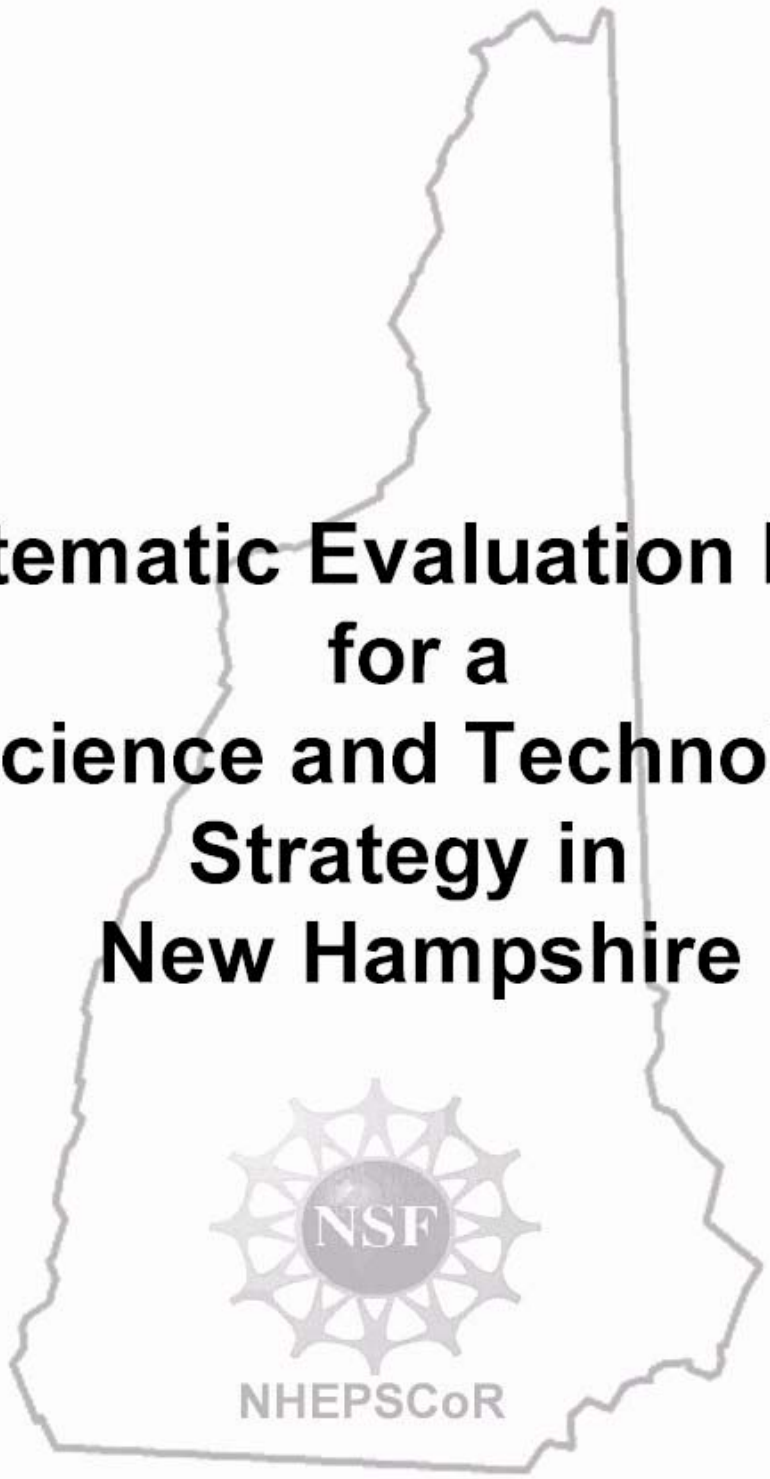
A Systematic Evaluation Process for a Science and Technology Strategy in New Hampshire



NorthStar Economics, Inc.

Rainey & Associates

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EXECUTIVE SUMMARY

This study identifies New Hampshire's strengths in science and technology that may form the basis for funding under the Experimental Program to Stimulate Competitive Research (EPSCoR). New Hampshire is preparing to enter the EPSCoR program which is funded by the National Science Foundation. The program is designed to identify strategic opportunities for science and technology-based economic development and increased research capacity. The goal of the EPSCoR program is to expand opportunities for researchers to become more competitive in securing Federal funding opportunities.

A critical early step in applying for the EPSCoR program is to independently evaluate a state's science, research and technology strengths. NorthStar Economics, Inc. was retained by the New Hampshire EPSCoR statewide committee to develop an on-going process that will systematically identify opportunities and potential barriers to New Hampshire's growth in key technology clusters. Mr. Thomas Rainey, President of Rainey & Associates, served as a senior advisor on the project.

In the process of this study, eleven technology areas or themes were identified and evaluated. Those eleven areas included the following:

- Biotechnology, Bioinformatics and Life Sciences (Bio-manufacturing)
- Healthcare/Medical Devices
- Information technologies/ Data Processing
- Sustainable (Environmental) Technologies
- Agriculture/Aquaculture/Marine Research
- Software Products and Services
- Homeland Security/Defense
- Precision Engineering/ Advanced Manufacturing
- Nanotechnologies/ New Materials
- Optics
- Space Science Technologies

Some of these technologies exist in a critical mass and represent core areas of strength in technology for New Hampshire. Other areas are not as robust and represent either emerging areas or stand-alone technologies.

Based upon a careful evaluation of these technologies, the existing and potential opportunities to commercialize these technologies, and the array of research programs on university campuses in New Hampshire, the consultants developed four broad theme areas that build on the information on the existing strength and future opportunities for economic development in science and technology. These theme areas include the following:

1. Information and Information Infrastructure Protection and Security
2. Biotechnology / Medical Devices and Bioinformatics
3. Sustainable Technologies and Research
4. Nanotechnology and New Materials

The consultants also identified the following emerging technologies that could provide scalable economic opportunity in the future:

1. Precision Engineering
2. Optics
3. Bio-refining

The consultants included a number of recommendations that deal with gaps and barriers and the need for infrastructure improvement to benefit statewide research and development efforts. The following "institutional themes" are candidates for EPSCoR investment to improve the overall economic development derived from technology:

1. Collaboration and Networking
2. Interdisciplinary Research
3. Technology Transfer
4. Mathematical, Statistical and Computational Tools and Models

Finally, the study contains suggested action steps that might be early projects once EPSCoR funding is achieved. These early projects might include:

- New Hampshire Science and Technology Directory of Experts that contains an online, searchable database of links to academic researchers and to instrumentation and lab facilities that could facilitate collaborative research projects.
- EPSCoR Graduate Fellowship in Biotechnology and Life Sciences that would provide support for ongoing research programs and provide applied research experiences for graduate students and faculty.
- New England EPSCoR Collaboration that would focus cooperative and complementary research projects and planning with EPSCoR programs in Maine and Vermont.
- Intellectual Property (IP) Mining Initiative that would map how existing, underutilized IP in universities and businesses could be licensed and or developed.
- Strategic Technology Innovation Services that could systematically identify federal and foundation funding opportunities that would sustain research programs, institutes and technology transfer incubators. These services would increase the volume of SBIR and STTR funding thus accelerating the technology transfer from fields such as bioinformatics, biometrics, precision engineering and nanotechnologies.
- Science and Technology Education Programs that educate the general public and state policy makers.
- Workforce Development Programs Related to Science and Technology that utilize the offering of the NH Community Technical College System and state colleges.

The study report also contains detailed information on state economic data, input obtained through interviews with key stakeholders, and major academic and research programs.

PROJECT METHODOLOGY

The Experimental Program to Stimulate Competitive Research (EPSCoR) is funded by the National Science Foundation. There are 25 states in the nation with EPSCoR programs. These are states that have historically received a smaller share of the national research budget. EPSCoR is designed to identify strategic needs and fund and seed science and technology-based economic development and research capacity building initiatives in collaboration with partner academic institutions, state leaders in government and private industry. The goal is to expand opportunities for researchers in EPSCoR states to become more competitive in securing Federal funding opportunities. EPSCoR programs have been used to provide seed grants, to fund equipment and research, to develop science and technology strategies, and greater access to national resources. The EPSCoR state governing committee is instrumental in identifying critical needs for each state.

NorthStar Economics, Inc. was retained by the New Hampshire EPSCoR statewide committee to develop an on-going process that will systematically identify opportunities and potential barriers to New Hampshire's growth in key technology clusters. Mr. Thomas Rainey, President of Rainey and Associates, assisted NorthStar as a senior advisor on the project.

Part of this project includes developing a systematic strategy to monitor and produce feedback about the direction of the development of research and technology in New Hampshire. One of the project outcomes is to identify key industry cluster leads that will provide information back to the governing committee on a regular basis. The input provided in this initial assessment will be used to identify immediate funding priorities and an action plan for the EPSCoR program.

The project methodology included extensive interviews. Interviews were conducted and meetings held with key business, academic and civic leaders related to technology training, research, regulatory oversight and industry. A common interview form and script were developed to help ensure consistency in gathering data. A copy of the interview form is included as Appendix 1 to this report

The interview process has encouraged consensus building, networking, education exchange and coordination of efforts with broad community input from the private, public and academic communities throughout New Hampshire.

The process raised awareness of the New Hampshire EPSCoR initiative and served as a catalyst to motivate future participation. The consultants found widespread and enthusiastic support for the EPSCoR initiative from the business, education and government stakeholders interviewed for the study.

IDENTIFYING CRITICAL NEEDS IN NEW HAMPSHIRE

Key assets and infrastructure, both in terms of physical and human/organizational resources have been identified and assessed to assist in developing an overall strategy to best guide the New Hampshire EPSCoR program.

NorthStar Economics has identified New Hampshire's existing core competencies in this report and provides suggestions for the infrastructure grant proposal to be submitted for capacity building in these priority areas with both short-term and long-term action items and goals.

The study examined and benchmarked:

- Major research themes (basic and applied)
- Key technology-based industries
- Entrepreneurial resources
- Government support
- Patents/Intellectual Property activity and success in licensing and commercializing New Hampshire based innovations.
- Research and development funded through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs in New Hampshire.
- Gaps in the skill sets of the New Hampshire workforce.
- Potential for outreach in New Hampshire's North Country and other underserved or distressed areas of the state.

ECONOMIC BACKGROUND AND CONTEXT

Economic Benchmarking

New Hampshire is not a big state, either in geography or population. Overshadowed by the size of the economy in neighboring Massachusetts, New Hampshire is heavily influenced by economic events in Massachusetts. When Massachusetts is doing well, there is a positive spill-over effect on the economy of New Hampshire. When Massachusetts' economy suffers, New Hampshire also experiences a downturn.

