities and fixed equipment	$218,605,846	$0	$121,251,600		80%
i. Major (purchase price >$50,000) research equipment purchased this year.	$2,807,857	$52,000	$16,074,033	5,300%	-83%
j. Number of positions FTE	527		0		
Faculty	13	8	432	63%	-97%
Research staff (non-faculty)	0	0	23		-100%
Professional staff	16	11	352	45%	-95%
Students	20	15	198	33%	-90%
Classified personnel	2	3	207	-33%	-99%
Research and Development Outcomes					
A. Publications					
1. Number of scientific peer-reviewed journal articles published	798	1	527	79,700%	51%
2. Number of scientific peer-reviewed book chapters published	119	1	30	11,800%	297%
3. Number of scientific peer-reviewed books published	36	0	64		-44%
4. Number of other scientific papers published	653	0	332		97%
5. Number of other scientific papers not published (e.g. research reports for industry)	927	0	768		21%

	2006 Total Attributable to State Funding	2005 Total Attributable to State Funding	2002 Total Attributable to State Funding	2005–2006 Percent Change for Universities	2002–2006 Percent change for Universities
B. Research Proposals					
1a. Number of extramural research proposal submitted	51	40	574	28%	-91%
1b. Dollars requested	$20,121,229	$23,327,249	$130,232,919	-14%	-85%
2a. Number of these proposals submitted jointly with other Maine institutions	7	5	43	40%	-84%
2b. Dollar Value	$7,054,933	$3,568,078	$9,943,894	98%	-29%
3a. Number of these proposals submitted jointly with non-Maine institutions only	10	7	66	43%	-85%
3b. Dollar Value	$7,898,786	$2,411,651	$10,482,110	228%	-25%
4. Number of these proposals submitted jointly with both Maine and non-Maine institutions	2	1	0	100%	
4b. Dollar Value	$1,676,366	$7,486,697	$0	-78%	
C. Research Awards					
1a. Number of new federal research grants, contracts, subcontracts (total value for all costs and years)	268	11	429	2,336%	-38%
1b. Dollar Value	$41,089,533	$37,311,371	$44,879,959	10%	-8%
2a. Number of these awarded under EPSCoR	1	3	6	-67%	-83%
2b. Dollar Value	$2,300,000	$2,856,081	$2,278,125	-19%	1%
3a. Number of these that were earmarked	19	19	0	0%	
3b. Dollar Value	$7,868,725	$8,570,836	$0	-8%	
4a. Total expenditures for research and development for FY06	3,950,999				
4b. Sources of funds for R&D expenditures: Federal	2,699,906				
State	446,909				
.Industry	0				
Individuals and foundations	804,184				
5a. Number of industrial research grants, contracts and subcontracts awarded	0	240	0	-100%	
5b. Dollar Value	$3,757,734	$3,736,208	$1,916,817	1%	96%
6a. Number of these industrial research contracts awarded by Maine companies	0	109	0	-100%	
6b. Dollar Value	0	$878,025	$0	-100%	
7a. Number of new foundation grants and gifts	57	1	2	5,600%	2,750%
7b. Dollar Value	$2,321,942	1,519,193		53%	

	2006 Total Attributable to State Funding	2005 Total Attributable to State Funding	2002 Total Attributable to State Funding	2005–2006 Percent Change for Universities	2002–2006 Percent change for Universities
D. Intellectual Property					
1. Number of disclosures made	19	17	$6	12%	217%
2. Number of patents applied for	10	9	4	11%	150%
3. Number of patents awarded	3	3		0%	
4. Number of copyrights obtained	0	0	0		
5. Number of plant breeder's rights obtained	0	0	0		
6. Number of licensing agreements signed	2	2	0	0%	
7. Number of licensing agreements signed with Maine companies	2	1	0	100%	
8. License income received this year	$285,000	$110,000	$0	159%	
E. Spin-off Companies					
1. Number of new companies formed	2	2	0	0%	
2. Number of jobs in these companies at spin-off	6	6	0	0%	
Gray areas = no data, or data question has changed significantly					
Questions shift over time, so cannot analyze over time					