New Hampshire's 2004 population is just below 1.3 million people and it ranks 41st in population. Total employment in New Hampshire was just under 800,000 in 2003.[1] New Hampshire is a state with a high concentration of manufacturing jobs. With 10.6% of its employment in manufacturing, it ranks 15th in the share of its workforce employed in manufacturing, just above Rhode Island and below Pennsylvania. This compares to the

[1] Economic data varies a bit in vintage as we choose to use the latest available. The combination of the data sets does not alter New Hampshire's relative rankings to any large degree or change the economic attributes and challenges of the state.

national average of employment in the manufacturing sector of just 9.1%. Indiana ranks first with a manufacturing employment share if 16.3%.

State	Population	Employment
Connecticut	3,503,604	2,106,756
Maine	1,317,253	805,098
Massachusetts	6,416,505	4,023,997
New Hampshire	1,299,500	798,526
Rhode Island	1,080,632	596,323
Vermont	621,394	411,341
Source: U.S. Census, 2004, U.S. Bureau of Economic Analysis, 2003		

New Hampshire's Gross State Product (GSP) in 2003 was just over $49 billion. Recent economic growth as reflected in a relative GSP index has outpaced much of the country and most of the New England states. The larger states in the New England region saw relatively little economic expansion since the last recession, while the northern tier of states fared much better.

State	2003 GSP (Million $)	2003 GSP Index (2000 = 100)
Connecticut	172,378	100.6
Maine	40,960	104.8
Massachusetts	297,343	100.8
New Hampshire	49,047	105.1
Rhode Island	39,569	104.5
Vermont	30,670	106.4
Source: U.S. Census, 2004, Bureau of Economic Analysis, 2003		

Sector analysis of the New Hampshire's economic illustrates some continuing trends. Manufacturing continues to play a declining but still significant role in the state's employment. The primary economic growth sectors are found in finance, health care and social services. Construction remains a derived demand from general economic and population growth in the region.

New Hampshire	Sector Output (million $)	
Industry	2001	2002
Construction	2,296	2,420
Manufacturing	6,052	5,797
Information	1,433	1,457
Finance and insurance	3,523	4,337
Educational services	679	756
Health care and social assistance	3,332	3,652
Arts, entertainment, and recreation	373	395
Government	3,962	4,249
Source: U.S. Bureau of Economic Analysis		

A snapshot of some of the primary high-tech industries in New Hampshire indicates the impacts of the last recession. In the period from 2001-2002, the computer, information, and software industries in the state showed contraction or very limited growth.

New Hampshire	**Employee Compensation** (million $)	
Industry	**2001**	**2002**
Computer Systems Design	741	695
Computer & Electronic products	1,194	1,145
Information & Data Processing	81	86
Publishing, including Software	780	778
Source: U.S. Bureau of Economic Analysis		

New Hampshire's high-tech sector was severely hit by the last economic downturn. New Hampshire lost the highest percentage of high-tech workers of any state in the nation, losing some 18% of its high-technology jobs from 2001 to 2002. Massachusetts lost over 13% of its high-tech jobs and this had a direct impact on the New Hampshire economy. Massachusetts lost almost 39,600 jobs during the downturn. New Hampshire lost over 8,400.

	High-Tech Employment Loss 2001-02	
State	**# of jobs**	**% of jobs**
Connecticut	-6,085	-7.39
Maine	-1,734	-9.20
Massachusetts	-39,568	-13.40
New Hampshire	-8,405	-18.19
NH Manufacturing	12,573	-12.36
Rhode Island	-495	-2.60
Vermont	-1,667	-8.71
Source: AeA Cyberstates 2003, U.S. Bureau of Economic Analysis		

In comparison to the high tech sectors, the loss of manufacturing jobs was more severe in terms of absolute numbers, although not as high in percentage terms due to the larger size of the manufacturing industry. New Hampshire's manufacturing sector lost 12,570 jobs from 2001 to 2002, a 12.4% decrease.
While it is difficult to ascertain trends through an economic downturn and the beginning of an economic recovery, it is expected that long-term general manufacturing employment trends will continue to trend downwards, at least as a share of total employment. On the other hand, high-technology employment, even in the manufacturing sector, is expected to increase. Moreover, earnings of high tech workers are expected to outpace manufacturing and all-sector earnings in the future.

With the positive outlook for high-technology employment and earnings, New Hampshire's focus on high-technology development is a sound strategy. Higher

employment growth in the high-tech sector coupled with its higher rate of earnings growth should at economic growth to the New Hampshire economy much more quickly than would reliance on traditional, mature industries.

New Hampshire's High-Tech Sector

Relative to its size, New Hampshire is a high-technology center, ranking high in its concentration of high-tech employment. According to AeA's Cyberstates 2003, New Hampshire employed 37,803 people in high-technology business in 2002, ranking 34th among states on employment levels alone, although it did drop from 31st in 2001. [2] Its concentration of high-technology workers based on population, on the other hand, puts New Hampshire tenth, with 72 of every 1,000 workers in high-tech industries. Colorado ranks highest with 98 high-technology workers per 1,000. Massachusetts is in second place. Vermont is ranked 11th in high tech worker concentration, one slot below New Hampshire. Mississippi is last with 24 high-technology workers per 1,000.

State	High-Tech Employment	High-Tech Employment Concentration (# per 1,000)
Connecticut	76,242	53.98
Maine	17,111	34.67
Massachusetts	255,744	91.77
New Hampshire	37,803	72.51
Rhode Island	18,553	45.92
Vermont	17,465	70.83
Source: AeA Cyberstates 2003		

New Hampshire's high-technology workers average annual earnings are 17th in the U.S., at $62,587 in 2001. Massachusetts and Connecticut have higher high-tech worker average annual earnings at $77,238 and $69,798, respectively, ranking 3rd and 8th. Washington State has highest high-technology worker average annual earnings at $94,705.

Manufacturing jobs are generally highly valued because of the relatively high wages paid in the sector. Manufacturing wages in New Hampshire are 56% higher on average than wages paid across all sectors, $45,968 versus $29,373. And while part of New Hampshire's high-technology employment occurs within the manufacturing sector (the other part is in the service sector), high-technology wages are 36% higher than average annual manufacturing wages. Average high-technology wages in New Hampshire are over double the average wage across all sectors.

[2] American Electronics Association (AeA), *Cyberstates 2003*.

State	High-Tech Annual Earnings (2001)	Relative to All Sector Earnings (%)	Relative to Manufacturing Earnings (%)
Connecticut	$69,798	180	124
Maine	45,123	190	120
Massachusetts	77,238	205	137
New Hampshire	62,587	213	136
Rhode Island	57,110	189	150
Vermont	55,566	231	136

Source: AeA Cyberstates 2003, U.S. Bureau of Economic Analysis

Most major high-technology industries in New Hampshire were adversely impacted by the last recession. The state's high-technology industry lost jobs after the 2001 industry downturn with employment losses continuing into 2003. Below is a list of New Hampshire high-technology industries that had a thousand or more employees in 2001 and what transpired in job numbers over two years. Circuit board manufacturing experienced a huge downturn, losing over half its jobs. Semiconductor devices and software publishers both lost more than 1,000 jobs each and on a percentage basis that represented a quarter to a third of workers in those industries.

HIGH TECH INDUSTRY IN NEW HAMPSHIRE	Employment		
Industry	2001	2002	2003
Electronic Computer Manufacturing	3,093	2,631	2,362
Circuit Board Manufacturing	4,401	2,326	1,707
Semiconductor & Related Devices	1,944	1,233	982
Printed Circuit Assembly Manufacturing	2,685	2,187	2,147
Electricity & Signal Testing Instruments	1,062	855	797
Software Publishers	4,077	3,380	3,042
Wired Telecommunications Carriers	1,829	1,555	1,362
Engineering Services	3,090	2,976	2,914
Computer Systems Design Services	2,116	1,813	1,711
R&D in Physical, Engineering, & Life Sciences	1,413	1,429	1,124

Source: U.S. Bureau of Labor Statistics

As the economic recovery in the U.S. shifts into high-gear, most of New Hampshire's high technology industries have stabilized and it is expected that 2004 data will reflect flat or increasing employment numbers. As stated above, the manufacturing industry which includes many high-technology business, suffered greater job losses that did the overall high-technology sector during the recent recession. Manufacturing is not expected to recover as quickly as the rest of the New Hampshire economy and the outlook for non-high-technology manufacturers is not as optimistic.

Economic Disparity

It is frequently noted that talented people are New Hampshire's competitive advantage. It is also stated that there are two New Hampshire's – the one of highly skilled, highly educated, high net worth individuals, engaged in high technology careers, and the other New Hampshire characterized by low wage jobs, aging "rust belt" infrastructure and limited opportunity.

The communities that are academic centers such as Hanover, Durham/Portsmouth, and Plymouth versus the North Country are a good example of this division. The demographics change dramatically as you look beyond these centers and into surrounding communities.

According to the U.S. Census Bureau Lebanon and Hanover, for example, possess a number of key demographics and economic characteristics that make them attractive for high-technology based entrepreneurship and venture investing. A total of 42% of Hanover's residents, for example, possess a bachelor's degree, and 20% possess advanced degrees. This is in stark contrast to the rest of Grafton County, where over 70 percent of the county's private employment is in retail and services, two of the lowest paying employment sectors. The North Country and communities in Western New Hampshire need high quality jobs that pay "living wages".

FINDINGS FROM THE INTERVIEW PROCESS

The following section is about the feedback gathered in the interview process. Given the amount of material gathered, this feedback is summarized without extensive commentary or analysis:

Familiarity with the EPSCoR Program

Most of the fifty people who were interviewed knew about EPSCoR because of their work at Dartmouth College or UNH or because they attended the December 2003 EPSCoR kickoff meeting. Those who didn't know much about EPSCoR were in the private sector and not members of the NH High Tech Council.

Almost without exception, there was enthusiastic support for the EPSCoR program.

Key metrics to measure the success of the EPSCoR program in New Hampshire

Increase in patents
Increase in R&D activity
Increase in scientific competitiveness
Increased contact and networking between high tech business and academic researchers
Increased tech transfer and commercialization
Private-public research projects with academic institutions
Success of partnerships
Academic program response to educational needs

Industry audit of existing and emerging technology industries and research

The responses to these questions are summarized in the next section of this report.

Major gaps and barriers to the development of technology research and commercialization

Lack of state R&D incentives
Disconnects between industry and the academic institutions
Lack of networks
Lack of follow-on capital
Lack of affordable housing
Weak technology transfer structure
Telecommunication (broadband) and technology tools (in the North)
Brain drain to Massachusetts and elsewhere
Lack of formal science and technology networks
Local decorporatization (headquarters and decision makers moving out of state)
Scattered approach to science and technology development
Lack of early stage seed capital
Lack of a support structure for entrepreneurs

Lack of leadership and management talent
Lack of coordination among the high tech associations in the state
Lack of leadership on economic development
Lack of collaboration among higher education institutions

Other comments and ideas

Locate an office of the High Tech Council at UNH
Fund a masters program in commercialization of technology
Support various technology advocacy groups such as NH Biotech Council and the NH Software Association

AUDIT OF MAJOR RESEARCH ASSETS AND THEMES

The following research themes where identified as areas of possible strategic importance to the State of New Hampshire:

1. Biotechnology, Bioinformatics and Life sciences (Biomanufacturing)
2. Healthcare/Medical Devices
3. Information technologies/ Data processing
4. Sustainable (Environmental) Technologies
5. Agri/Aquaculture/Marine research
6. Software Products and Services
7. Homeland Security/Defense
8. Precision Engineering/ Advanced Manufacturing
9. Nanotechnologies/ New materials
10. Optics
11. Space Science Technologies

The list of possible strategic technologies was identified by the consultants through consultation with the EPSCoR Committee, interviews with key stakeholders throughout the State of New Hampshire, and analysis of data on research and technology companies within the state.

While some of these sectors are well established technology clusters, others are emerging technology areas that have high potential for growth. Several of the emerging technology areas identified as strengths in New Hampshire such as environmental technologies, life sciences and precision engineering, new materials and nanotechnologies are both exciting and challenging in that the lines blur between where one industry ends and the next begins.

State science and technology strategies seek to coordinate government activities more efficiently and fully utilize all of the assets the state has at its disposal. A critical strategy for enhancing research effectiveness is the breaking down of institutional barriers to improve communication and collaboration between various disciplines, departments, and state institutions. By removing institutional obstacles and improving cooperation between various actors, state governments can coordinate intellectual resources and in doing so, forge new linkages, which facilitate the flow of people and research, and overcome bottlenecks in the innovation process.

This strategy encourages new "cross-over" disciplines from several fields, and encourage less compartmentalization, less duplication of efforts, greater mobility, formal and informal communication, and efficiency of resources.

The New Hampshire EPSCoR program offers an excellent opportunity for the State of New Hampshire to better coordinate and leverage this existing "intellectual capital."

High technologies such as biotechnology and bioinformatics, no longer require physical locations in larger metropolitan areas. High speed internet access, secure networks, fax machines, teleconferencing and express delivery, remove barriers to researchers and technology businesses locating in areas where employees can enjoy a greater quality of life with minimal commuting requirements.

MAJOR ACADEMIC RESOURCES

Dartmouth College

Founded in 1769, Dartmouth College is one of the oldest and most prestigious Liberal Arts Colleges in the U.S. Dartmouth College offers 16 graduate programs and is home to 5,600 students and 1,200 institutional faculty from around the world. A total of 98% of the faculty possess a doctorate or equivalent degrees.

Research, Technology Licensing and Commercialization

Dartmouth's share of sponsored research has increased dramatically over the past five years, and it now enjoys the largest research budget of all Northern New England universities. 2003 sponsored research totaled $163 million. The largest single source of funding is the National Institute of Health (NIH) for medical research. Dartmouth ranks 58th among the nation's 125 medical schools in terms of funding from NIH and is in the 82nd percentile for funding per basic science faculty member.[3] In Fiscal year 2003 the college had 41 invention disclosures and 81 active license agreements. Of these, 71% originated from the Medical School and 10% from the Thayer School of Engineering.[4]

Dartmouth Medical School's overall research funding – 65% of which comes from NIH, was $80.7 million in Fiscal Year 2001, up 14% from $70.8 million received in 1999. This upward trend is expected to continue as the nation's commitment to biomedical research grows with an aging population, and due to the war on terrorism, which requires new measures to combat bio-terrorism. As an example, NIH awarded a Dartmouth professor of microbiology and immunology $11.6 million for a Center of Biomedical Research Excellence. This center partners with several investigators from the University of New Hampshire. The Institute for Security and Technology Studies is conducting significant research in the area of bio-terrorism prevention.

[3] Research is Still Strong for DMS Faculty, Dartmouth Medical Magazine, Winter 2001
[4] Dartmouth College Fiscal Year 2003 Annual Report

Amos Tuck School of Business – Consistently ranked among the top ten business schools in the country, Tuck's alumni network and top graduates are well positioned to assist New Hampshire entrepreneurs as mentors and managers. Tuck has several student clubs which support local businesses including the Student Consulting Services (TSCS), a free student consulting service for local businesses focused on business plan development, marketing, technology, valuation and investment, and an Entrepreneurship Club, and Healthcare Technology Club.

Dartmouth-Hitchcock Medical Center (DHMC) –located three miles from the main campus. Together with Dartmouth Medical School, they comprise a top ranked tertiary care teaching hospital (2,000 full-time and adjunct Dartmouth faculty.) This medical center's mission rests on the "three legged stool" of clinical excellence, teaching, and research. The respective Board of Trustees has encouraged community service and outreach. The medical center and the College have considerable research strength in microbiology, immunology, the neuroscience, and genetics and they are actively expanding their focus.

Dartmouth Hitchcock Medical Center has developed an additional 160,000 square feet of space of which 100,000 will be used primarily for cancer research. This entire expansion will be completed in 2006 at a cost of $224 million. At the same time, there are plans to develop an additional 300,000 square foot life sciences facility on the Dartmouth campus to further expand its teaching and research capabilities in biotechnology.

Department of Computer Science

Dartmouth College's Computer Science Department is quick to point out that their expertise extends far beyond software development. The Computer Science laboratory conducts research in Computational Biology & Chemistry, Micro-electromechanical Systems (MEMS) and Micro robotics.

Other research includes robotics, information capture and access, mobile computing, and augmented reality systems. The Image Science Group's research focuses on topics in image processing, computer vision, and computational and human aspects of perception. Cyber security is a core technology focus for the Institute for Security Technology Studies who partner with industry in the carrying out their mandate. Past innovations include time-sharing, BASIC, and new advances in security and mobile computing.

Thayer School of Engineering - The Thayer School has produced over a dozen companies and over a thousand high wage jobs since the 1950's. These developments are a direct result of Dartmouth's recruitment of world-class faculty in the fields of material engineering, fluid mechanics, mechanical and chemical and communications and a strong entrepreneurial spirit among faculty, staff and graduates.

University of New Hampshire (UNH)

Founded in 1866 and relocated from Hanover to Durham in 1890, UNH is home to 10,500 undergraduate students and 2,100 graduates at the main campus and offers a wide variety of graduate programs. UNH has 94,000 graduates from all over the world and offers 2,000 classes in over 100 majors.

While the majority of Dartmouth College's sponsored research funding comes from NIH for medical research, the majority of UNH's funding comes from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) which increased by 40% to $23.8 million in 2003. UNH's second largest sponsor is the National Aeronautics and Space Administration (NASA), which also increased by 9% in 2003 to total $9 million. UNH has a unique capability to contribute to biosciences in areas related to the environment, ocean and deep sea studies, agriculture and aquaculture.

Research, Technology Licensing and Commercialization

Established as an agricultural college, UNH is now a comprehensive land, sea, and space grant university and has the third largest annual research expenditure of all the Northern New England universities. UNH successfully raised $100 million in capital investments to improve science and engineering buildings at a time as the state was reducing funding to the university. UNH currently receives only 15% of its overall budget from the state of New Hampshire. Out of necessity, UNH has had to be entrepreneurial in how it funds its core mission, and new initiatives.

The NH-BRIN Center for Structural Biology was established in October 2001 with funding from the National Institute of Health to initiate three interrelated core activities: research in proteomics, bioinformatics, and outreach to recruit promising new students and researchers into the field. This center brings together a cross section of experts in structural biology to understand the molecular entities involved in cell function. Studies at the center focus on factors beyond a genome to the molecules directly involved in cell function. The core of this center is built around mass spectrometry instrumentation and high throughput molecular analysis to sequence the isolated structures under robotic control. The goal of the center is to unravel the complexity and critical roles of glycosylation.

The Research Computing Center's Interoperability Lab provides performance testing services for over 100 vendors of computer communication devices. The Laboratory is also developing a new generation of police cars. These cars are voice operated and test new developments in design, function, and service.

The Institute for the Study of Earth, Oceans and Space (EOS) conducts research projects that are nationally recognized, particularly in the areas of climate change, and life sciences. The NASA certified machine shop at the Institute has designed and fabricated advanced instruments for 14 NASA missions. EOS is well known for innovations in ocean mapping, and modeling.

Open Ocean Aquaculture Project (OOA) – The Open Ocean Aquaculture Project (OOA) was started in 1998. It is now part of a regional effort to demonstrate the feasibility of off-shore aquaculture and to further the establishment of a viable commercial aquaculture in New England. The program includes an open ocean demonstration project and the ongoing research budget of approximately $2.4 million explores the technology, biology, environmental impact and economics of open ocean fisheries.

OOA is part of the Cooperative Institute of New England Mariculture and Fisheries (CINEMAR) which was established in the year 2000. CINEMAR was founded by the National Oceanic and Atmospheric Administration (NOAA) and UNH. The OOA project came under the administration of CINEMAR in 2001 and serves as the cornerstone project of the mariculture component of the Institute.

The Environmental Research Group (ERG) is focused on applied and fundamental environmental engineering and science research. In 2001 ERG moved into a state-of-the-art Environmental building on campus. This interdisciplinary program ties three departments: civil engineering, microbiology, and chemical engineering, together to solve real world problems in areas such as water treatment technologies, bio-remediation, and electro-technologies research. This program has been involved in microbial (including genetically altered) treatment of water.

The Hubbard Center for Genome Studies - launched in September 2001, The Hubbard Center is devoted to understanding the structure and function of genomes across the spectrum of life. Genomics is a new area of biology made possible by large-scale DNA sequencing efforts that study the complete genome and its protein expression patterns. This center occupies 7,500 square feet of space in the new Environmental Technology Building on campus. The center will focus on aquatic and marine organisms and environmental genomics. The center will also develop a focus on in the multi-disciplinary field of bioinformatics.

The Center to Advance Molecular Science Interaction (CAMIS) is engaged in developing new analytical instrumentation that is used primarily by biopharmaceutical researchers to characterize molecules. The accurate description of molecular interactions is a central element in understanding disease mechanisms and is essential for devising safe and effective drugs. CAMIS is a world leader in the development of data acquisition systems for the analytical ultracentrifuge. Its research is on the cutting edge of biomedical and biomaterials. These unique instruments and first principal methods to characterize molecular interactions in otherwise intractable chemical systems is on the cutting edge of biomedical and biomaterials research. The founder of the center is a renowned biochemist and an expert in analytical methods.

Biomolecular Interaction Technology Center (BITC) was designed to serve as a university-industry Research Center and was created in 2002 with a grant by NSF. BITS is a new consortium of biopharmaceutical companies that will allow them to access the instrumentation developed at CAMIS for testing purposes.