Nonprofit Results Attributable to State Investment, 2002–2006

	2006 Attributable to State Funding	2005 Attributable to State Funding	2002 Attributable to State Funding	2005–2006 Percent Change for Nonprofits	2002–2006 Percent Change for Nonprofits
Institutional Capacity					
a. Number (headcount) of enrolled science and engineering graduate students in fall semester	0	0	0		
b. Number of science and engineering graduate degrees conferred	0	0	0		
c. DELETED (Number of degree programs)		0			
d. Number (headcount) undergraduate students enrolled in science and engineering majors in fall semester	0	0	0		
e. Number of undergraduate students science and engineering degrees conferred	0	53		-100%	
f. DELETED (Number [FTE] of graduate students participating in science and engineering programs)		22.3			
g. Total R&D space	72,249	76,534	9,755	-6%	641%
h. Current, depreciated, value of facilities and fixed equipment	$15,895,815	$39,547,714	$33,631,300	-60%	-53%
i. Major (purchase price >$50,000) research equipment purchased this year	$301,992	$1,324,887	$320,000	-77%	-6%
j. Number of positions FTE	33		0		
Faculty	0	4	0	-100%	
Research staff (non-faculty)	19.3	20	0	-5%	
Professional staff	25.5	31	52	-18%	-51%
Students	22	24	0	-7%	
Classified personnel	26.5	10	9	165%	194%
Research and Development Outcomes					
A. Publications					
1. Number of scientific peer-reviewed journal articles published	238	198	153	20%	56%
2. Number of scientific peer-reviewed book chapters published	9	15	11	-40%	-18%
3. Number of scientific peer-reviewed books published	1	2	1	-50%	0%
4. Number of other scientific papers published	61	44	0	39%	
5. Number of other scientific papers not published (e.g., research reports for industry)	21	7	0	200%	

	2006 Attributable to State Funding	2005 Attributable to State Funding	2002 Attributable to State Funding	2005–2006 Percent Change for Nonprofits	2002–2006 Percent Change for Nonprofits
B. Research Proposals					
1a. Number of extramural research proposal submitted	188	189	106	-1%	77%
1b. Dollars requested	$107,147,465	$132,209,770	$92,252,970	-19%	16%
2a. Number of these proposals submitted jointly with other Maine institutions	20	16	1	25%	1900%
2b. Dollar Value	$80,14,193	$4,818,774	$8,218,269	66%	-2%
3a. Number of these proposals submitted jointly with non-Maine institutions only	39	42	20	-7%	95%
3b. Dollar Value	$20,298,484	$27,455,139	$35,698,533	-26%	-43%
4a. Number of these proposals submitted jointly with both Maine and non-Maine institutions	50	54	21	-7%	138%
4b. Dollar Value	$26,523,231	$31,036,928	$43,916,802	-15%	-40%
C. Research Awards					
1a. Number of new federal research grants, contracts, subcontracts (total value for all costs and years)	48	51	41	-6%	17%
1b. Dollar Value	$32,965,792	$48,365,156	$47,176,309	-32%	-30%
2a. Number of these awarded under EPSCoR	0	0	0		
2b. Dollar Value	$2,000,000	$0	$0		
3a. Number of these that were earmarked	1	1	0	0%	
3b. Dollar Value	$24,5516	$120,280	$0	104%	
4a. Total expenditures for research and development for FY06	$73,083,281				
4b. Sources of funds for R&D expenditures: Federal	$64,574,156				
State	$1,359,703				
Industry	$330,596				
Individuals and foundations	$7,306,191				
5a. Number of industrial research grants, contracts and subcontracts awarded	6	1	2	500%	200%
5b. Dollar Value	$1,935,742	$86,098	$175,604	2148%	1002%
6a. Number of these industrial research contracts awarded by Maine companies	4	0	0		
6b. Dollar Value	$170,826	$0	$0		
7a. Number of new foundation grants and gifts	35	39	20	-10%	75%
7b. Dollar Value	$7,957,902	$6,295,725		26%	

	2006 Attributable to State Funding	2005 Attributable to State Funding	2002 Attributable to State Funding	2005–2006 Percent Change for Nonprofits	2002–2006 Percent Change for Nonprofits
D. Intellectual Property					
1. Number of disclosures made	18	16	$2	13%	800%
2. Number of patents applied for	6	6	0	0%	
3. Number of patents awarded	1	0			
4. Number of copyrights obtained	0	1	0	-100%	
5. Number of plant breeder's rights obtained	0	0	0		
6. Number of licensing agreements signed	2	1	0	100%	
7. Number of licensing agreements signed with Maine companies	0	0	0		
8. License income received this year	$136,472	$347,762	$0	-61%	
E. Spin-off Companies					
1. Number of new companies formed	1	1	0	0%	
2. Number of jobs in these companies at spin-off	2.5	1.5	0	67%	

Gray areas = no data, or data question has changed significantly

Questions shift over time, so cannot analyze over time

Attachment E

IMPLAN Assumptions and Findings

IMPLAN Analysis

For this analysis, we will assume that company (and university) expenditures arising from new labor hired as a result of Maine's investments directly increase demand for the output of economic sectors that receive these funds. To meet these demands, production of the companies increases, meaning that they hire more people and purchase additional nonlabor inputs (i.e., materials, energy). Other sectors of the economy respond by increasing output leading to additional purchase of labor and nonlabor inputs (or "indirect" impacts). In addition, the accompanying increases in employment and increased profits associated with household ownership of firms lead to higher household incomes. As a result, households will purchases more goods and services (or "induced" impacts). These feedbacks continue indefinitely but become smaller and smaller in each round as a result of "leakages." For example, not all income is spent (some is saved), and what is spent is not necessarily spent within the regional economy of interest. The measure of the economic impact resulting from the investment funds we will use in this analysis is the sum of the regional economy's associated direct, indirect, and induced responses as shown in the following formula:

Policy shock → Direct impacts + Indirect Impacts + Induced Impacts = Total Impact

Economic Impact Model and Input Requirements

IMPLAN is a widely used, commercially available, input-output (I/O) modeling framework used to measure the responses described above. I/O models are mathematical models that describe links among sectors of the economy. They allow us to analyze the influence of economic changes such as those experienced by grant and assistance recipients on the regional economy. Production technologies describe the labor and other input requirements each industry must purchase to produce its own output. Using these relationships, I/O models provide estimates of the indirect and induced spending changes associated with the direct change in final demand. Other things being equal, the higher the propensity for households and firms within the region to purchase goods and services from local sources, the higher the multipliers for the region will be.

To use IMPLAN, we collected the following inputs:

- Identification of industries receiving funds
- Estimate of the increase in demand for the output of each sector that receives the funds. Conceptually, we approximated the increase in demand for output using data on increased labor for the affected sectors. We had data on revenue increases, but since labor and revenue changes are interdependent and the labor data was more reliable, we used only labor data.
- IMPLAN data files containing information on the state of Maine

Limitations of the IMPLAN Approach

The use of I/O models remains popular because they provide cost-effective and readily understandable estimates of the regional impacts of a policy change that will affect the local economy. However, it is important to recognize that although IMPLAN analysis explicitly estimates the direct, indirect, and induced impacts, these measures do not account for resource scarcity. Using resources for investment funds means that they are not available for use by households and businesses in the economy. Economists refer to this value as "opportunity cost"—the value the resources would have had in their best alternative use. For example, if the investment fund is financed by income taxes, households will have less disposable income and may reduce their spending on other goods. In this case, the increased spending may be partially offset by reductions in consumption spending. The equation below illustrates an alternative measure of economic impacts resulting from a policy shock:

Policy shock → Direct Impacts + Indirect Impacts + Induced Impacts
– Opportunity Costs = Net Impacts

The second limitation of the model is that it assumes fixed prices—no market price changes are estimated, and the behavioral responses to these price changes are ignored.

As a result, issues related to substitution possibilities in production/consumption are not considered.

Although analysis of these issues is beyond the scope of work, results from an IMPLAN analysis should be interpreted in light of these limitations. The IMPLAN impact estimates are likely overstated because of failure to account for offsetting effects elsewhere in the economy.

Further, in this specific case, several additional assumptions were made that limit the interpretation and reliability of the results.

1. **Estimates are based on survey respondents, not all funded firms**: We used revenue/labor impacts only from the firms that provided responses to the survey (approximately 50% of those to which surveys were sent) because we did not feel comfortable that the responses were representative of the entire group of funding recipients. This implies that the benefits are underestimates.
2. **Impacts are from investments between 2000 and 2006**: The companies/ universities surveyed received money at some point between 2000 and 2006, and, as such, the numbers reported are more than just the benefits of 2006 investments and thus are likely overestimates.
3. **Impacts are based on all reported new hires:** The impacts provided by survey respondents represent all new staff hires in the year 2006, some of which can accurately be attributed to Maine's investments and some of which should not be.

4. **Investments were not exogenous**: Since the investments made by the state included taxes collected from state households, the impact (shock) being estimated here is not fully exogenous. This means that the income effects described therein should be somewhat lower, and hence, the benefit estimates are overestimates.
5. **Exact data on the beneficiaries of new revenue and use of such were not available:** New revenue and employment were distributed based on survey response and available North American Industry Classification Systems (NAICS) (U.S. Census codes) and IMPLAN data. Further, without knowing how and where new revenue dollars were spent (i.e., in-state vs. out-of-state, capital, etc.), impact estimates are much less accurate in general.

IMPLAN Results

As noted above, we characterized the impacts of Maine's investments as changes to final demand by looking at increased labor hired by private sector, university, and research institution recipients of state grants. We ran IMPLAN models for each program separately and then together.

Maine invested $6,041,642 in 2006. According to the IMPLAN model, this resulted in $53,920,416 of direct impact on the Maine economy, $16,995,416 in indirect impact, and $15,659,028 of induced impact, for a total of $86,574,860. This is based on reported new labor for 2006, and results are expressed in 2006 dollars.

Expressed in jobs, the private sector grants resulted in 385.4 direct positions, 156.4 indirect jobs, and 175.0 induced jobs, for a total of 716.8

The investment in the private sector resulted in an impact of more than 14 times the original investment.