UNH Office of Intellectual Property Management (OIPM) was launched in November 2000. This office reports to the Vice President of Research and Public Service. While the University of New Hampshire has long been considered a serious research intuition, the active pursuit of technology licensing, technology transfer and commercialization is a relatively recent activity.

The establishment of the OIPM provided the organizational structure and resources necessary to support the growth of UNH's research programs and put in place the mechanisms necessary to protect proprietary research though patents, copyrights, and trademarks. This initiative also provides a strong mandate to transfer intellectual properties from UNH to industry for commercial products, economic development, and public benefit.

In fiscal year 2004, the office received and processed 19 invention disclosures, negotiated 9 new license agreements bringing the total to 35 active license agreements that represent technology innovation from a wide cross section for the research at UNH. UNH has also launched an intellectual property protection project, undertaken in cooperation with **Franklin Pierce Law School** and funded by the U.S. Patent and Trademark Office.

Other areas of strategic interest within UNH are:

- Drug design and synthesis in the Chemistry Department in collaboration with the Structural Biology Center
- Applications in rheology to biotech problems in the Chemical and Mechanical Engineering Departments
- Bioengineering sensors (Electrical Engineering)

INDUSTRY RESEARCH AND TECHNOLOGY TRANSFER

In addition to the research programs at Dartmouth, UNH, and other universities and academic research centers, there is a substantial amount of research conducted by private businesses within the state. While it is difficult to gauge the exact annual amount of research expenditures by private business, it is possible to provide several measures that give an indication of industry research activity and the transfer of that research and university research into intellectual property in the form of U.S. patents.

The table below shows patent activity for New Hampshire in the period 2000-2004. On a per capita basis, New Hampshire ranks in the top ten states. Patent applications and patents issued reached a peak in 2001 and following the 2001 recession, activity declined in the next two years. However, in 2004 patent filings and patents issued began to rise again and are tracking a national rise in both measures. For comparison purposes, the patent application filings and patents issued number for the State of Vermont are included in parentheses in the table.

Patents Applications and Patents Issued for New Hampshire (and Vermont): FY2000-FY2004

Year	Applications Filed	Patents Issued
2004	1055 (687)	699 (442)
2003	969 (511)	721 (465)
2002	1180 (625)	639 (485)
2001	1324 (776)	715 (505)
2000	1177 (676)	711 (426)

Other indicators of research activity and technology transfer include Small Business Innovation Research (SBIR) awards and Small Business Technology Transfer (STTR) awards. SBIR and STTR research awards are evaluated and funded by federal agencies such as the Department of Defense and NASA.

New Hampshire has a relatively high level of SBIR activity. In the period 1999-2002, there were on average 46 awards per year and the average annual level of funding for Phase 1 SBIR's was nearly $4 million per year.

New Hampshire also had a relatively high level of SBIR, Phase 2 awards. In the period 1999-2002, there was an average of 23 Phase 2 awards Phase 2 average annual funding amounted to $15 million.

It should be noted that over half of the Phase 1 and 2 awards went to one New Hampshire company – Creare, Inc. They have achieved a very successful track record in SBIR competition.

SBIR Awards to New Hampshire Companies: 1999-2002

	Phase 1		Phase 2	
Year	**Awards**	**$ (Million)**	**Awards**	**$ (Million)**
1999	50	$ 4.043	15	$ 10.758
2000	37	$ 3.122	23	$ 14.652
2001	48	$ 4.131	22	$ 12.273
2002	52	$ 4.541	33	$ 22.844

SSTR awards for New Hampshire are shown in the table below. There are far fewer STTR awards granted nationally though the funding level per grant can range up to $1 million.

STTR Awards to New Hampshire Companies: 1999-2002

Year	Phase 1		Phase 2	
	Awards	**$ (Million)**	**Awards**	**$ (Million)**
1999	3	$ .210	0	$ 0
2000	0	$ 0	0	$ 0
2001	4	$ .339	0	$ 0
2002	1	$ .100	3	$ 2.060

The commercialization of research that leads to new companies and high paying jobs is an important outcome of university and business research. In the tables below, we track "where the money goes" in terms of venture capital investments. Most venture capital (VC) investments are made in new companies that are formed around the commercialization of new technologies. The table below gives a nationwide perspective to VC investing in 2004.

VC investing in the U.S. in 2004 was overwhelmingly directed at two areas – software and biotechnology. These areas in the view of VC professionals had the greatest potential for return on investment and comprised over one third of VC investments in 2004.

2004 Venture Capital Investments in the United States by Sector

2004	**Deals**	**Dollars (Million)**
Software	362	$ 5,052.7
Biotechnology	328	$ 3,826.6
Telecommunications	231	$ 1,854.7
Medical Devices	250	$ 1,818.0
Semiconductors	202	$ 1,630.5
Networking and Equipment	174	$ 1,558.0
Media and Entertainment	119	$ 890.6
IT Services	131	$ 767.8
Industrial Energy	127	$ 676.5
Computers	61	$ 508.2

Venture capital investments in New England tracked the U.S. trend in that biotechnology and software were far and away the hot investment areas though the top two spots were reversed in New England. Other areas that drew significant VC money included IT services, medical devices, and media and entertainment.

2004 Venture Capital Investments in the New England by Sector

2004	Deals	Dollars (Million)
Biotechnology	18	$ 216
Software	29	$ 182
IT Services	12	$ 98
Medical Devices	10	$ 72
Media and Entertainment	7	$ 59
Telecommunications	7	$ 49
Semiconductors	7	$ 44
Consumer Products and Services	2	$ 26
Business Products and Services	5	$ 20
Industrial Energy	2	$ 15

From the data available from the State of New Hampshire in appears as though Hew Hampshire follows the U.S. and New England data. Data for the fourth quarter of 2004 showed that New Hampshire had five VC deals and those deals were in software(2), medical devices and equipment, semiconductors and industrial energy.

The table below shows total VC investments in New Hampshire for the period from 1998-2004.

Venture Capital Investments in New Hampshire 1998-2004

Year	Amount ($Million)
1998	$ 179.2
1999	$ 198.2
2000	$ 724.5
2001	$ 250.9
2002	$ 219.2
2003	$ 161.1
2004	$ 146.0

MAJOR RESEARCH THEMES

Part of the scope of work of this project was to do a research audit of the academic and industrial research for New Hampshire. With the guidance of the EPSCoR committee and from the input gathered in the interviews, eleven possible research areas or themes were identified. What follows is a summary of each area. The summary for each research theme area includes a brief definition of the research and a listing of the major assets within the state that support the research. We have also tried to identify the market opportunity leading from the research to commercialization and business opportunity. Where possible, we have identified "leads" which signifies a person, persons or organizations that might be able to monitor this area and feedback information to the EPSCoR Program.

1. Biotechnology, Life Sciences

Definition

The term "biomedical" for the purpose of this study includes the broad areas of health and medical care, and a diverse range of biotechnology and medical technology. While based primarily on the life sciences, important interdependencies exist in the broad biomedical arena with the physical sciences and related technologies. Biotechnology, a component of the broader concept of "biomedical," has been defined by the Federal Office of Technology Assessment as "those techniques that use live organisms (or parts of organisms) to modify products, to improve plants or animals, or develop micro organisms for specific uses."

Assets in New Hampshire

New Hampshire is in close proximity to one of the most outstanding and oldest biotechnology centers in the world – located around Boston and Cambridge, Massachusetts. The extraordinary success of Massachusetts' biotechnology industry provides an opportunity for New Hampshire to align its resources and serve as a partner in that growth.

According to the New Hampshire Biotechnology Council, the biotechnology industry in New Hampshire is old and well established, going back twenty years. The industry itself is only 30 years old from its start in the late 1970's. There is a significant depth, breath and diversity to the biosciences industry in New Hampshire. However, New Hampshire biotechnology is best categorized as high tech manufacturing. Lonza, for example, is one of the world's premier contract manufacturers of recombinant proteins and antibodies for the pharmaceutical industry and had been located in Portsmouth, New Hampshire for over 10 years.

A large segment of the bioscience industry in New Hampshire is the OEM (original manufacture) segment that includes companies manufacturing and marketing laboratory products and equipment for cell culture, molecular biology, clinical testing, drug screening, prenatal screening, liquid handling, diagnostic, image analysis, and pharmaceutical

markets. Bioinformatics and medical informatics is a rapidly expanding biotechnology segment in New Hampshire. Companies are involved in geomatics, proteomics, spectroscopy, and regulatory data analyses and management. Several companies provide formulation and contract R&D services for the pharmaceutical industry, and other companies manufacture blood substitute materials, cell culture additives, radio-pharmaceuticals, immunoassay reagents, kits and antibodies. Several testing labs in New Hampshire supply analytical, chemistry, clinical and biotechnology testing services and products to the industry. Corporate headquarters of several very large global companies are located in New Hampshire including Fisher Scientific, GenTek and Tyco International.

One of the greatest weaknesses of biotechnology in New Hampshire is its "perception problem". It is widely assumed by many, inside and outside of the industry, that there is no biotechnology sector in the state. This problem is being addressed by the New Hampshire Biotechnology Council and its partners who are forming a more cohesive identity and network.

New Hampshire must play a role in the genomics revolution in order to stay abreast of the science, medicine and diagnostic breakthroughs created through biotechnology. Biotechnology is a viable economic development vehicle that affects all levels of education, job formation & retention, sales and global trade.

One strategy that has been effectively used to recruit and retain biotechnology and life sciences companies has been providing a pool of skilled and available workforce at the technician level. This initiative has been driven by New Hampshire's Community Technical College Biotechnology programs that have been extremely responsive in working with life science employers.

The **NHCTC Pease Emerging Technologies Center** is a state and regional center for Biotechnology Education and Training. The Center produces workers with biotechnology skills, knowledge and attributes for the biotechnology industry and mentors these workers into good jobs. The Center models the biotechnology industry by using its tools, processes, and regulatory structure to teach what is called Virtual Workplace.

The Center supports the Northeast Region of Bio-Link, a National Science Foundation (NSF) Advanced Technological Education (ATE) Center for Biotechnology whose goals are to provide biotechnology support services, improve biotechnology instruction and learning, share information and resources, and foster collaboration and partnerships.

The Center has become a training lab for Lonza Biologics, a firm taking groups of new hires and putting them through a basic course using their equipment and adding large-scale bio-manufacturing equipment and skills.

The Center works closely with the Eastern Region (School-to-Work) Partnership (ERP) and the New Hampshire Science Instrumentation Project (NHSIP) to help train teachers in the use of biotechnology's tools and processes and to help provide these teachers with supplies, equipment, and instructional materials.

Keene State College (KSC) just opened (late 2004) a new $30 million science building. The new science center provides state-of-the-art instructional space and outfitted lab space with wet labs and ventilation hoods. The facility contains some of the latest chemical and physical monitoring device equipment, such as chemical spectrometers. They expect to add more equipment funded by grants and private sector affiliations. KSC is receptive to and actively encourages private businesses in the region to use KSC science facilities and employ their faculty and students. KSC is building the pubic/private partnerships that will help discover, develop, and transfer new technologies to the private sector.

Opportunities and Challenges

The Four Distinct Segments in New Hampshire's Biotechnology Industry:

- Biomanufacturing, Testing and Bio Related Disciplines
- Medical Devices
- Original Manufacture of Equipment, Laboratory Instruments, and Supplies
- Bioinformatics and Medical Informatics

New Hampshire is well positioned for biotechnology growth with over 120 firms in biotechnology related fields.[5] The industry focus can be characterized as being primarily manufacturing related. Bioinformatics (including medical informatics) is a rapidly expanding biotechnology segment in New Hampshire.

Over the past two decades there has been a shift in the traditional manufacturing industries in the state away from machinery-based manufacturing and towards value-added, high-technology manufacturing. The impetus for this shift came in large part from the decline of the defense industry during the 1980s.

Manufacturing in the biotechnology industry in New Hampshire is old and well established, going back to the late 1970s. In 1978, Verax, in West Lebanon, (now Stryker Biotech) opened its doors as one of the world's first biotechnology companies[6]

According to the New Hampshire Biotechnology Council, the 120 companies that make up the biosciences industry cover four distinct industry segments with a heavy emphasis on manufacturing rather than research and development. The breakdown is as follows:

Biomanufacturing

There are 24 companies, or 20% of the total industry, involved in biomanufacturing, testing, and biotechnology related disciplines. Biomanufacturing refers to the production of therapeutic proteins in living cells. These cells can be mammalian, yeast, insect or bacterial cells. They are manipulated through genetic engineering to function as small factories producing therapeutic proteins.

[5] New Hampshire Biotechnology Council
[6] Business in New Hampshire, page 9, January 2003

Original Manufacture of Equipment

There are 41 companies, or 34% of the total industry, involved in the original manufacture of equipment, laboratory instruments, and supplies. This segment of the bioscience industry includes companies manufacturing and marketing laboratory products and equipment for cell culture, molecular biology, clinical testing, drug screening, prenatal screening, liquid handling, diagnostic, image analysis, and pharmaceutical markets.

Bioinformatics

There are 14 companies involved in bioinformatics, and medical informatics related to software development, computer programming, and consulting. These companies make up 12% of the overall industry base.

New Hampshire's excellent Information Technology infrastructure is complimentary to the biosciences industry, as modeling and simulation are becoming increasingly powerful complements to theory and experimentation in genomics and other areas of engineering and design. The field of bioinformatics relies on large, shared scientific databases, such as gene and protein databanks, that are now available and considered key resources in biotechnology development.

Biotechnology Related Patents

New Hampshire ranks eighth in the number of patents issued per 1000 workers, and sixteenth in R&D per capita. In 1998 the US Patent and Trademark Office issued 649 patents from New Hampshire individuals. In 1999 there were 690, and in 2000, the number declined somewhat to 626 patents. An estimated 20% of these are in the biotechnology area.

Medical Devices (See Number 2)

Challenges

Economic development in New Hampshire can be difficult, since there are few state-backed incentives, such as bonds, low interest loans or tax credits to entice businesses to relocate here. More must be done to promote and develop the biotechnology industry. New Hampshire may not be competitive with other states (region or countries) that have made dramatic investments in biotechnology infrastructure over the past decade and have launched extensive biotechnology development initiatives.

Opportunities

Three keys to building a strong base for New Hampshire's biotech industry include building upon the significant existing intellectual and physical infrastructure base in the state, providing greater access to capital, and an available pool of highly educated and

technologically skilled workers. This study found that New Hampshire has many of the key "ingredients" to be competitive in biotechnology.

Given the extensive land, farm and barn infrastructure present at our universities, there are opportunities for animal, marine and crop biotechnology programs to be pursued more aggressively. These programs could include transgenic animals, animal cloning, genetically modified foods, aquaculture, and biotech derived pesticides or herbicides, among others.

2. Healthcare and Medical Devices

Definition

The term "Medical Technology" encompasses many diverse areas of science and technology, including computer science Informatics, software, fiber optics, materials science, specialized electronics related to health care. The goal of biotechnology and medical technology is to produce new or improved medical devices and processes, human therapeutics and diagnostics, innovative health care, improved crops and livestock, and advanced drugs and food processing techniques.

Assets in New Hampshire

There are 43 companies, or 32% of the total biotech industry, involved in manufacturing all or part of medical devices or kits. Multiple companies are developing biomedical devices in New Hampshire for uses such as balloon angioplasty, surgery, laser micro machining, electrotherapy, sapphire products, and their components. This medical device segment overlaps, in part, with the traditional healthcare industry.

NH Medical Device Consortium

In January of 2004, the New Hampshire Biotechnology Council in collaboration with the Medical Device Manufacturers Association in Washington, D.C, launched the New Hampshire Medical Device Consortium. The Medical Device Consortium is a working group that is associated with the medical device market in New Hampshire. The consortium is seeking ways to help individual medical device companies and to help expand and grow the medical device industry in New Hampshire.

3. Information Technology / Data Processing

Definition

The term "information technology" encompasses all matters related to computer science including the design, development, installation and implementation of information systems and applications. "Data processing" deals with the organization of data to extract information and includes recording, classifying, calculating, summarizing, distributing and storing data.

Assets in New Hampshire

In the 1990's the East Coast of New Hampshire branded itself the "e coast" as over 1,000 companies in the region were identified as "new economy" IT, Internet, software related businesses. Over-saturation in the world telecommunications sector combined with a stock market adjustment that significantly lowered the overall value of IT stocks resulted in lay offs and slow downs since 2000. As the second largest high-technology employer in the nation on a per capita basis, New Hampshire's business and industrial community was bound to feel the effects of the downward spiral in this industry. In the first three quarters of 2001, 60 of New Hampshire's high-technology companies laid off a total of 7,000 workers. Many of these layoffs were in information technologies.

UNH's Research Computing Center's Interoperability Lab provides performance testing services for over 100 vendors of computer communication devices. The Laboratory is also developing a new generation of police cars. These cars are voice operated and test new developments in design, function, and service.

4. Sustainable Technologies

Definition

The term "sustainable technologies" refers to biomass, solar, wind, geothermal, hydrogen, bio-based and agricultural products such as biodiesel fuels that are considered clean and renewable energy technologies. The term is also broadly used to cover energy conservation and related products and services that increase efficiency, reduce pollution and waste, and protect the environment. The term therefore covers a broad range of products, services, research and teaching.

While based primarily on environmental and renewable-energy related products and services, important interdependencies exist that covers fields such as biotechnology, food science, computer science, software development, materials science, and specialized electronics that create new products and processes to ultimately provide energy and/or protect the environment. The term also often implies a "social justice" component. The individuals, communities and businesses that pursue sustainable technologies are often as concerned about social issues, such as efforts to stop global climate change and greenhouse gas emissions, and "non-sustainable" exploitative or destructive business and consumer practices.

Assets in New Hampshire

New Hampshire is a leader in environmental studies and environmental research. The following are some of the assets that provide New Hampshire with a competitive edge in sustainable technologies:

University of New Hampshire

While the majority of Dartmouth College's sponsored research funding comes from NIH for medical research, the majority of UNH's funding comes from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) which increased by 40% to $23.8 million in 1993. UNH's second largest sponsor is the National Aeronautics and Space Administration (NASA), which also increased by 9% in 1993 to a total $9 million.

The Institute for the Study of Earth, Oceans and Space (EOS) conducts research projects that are nationally recognized, particularly in the areas of climate change, and life sciences. The NASA certified machine shop at the Institute has designed and fabricated advanced instruments for 14 NASA missions. EOS is well known for innovations in ocean mapping, and modeling.

The Environmental Research Group (ERG) was founded in 1987; this program's fundamental mission is applied and fundamental environmental engineering and science research. In 2001 ERG moved into a new state-of-the-art Environmental building on campus. This interdisciplinary program ties three departments (microbiology, civil and chemical engineering) together to solve real world problems in areas such as water treatment technologies, bio-remediation, and electro-technologies research.

Plymouth State University (PSU)

Plymouth State University has launched a Center for the Environment which is a collaborative effort between the PSU Biological Sciences and Chemical, Earth, Atmospheric a Physical Sciences departments. This center is designed to increase both research and outreach and expand PSU's role as a regional university. The center is located in the newly renovated 76,000 square feet Boyd Science Center on the main campus. Dr. Steve Kahl, Director, is partnering with the Hubbard Brook Forest in many innovative ways, such as jointly funding a hydrologist who will serve as both a resource to the forest and a faculty member at PSU. Steve Kahl, formerly with the University of Maine, brings not only expertise to the Center, but also $1 million in funding from EPA and another $450,000 in federal funding for water studies. Steve Kahl has done research in water safety monitoring for homeland security using detectors to monitor algae levels as an indicator of toxins in the water. This process can be used to identify an acute threat to water supplies as well as assist in water processing.

The Hubbard Brook Forest Research initiative is a USDA Forest Service funded joint research and development initiative between UVM, Rubinstein School of Environmental and Natural Resources and UNH.

The Market: The Promise of Renewable Energy

According to Platts Research and Consulting, energy market consultants, there has been a dramatic increase in the Clean Energy market in recent years. This upsurge is due to several factors and key trends in the global power industry:

- Growing awareness that the existing power and distribution system in North America is polluting, inefficient, antiquated and highly vulnerable as an overly centralized system
- The subsequent restructuring, deregulation and (decentralization) of the electric utility industry and a move towards distributed technology
- Global environmental concerns: global warming/toxic waste from coal burning plants
- Concerns about over reliance/dependence on foreign petroleum (National Security)
- Concerns about the aging U.S. power grid and infrastructure (Reliability)
- Rapid development of sophisticated information and communication technologies
- Rapid improvement in technology cost and performance
- Rising demand for power

New regulations requiring significantly lower emissions, mandated clean ups
Increased federal funding in research and development of alternative energies
Renewable energy technologies such as fuel cells, hydrogen, solar, biomass, wind, and hydro electric are gradually gaining consumer acceptance with the introduction of hybrid cars, clean biofuels, wind farms, and more products for residential energy generation. Success in fuel cell technology is beginning to open new frontiers in automotive and other industries. The potential market is enormous, however current clean energy market share is only 3% in the U.S., and 8% globally.

Clean energy technologies blur the boundaries among industries such as agriculture, new materials, chemicals, computing and software and other technologies such as nano-technologies. Breakthroughs in hydrogen technology and fuel cells would not have been possible without other technological breakthroughs over the past ten years in areas such as computer science and microelectronics. These advances were made possible by large federal investments in physics, chemistry, mathematics, biology and many other basic research and support in science and engineering.

According to Nancy Floyd, a founding partner of Nth Power, a venture capital firm specialized in the energy sector, “the energy technology sector is one of the better performers.” Venture investment went from $400,000 in 1999 to $1 billion in 2000, according to a press release by the National Renewable Energy Laboratory. Many states are mandating that some percentage of the megawatts used statewide each year come from renewable energy generation. Both Texas and California have introduced bills designed to increase the supply of renewable energy.

The Bush Administration pledged that it would support tax credit for power produced from renewable and alternative sources of energies at a cost of $1.4 billion over ten years. At the same time, agencies such as the U.S. Environmental Protection Agency (EPA) are reducing allowable exhaust emissions. The private sector is responding with technological solutions. Corporations such as John Deere & Co, Pepsi have embarked on major programs to adopt ethanol-blended fuels for their engines and delivery trucks. The Hunts Point Cooperative in the Bronx, New York – the largest wholesale food distribution center in the

world, is switching its entire 500 diesel-powered refrigeration units to a special new oxygenated “clean diesel” fuel to cut emissions.

The U.S. market for renewable energy is expected to increase 34% between 1996 and 2020, with and estimated 26% being used for electricity generation. Landfill, wind and biomass are seen as the most important renewable energy sources in the U.S. Recent power shortages and a nationwide back out in August 2003 focused attention on the nation’s aging power grid.

To reduce national dependence on foreign energy sources, the Bush administration has increased federal funding in several important areas. The fiscal year 2005 budget calls for a 43% increase in funding ($240 million) for hydrogen based fuel cell research, for example.

The alternative energy industry could be best described as in an early stage of rapid development. As other industries considered New Economy drivers (biotech, Internet, healthcare) the industry is chaotic, offering both great opportunities, and the threat of failure as competing and rapidly evolving alternatives enter the market. The industry’s growth is inevitable; and where there is growth driven by new technologies and new start up companies, there is opportunity for those willing to take risks.

Trends in Global Energy Use by Source, 1990 – 98
Source Annual Rate of Growth

Wind Power	22%
Photovoltaic	18%
Geothermal Power	6%
Natural Gas	4%
Oil	2%
Nuclear Power	1%
Coal	0%

(Source: Worldwatch)

The Forest Bio Refinery Project

The American Forest and Paper Association (AF&PA) has undertaken a major initiative called Agenda 2020. This initiative consists of there parts:

- Sustainable Forest Productivity
- Extracting Value Prior to Pulping
- New Value Streams (Power and chemicals) from Residual and Spent Pulping Liquors)

Agenda 2020 promises to reshape the pulp and paper industry and through changes in the manufacturing processes, produce a more environmentally sustainable supply of pulp, paper, chemicals and energy.

New Hampshire has both forests and paper mills that could benefit from this initiative. On-going research and development of the Biorefining process may be in turning around the declining fortunes of the paper industry in this region.

5. Aquaculture and Agriculture

Definition

Aquaculture involves the propagation, cultivation and marketing of plants and animals that live in the water. Examples of commercial aquaculture include the raising of fish and shellfish and the growing of plants such as algae.

Agriculture involves the raising of crops and animals for food, feed, fiber, fuel and other products.

Biotechnology and genetic modification will play an important role in agriculture, food, and veterinary sciences into the foreseeable future. UNH is a significant national contributor to the body of knowledge around the growing aquaculture industry.

Assets in New Hampshire

Open Ocean Aquaculture Project (OOA) – The Open Ocean Aquaculture Project (OOA) was started in 1998. The program includes an open ocean demonstration project and the ongoing research budget of approximately $2.4 million explores the technology, biology, environmental impact and economics of open ocean fisheries.

OOA is part of the Cooperative Institute of New England Mariculture and Fisheries (CINEMAR) which was established in the year 2000. CINEMAR was founded by the National Oceanic and Atmospheric Administration (NOAA) and UNH. The OOA project came under the administration of CINEMAR in 2001 and serves as the cornerstone project of the mariculture component of the Institute.

The following researchers are engaged in exciting research projects that are as far reaching as food production to cancer research:

- Dr. Tom Kocher - Discovering a way of selecting tilapia fish for breeding and optimum growth.

- Dr. Chuck Walker – Engaged in synchronized development of high-quality sea urchin roe for the Asian market. He has also developed the clam as a model for human leukemia studies to be used to test the effectiveness of anti-cancer agents.

- Dr. Paul Fisher – Does horticulture work with ornamental flowers. He has patented software to help growers schedule blooming at desired intervals.

- Dr. Subhash Minocha – Specializing in genetic modification of plants. In collaboration with several companies, he expresses desirable proteins from plants.

- Dr. Hunt Howell – Directs the Open Ocean Aquaculture project, an innovative new system designed at UNH which allows fish farming in deep ocean waters.

This research is significant because fish is a growing source of protein in diets across the globe and the ability to raise these large, fast growing fish in farms creates an ecologically sustainable food source for the world.

6. Software Products and Services

Definition

Software refers to a computer program that provides commands and instructions that enable a computer to perform various calculations, data analysis and other tasks. Software products are written in a specific language or code. The installation and maintenance of software programs is part of the software service business.

Assets in New Hampshire

Dartmouth College, Department of Computer Science – Past innovations include time-sharing, BASIC, and new advances in security and mobile computing. Dept. of Computer Science Image Science Group is focusing on image processing, computer vision, and computational and human aspects of perception. Other projects include research in computational biology and chemistry, micro-electromechanical systems and micro-robotics.

Institute for Security Technology Studies – This Department of Justice/Department of Commerce funded center for the study of cyber security at Dartmouth College has excellent potential for spinning off commercial products and services.

Clusters of IT and Software Companies and Workers: In the 1990's the East Coast of New Hampshire branded itself the "e coast" as over 1,000 companies in the region were identified as "new economy" IT, Internet, software related businesses. New Hampshire benefits from its proximity to Boston which is the home of one of the nation's largest concentrations of it/Software firms.

UNH's Research Computing Center's Interoperability Lab provides performance testing services for over 100 vendors of computer communication devices. The Laboratory is also developing a new generation of police cars. These cars are voice operated and test new developments in design, function, and service.

Financial Software Development- Liberty Mutual and Fidelity Investments have software development operations located in New Hampshire. Several thousand workers are employed in these operations.

The Market

The drive to automate back office and administrative services and the increasing demand for integrating medical records and information will continue to drive computer software and services. This industry grew rapidly in the late 1990's as the Y2K issue was a priority. After a considerable consolidation in the early 2000's, the industry is growing again. In 2004, aggregate industry revenue was $168 billion. That number is forecasted to rise to $220 billion by 2008.

7. Defense and Homeland Security

Definition

National defense includes building and maintaining military forces to defend the national interests. Homeland Security became a term of art following the terrorist attacks of September 11, 2001. Homeland Security focuses on efforts to prevent terrorist attacks and disruption within the geographic boundaries of the United States.

Assets in New Hampshire

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) based in Hanover, New Hampshire has participated in 29 Intergovernmental Cooperation Agreements (ICAs) since 1997. The range of technologies represented includes low temperature impact on systems performance, environmental clean up, advanced materials, structural design, pavement design, and icing and anti-icing technologies. CRREL has a mandate to work with surrounding communities on technology transfer and commercialization.

The Institute for Security Technology Studies (ITIS) - at Dartmouth College. The institute is dedicated to interdisciplinary research that focuses on critical national needs for security technology and policy in cyber and emergency response environments. ITIS projects involve over 100 researchers and the projects are funded by 16 government and corporate sponsors. ITIS is member of the Institute for Information Infrastructure Protection (I3P), a national consortium of 24 academic institutions, non-profit organizations and federal laboratories.

Defense Contractors and Research Firms New Hampshire is home to several firms that are defense contractors and research firms. Prominent in this list is BAE Systems and Creare, Inc.

Ice Engineering, a spin off company in Hanover, NH finds innovative ways to incorporate new materials. Victor Petrenko, a Dartmouth College, Thayer School of Engineering Professor has specialized in ice engineering, and developing technologies around the physics of ice. These innovations include thin plastic film impregnated with electrodes that de-ice the wings of aircraft, to car winter tires that adhere more tightly to icy roads, to cross country skis and snowboards that grip, and de-icing applications for offshore oil rigs, power lines, roofs and shoes. He is currently working on windshields and bridges that have de-icing properties built in to them. This fascinating applied research promises to create a safer, more efficient world through by understanding and applying lessons from the physics of ice.

Search and Retrieve Experiment, Colebrook, NH – This project is a consortium of defense contractors that is funded by the Department of Defense (DoD). The mission of this project is to crate a world wide procurement system that will allow the DoD to acquire parts and supplies within very short timeframes to supply military operations. B.A.E. Systems, Honeywell, Banta Corporation, Dell and General Motors are included in the consortium.

The Market

The budget for the Department of Homeland Security for fiscal 2006 will exceed $41 billion, a 7% increase over fiscal 2005. The budget includes money for aviation safety, training of first responders, sensor technology for explosives and biological agents, port security and a host of other applications.

8. Nanotechnology / New Materials

Definition

Nanotechnologies have been defined by the National Nanotechnology Initiative" as the science of very small, nano-sized objects. "Nano" is a measurement equaling one-billionth, so nanotechnologies deal with materials that are measured in a billionth of a meter. One nanometer is approximately 80,000 to 100,000 times smaller than the width of one strand of human hair, or approximately ten hydrogen atoms wide. Nanotechnology, like biotechnology is inherently multi-disciplinary in nature, and draws on knowledge from chemistry, biology, chemistry, physics, computer science, and many other disciplines. Nanoscale technologies deal with materials at a molecular level.

Assets in New Hampshire

Nanotechnology at UNH

The University of New Hampshire, in partnership with The University of Massachusetts at Lowell and Northeastern University, received a $12.4 million grant in 2004 to develop a nanomanufacturing initiative designed to create nano scale assembly lines scaled to one-billionth of a meter.

This five-year National Science Foundation grant will allow researchers at UNH's Center for High-Rate Nanomanufacturing (Director, Prof. Glen Miller, Organic chemist) to develop 12 tools and two products, as well as credibility as a player in the growing nanotechnology industry. These tools, invisible to the human eye, will serve as critical assets necessary to research develop and potentially commercialize nanoscale devices such as nanotube memory chips, and biosensors that can be implanted in the human body for early disease detection.

The center will focus on molecular design, fabricating nanoscale building blocks in the form of carbon nanotube materials that self-assemble at high rates and in large volumes. The consortium of academic partners is working with 15 companies to develop a nanotube memory chip that would replace the current electronic memory chip in today's electronic devices.

Center for Nanomaterials at Dartmouth - Dr. Ian Baker, Director

The Dartmouth Molecular Materials Group was established in 1997 to bring together faculty and students involved in studying the microscopic properties of materials, from the atomic scale to large polymers. In 2002, according to the group's website, faculty from the Thayer School of Engineering secured a grant from the National Institute for Standards and Technology (NIST) to explore nanomagnetic materials. That same year the Center for Nanomaterials at Dartmouth was formed as an umbrella organization to coordinate activities. There are currently 5 post doctoral fellows and 17 graduate students studying in Dartmouth's nanotechnology programs. Dartmouth also as an extensive list of facilities and equipment to support research and has made its equipment available to companies on a pay-per-use basis.

The Nanomaterials program has partnered with NSF-REU and DOD to create the ASSURE program in Nanomaterials and Nanotechnology. This program offers advanced programs in nanocrystals, thin film chemistry, semiconductor clusters, and impressive laboratory assets including clean-rooms, electron and other high-end microscopes and measuring devices.

In January 2003 a small nanotechnology firm, Seldon Laboratories, was launched in Windsor, Vermont, approx. 15 miles south of Dartmouth College, by a Dartmouth graduate student. This company has been successful in securing specialized lab equipment from Dartmouth College and a $2.4 million in Federal contracts from the US Air Force to develop nano-tube materials for water filtration, among other applications.

Seldon Technologies plans to commercialize an impressive range of products related to nano-carbon filters/ nano-tubes. According to the founders, this technology can be applied to military, industrial, automotive, and residential uses. Because of the revolutionary nature of carbon nanotube materials and the vast potential market, Seldon Laboratories is viewed as a potential regional economic driver and a magnet for other similar businesses in this niche industry. Other companies have expressed an interest in being near or co-located with Seldon Laboratories to share its state-of-the-art laboratory equipment and expertise.

Seldon's core technology involves binding together carbon nanotubes to create a filter that rids fluids of microorganisms without chemicals, heat or ultraviolet light. Nanotube materials are not new, but are only recently finding their way out laboratories and into products. Seldon Laboratories LLC has already delivered a prototype filter to the U.S. Air Force for testing. This filter kills biological pathogens as water passes through it. Seldon is now working on enhancements to eliminate poisons and pollutants. This $2 million contract would allow for the development of an improved version of the filter that blocks poisons, debris and other pollutants, resulting in water pure enough to use for medical purposes right on the battlefield.

Carbon nanotube technology is not a new technology, according to Dr. Ian Baker, Director of the Nanomaterials Center at Dartmouth College. There are a number of companies attempting to commercialize products using carbon nanotube technology. Carbon nanotube materials are a disruptive technology (rather than an incremental) in a fragmented market with no clear leaders or dominant competitors.

Clean water problem is likely to increase and the potential for market growth is excellent. Seldon claims to actually kill microorganisms rather than simply filter them. This is a revolutionary technology that involves manipulating organisms at an atom scale.

The Town of Windsor's existing plans call for a high-technology, specialty-themed nanotechnology campus that would attract other nanotechnology companies to the area. According the plan's primary architect Jill Michaels, the goal is to partner with Dartmouth College to create a technology cluster around nanotechnology spin offs from these businesses and from Dartmouth's research activities.

The Market

Nanotechnology is has captured popular imagination, federal research funding, state economic development funding, and more recently, venture capital funding. This once obscure field of new materials is now featured in entire issues of Scientific American and Red Herring Magazine.[7] The National Science Foundation estimates that nanotechnology could be a $1 trillion market by 2015. The recently created National Nanotechnology Initiative authorizes the largest funding for US scientific research since the space race with a total of $3.7 billion over the next four years. In economic development, scientific and in investment circles, Nanotechnology is considered to be "the next big thing" and some go as far as to describe it as the "next industrial revolution".[8]

Nobel Laureate Richard P. Feynman's classic presentation in December 1959 entitled "There's Plenty of Room at the Bottom" forecast a new field of physics with "an enormous number of technical applications." Almost thirty years later MIT professor K. Eric Drexler's book *Engines of Creation* (1987) began with a foreword by Marvin Minsky describing the promise of nanotechnology as being virtually limitless. Minsky describes

[7] Troy May, health sciences writer for the American Business Journals
[8] Robert Gavin, Boston Globe, Nanotech Next Big Thing, States, Colleges Jockey for Research Dollars 03/08/04

machines the size of viruses traveling through human capillaries to enter and repair human cells "healing disease, reversing the ravages of age, and making our bodies stronger than before."[9]

According to Minsky, these "intelligent machines" could be programmed to work in unison as a trillion parallel processing devices that would record patterns and then cross reference new experiences and exploit "memories" to improve their performance. This molecular level engineering would make possible tiny organic machines, smaller than a living cell, which would function as atom stacking assemblers programmed to build themselves, and repair or construct things at an atomic level. While research has been on-going since the late 80's, until very recently there have been few actual products and little in the way of commercialization of nanotechnology.

According to Troy May, health sciences writer for the American Business Journals, nanotechnology research experienced a major breakthrough when Rice University Professor Richard Smalley won the 1996 Nobel Prize for discovering a new form of carbon. This super-carbon, made up of sixty carbon atoms, is becoming one of the growing number of critical ingredients to a new class of nano-sized products that include "smart pharmaceuticals, electronic devices and high performance bulk materials.

The vision of using nanoscale devices to provide high speed genome sequencing in minutes to analyze a patient while they are at the doctor's office or hospital and use this information to prescribe precise or "personalized" medicines that do not produce negative side effects and treat an illness in a way that is tailored to each person's unique chemistry. This industry will be revolutionary in how doctors treat patients and how pharmaceutical companies develop drugs to treat disease.

There are several technological hurdles to overcome. While the medical community has not yet been able to use nano devices to do on-the-spot genome sequencing, or to send nano-robots to do heart surgery, what is possible using nano technologies is impressive. There are "labs on a chip", electronic paper, interactive product packaging, implantable drug delivery systems, nano manipulations using force fields to move very small objects in predictable ways, harvesting power at a micro levels, and building mechanical devices so small that dust mites tower over them under an electron microscope. These innovations are already finding their way into our homes and offices in the form of appliances and electronics, sun screen lotions, security systems, watch batteries, medical devices, and water purification.

Material engineers, scientists and designers have, for example, made terrific breakthroughs in the use of thin film technologies, and applying chemistry, physics, and biology at the nano-scale. However, much work remains to be done in nano-materials research and development. The principles of science apply differently at the nano-level, and researchers have many problems to solve to fully realize the potential. The Defense Advanced Research Projects Agency (DARPA), the central research and development agency for the U.S. Department of Defense, is investing significant levels of funding on molecular level

[9] Forward by Dr. Marvin Misky in K. Eric Drexler's book *Engines of Creation* (1987)

research to investigate such novel uses as using specially designed molecules, each about 1 nanometer in size, to increase data storage and processing speeds in electronics.

The promise of nanotechnology is vast, covering electronics, materials, biotechnology, and there are a myriad of potential applications. According to the media, nanotechnology will allow for tires that never go flat, drill bits that never get dull, clothes that never need cleaning, kitchens that do not require cleaning, and so on. Nanotechnology also promises to minimize waste in production, the need for natural resources, and to dramatically reduce the amount of energy required to heat our homes, power our electronics, etc. In short, nanotechnology promises to change nearly every aspect of our lives.

The down side of nanotechnology is the growing fear regarding the potential health and environmental impact of working with and developing these new materials. Popular culture has already laid out frightening worst case scenarios, such as nano-sized robots run amok and the devastating unintentional human and environmental impacts of "tampering" with nature at the nano level. Industry experts agree that finely divided solids do interact with the human body in completely unexpected ways, and nanoscale solids and particles could potentially create unique health problems if measures are not taken to mitigate such risks. Some investors have shunned nanotechnology, calling it this century's asbestos. Because the field is so new, no one yet understands the consequences of nanotechnology. Like genetically altered crops, the consensus at this time is to proceed with caution and that the potential benefits far outweigh the potential negatives.

UNH, with its academic partners, is now offering seminars on interfacing biological systems, nanomanufacturing, and molecular modeling along with environmental, regulatory, and ethical issues associated with these new technologies. These courses are co-taught by faculty from each of the participating universities.

Worldwide Nanotechnology Research

Billions of dollars are being poured into nanotechnology research and development in most industrialized countries around the world. The National Nanotechnology Initiative (NNI) reported that Japan will be increasing its finding and will invest nearly $1 billion (there are over ten companies in Japan with Nanotech centers), Korea will invest $1.1 billion by 2007, and Taiwan will spend $660 million.

In the U.S. according to the NSF, there has been a 30% increase in Nanotech research funding, bringing the total 2004 level to $930 million and and estimated $982 million for 2005. Europe as a whole, will invest below the U.S. level of funding.

Four regions of the U.S. are thought to be the areas that have reached critical mass, in terms of activity and funding. These areas are: Texas, Boston/New York corridor, the Midwest and California.

9. Precision Engineering

Definition

The state-of-the-art in precision manufacturing refers to several scales: macro (dimensions of feet to hundreds of feet), meso (maximum dimensions of several inches to several feet) and micro (dimensions on the order of a human hair). The current R&D focus is on the integrated design and manufacturing of micro systems. Research areas include precision motion control, micro robotic manipulation, micro sensor assembly and packaging, and distributed sensor architectures. Sensor technology represents a major thrust. The key goal is to reduce costs and time to market by developing modular sensor architectures and a generic packaging platform for a broad array of industrial, medical, and homeland security applications. This includes machining of advanced materials directed at the development and application of new, cost-effective machining solutions for materials such as ceramics and composites. Precision engineering includes Intelligent Systems Approach to Manufacturing- targeting a "system of systems" approach to the application of total solutions, including tools, machine parameters, design for manufacturing, and operator training

Assets in New Hampshire

The Upper Connecticut River Valley of New Hampshire is a region that is know as "Precision Valley" and the "cradle of inventions" as the birthplace of many well-know industrial, military and household products such as the spring clothes pin; breechloader rifle with interchangeable parts; steam shovel; corn planter; broom holders and straw cutters. Many of these developments took place on the other side of the river in Vermont in industrial towns like Springfield and Windsor as skilled machinists built products with precision accuracy, from thousandths, ten-thousands, and finally millionths of an inch. These towns were critical to the industrial base of the U.S. war efforts through the Second World War.

Beginning in the late 1970's however, foreign competition, combined with labor–management strife, domestic consolidation, aging manufacturing infrastructure, shifting global divisions of labor and a reluctance to invest in or adopt new technologies led the town into a downward spiral as companies laid off workers and left town. By the end of the 1980's the region was in serious economic trouble. This severe downturn mirrored what was happening nationwide as the U.S. manufacturing sector saw employment fall for 38 consecutive months with a net loss of over 3.1 million jobs – a 17.5 percent decline since July 2000. Many of these jobs were moved offshore to low wage, low tax and low regulatory environment countries.

As anchor manufacturing companies closed, towns in the region were left with millions of square feet of vacant industrial space and a sense of despair.

From a national perspective, the U.S. Department of Defense' ability to incorporate and introduce precision manufacturing technologies into the supply chain has been hampered

by a steady flow of precision technologies to foreign countries; the reluctance and/or inability of U.S. suppliers to invest in emerging precision manufacturing capabilities; and the general evolution in the United States from a manufacturing-based economy to a service-based economy.

This negative trend in precision manufacturing threatens to hinder the Department of Defense in the same way that the erosion of other high tech has in recent years (e.g., composites, electro-optics manufacturing, and advanced materials). The only way to ensure that our nation retains capabilities that surpass those of foreign suppliers is to consistently push the technology envelope, and to encourage U.S. suppliers to meet the advanced and projected needs of the U.S. government. The current network of Defense funded Centers of Excellence addresses these needs in more than ten technology areas. According to representatives from the defense industry, there is a rapidly growing demand for precision engineering and manufacturing.

To address this growing need, New Hampshire-based Daniel Thompson, former Director of Precision Engineering at the Lawrence Livermore National Laboratory is promoting the creation of a National Center for Precision Engineering in the Upper Valley. While this initiative is not focused on nanoscale manufacturing, the program could be interesting as a potential strategic partner and collaborator.

This initiative would integrate complimentary technologies to develop small, micro-scale systems, rather than nano scale, to meet the needs of commercial and defense customers. The end products would be: high value added, high quality, high performance, reliable, flexible, simple, compact and easy to assemble in large numbers. At the same time they would be low cost, low weight, and require low power. The market for these micro-scale systems spans multiple industries including:

- Electronics/telecommunications (optical display screens, laser radar, infrared projectors)
- Automotive (airbags in cars, engine components, micro-actuators)
- Appliances/ industrial (flexible hinges)
- Household/pharmaceutical (micro sensors)
- Semiconductor and OEM (adaptive optics and light modulation)
- Defense (munitions fuses)

The focus of this initiative will be specifically on micro-assembly and packaging; an area of critical importance to accelerate U.S. manufacturing competitiveness in this international growth market.

This initiative is also intended to commercialize new products and services, better integrate Upper Valley skill center in manufacturing and forge a strong partnership between Dartmouth College, UNH and the NH Community Technical College System. The goal is to leverage intellectual assets and infrastructure at these institutions and create greater economic prosperity and a higher tax-base throughout the region.

New Hampshire has a compelling opportunity to participate and fully benefit from its proximity to Dartmouth College and from the new start-up nanotechnology company Seldon Laboratories in many important ways.

An existing problem is locating skilled workers for precision engineering and eventually nanotechnology manufacturing. An opportunity exists for the state Community Technical college, Dartmouth College and Seldon Laboratories to create a world class program for training entry level technicians in the nanotechnology fields. Seldon Laboratories is already discussing a training program for its own technician level workers.

A model that could be used is the Portsmouth-based New Hampshire Community Technical College Biotechnology Education and Training Center. This center is the first of its kind in the nation and is devoted to the education of technicians for the biotechnology industry and to the education of faculty and teachers responsible for biotechnology education and training. Dr. Sonia Wallman, Director, is a nationally recognized expert in the area of biotechnology workforce training, program design, and implementation. This unique biotechnology-training program has supported New Hampshire's existing biomedical sector and has been a key asset in attracting and recruiting biotechnology companies to the region. Federal Advanced Technology Education and Bio-Link grants enabled this program to expand its influence on both a regional and national level..

This biotechnology model could be adapted to training nanotechnology technician level workers. The Center could be enlisted to play an important role in preparing target communities for the growth of new high technology manufacturers, such as Seldon Laboratories and other similar businesses. This could be a lure to the Upper Valley and a source of high wage entry level jobs for the local workforce as the precision engineering and eventual nanotechnology industry grows and requires trained workers.

Keene, New Hampshire -is the global center for ultra precision machining and grinding of small components supplying electro-optics industry. Mid 60's air bearing/ ball bearing technologies – Diamond turning axicemetric components

10. Optics

Definition

Optics is the branch of physics that involves the properties and phenomena of both visible and invisible light. Optics technology is being applied to a number of fields including manufacturing, agriculture, climate and weather projections, mapping and homeland security.

Assets in New Hampshire

The Institute for the Study of Earth, Oceans and Space (EOS) conducts research projects that are nationally recognized, particularly in the areas of climate change, and life sciences. EOS is currently engaged in a project called GroundWinds which uses optical

technology to forecast ground winds at any point around the globe. EOS is well known for innovations in ocean mapping, and modeling.

Existing Businesses Currently, there are a number of optics firms in New Hampshire and several are engaged in research programs. The most interesting applications and research include the ground wind project at UNH's Institute for the Study of Earth, Oceans and Space and defense and homeland security applied research involving SBIR projects with several New Hampshire companies.

New Hampshire is home to a number of businesses that use or produce products with optical technology. Moore Nanotechnology is dedicated to developing and manufacturing ultra-precision manufacturing systems. Diversified Optical Products (DiOP) develops and manufactures thermal imaging products for surveillance safety and security applications. Iris AO, Inc. build small scale micromechanical system that are applied in retinal and biomedical imaging, portable laser communications and horizontal imaging.

The Market

The market for optics technology and products applying that technology is large and growing. Optics technology is now a major player and supplier in the telecommunications industry. Optic technology applied to medical imaging has enormous growth opportunities. Applications in agriculture, mapping, climate studies and weather forecasting are other rapid growth areas. The application of optic technology to infrared, biological and a host of other sensor protocols hold enormous market potential.
Two market areas represent special opportunities for New Hampshire. The first is the application of optic technologies in manufacturing. The demand for subnanometer precision, the use of optics in positioning devices and the application of optical technology to improve speed and quality in manufacturing systems are all areas that fit with New Hampshire's concentration of manufacturers.

A second application involves defense, homeland defense and security applications of optic technology. The presence of defense contractors such as B.A.E. Systems and Creare, Inc. form the natural intersection of research and application in this field. Possible applications of optic technology include port security, optically-based biological agent sensors, and other sensor and surveillance technologies.

11. Space Technologies

Definition

Space science technologies are integral to on-going space science programs and projects. Space science involves the exploration of the earth and the solar system through space flight, satellite operations, and planetary exploration.

Assets in New Hampshire

Existing Companies Engaged in Production and Research –
New England Wire in Lisbon, NH – Do space technologies in North Country
Mt. Washington Valley, Ceramco – makes ceramic tiles for the space industry.
Creare, Inc does extensive research and design work for NASA

The Institute for the Study of Earth, Oceans and Space (EOS) at UNH conducts research projects that are nationally recognized, particularly in the areas of climate change, and life sciences. The NASA certified machine shop at the Institute has designed and fabricated advanced instruments for 14 NASA missions. EOS is well known for innovations in ocean mapping, and modeling.

The Market

Space science continues to deliver a stream of products and ideas that are and can be commercialized. The intersection of satellite based measurements and the Internet are providing efficient tools for collecting and delivering data on weather, growing conditions and climate change. Increasingly, space science research is producing useful information that can be applied to agriculture, weather forecasting and risk management.

RECOMMENDATIONS

In the process of this study we started with eleven technology areas or themes to explore. Those eleven areas included the following:

- Biotechnology, Bioinformatics and Life Sciences (Bio-manufacturing)
- Healthcare/Medical Devices
- Information technologies/ Data Processing
- Sustainable (Environmental) Technologies
- Agriculture/Aquaculture/Marine Research
- Software Products and Services
- Homeland Security/Defense
- Precision Engineering/ Advanced Manufacturing
- Nanotechnologies/ New Materials
- Optics
- Space Science Technologies

Some of these technologies exist in a critical mass and represent core areas of strength in technology for New Hampshire. Other areas are not as robust and represent either emerging areas or stand-alone technologies.

The NorthStar team recommends that the New Hampshire EPSCoR program pursue technology-based economic development and research building capacity in four broad theme areas that build on the information we gathered and the technology assets in the state. We also recommend that the EPSCoR Program monitor a number of emerging technologies that could provide scalable economic opportunity in the future. Finally, we include a number of recommendations that deal with gaps and barriers and the need for infrastructure improvement to benefit statewide research and development efforts. These "institutional themes" are candidates for EPSCoR investment to improve the overall economic development derived from technology.

Core Themes:

5. Information and Information Infrastructure Protection and Security

Theme: Basic and applied research to enable the development of protocols, processes and software products to protect and secure information and information infrastructure in a knowledge economy.

Rationale: New Hampshire has a significant number of firms engaged in software development related to information security, IT forensics, IP security, and related areas. These assets are located across the southern part of the state. They are complemented by academic programs and institutes and proximity to major IT resources in Massachusetts. In addition, Dartmouth College hosts the Institute for Information and Infrastructure Protection, a consortium of twenty-three academic and not-for-profit research organizations focused on cyber security and information

infrastructure protection research and development. UNH also has research application capability through its research computing center as well as with the College of Engineering and Physical Sciences.

6. Biotechnology / Medical Devices and Bioinformatics

Theme: Given the extensive land, farm and lab infrastructure present in New Hampshire's academic institutions, there are opportunities for animal, marine and crop biotechnology programs to be pursued more aggressively. These programs could include transgenic animals, animal cloning, genetically modified foods, aquaculture, and biotech derived pesticides or herbicides, among others.

Rationale: New Hampshire is well positioned for biotechnology growth with over 120 firms in biotechnology related fields. The industry focus can be characterized as being primarily manufacturing related. Bioinformatics (including medical informatics) is also a rapidly expanding biotechnology segment in New Hampshire.

Biotechnology is a very competitive field. Virtually every state with a major research university has devoted resources and is planning on extensive economic development around the area of biotechnology. It may be difficult at this stage of the game for New Hampshire to carve out a distinctive niche in this field. Having said that, it is also important to recognize the existing biotechnology businesses and research programs that contribute to the state's economy and may be winners in the future in this competitive field.

7. Sustainable Technologies and Research

Theme: multidisciplinary research and development focused on environmentally sound and sustainable practices in a variety of fields such as soil and water remediation, renewable energy, remanufacturing, clean manufacturing processes, energy efficiency, life cycle analysis and impact and risk assessment.

Rationale: The term "sustainable technologies" refers to biomass, solar, wind, geothermal, hydrogen, bio-based and agricultural products such as biodiesel fuels that are considered clean and renewable energy technologies. The term is also broadly used to cover energy conservation and related products and services that increase efficiency, reduce pollution and waste, and protect the environment. The term therefore covers a broad range of products, services, research and teaching.

While based primarily on environmental and renewable-energy related products and services, important interdependencies exist that covers fields such as biotechnology, food science, computer science, software development, materials science, Biorefining, and specialized electronics that create new products and processes to ultimately provide energy and/or protect the environment.

8. Nanotechnology and New Materials

Theme: Basic and applied research in nanoscale technologies focused on nano-scale manufacturing and application to other parts of the Hew Hampshire economy. Nanotechnology is a relatively new field of inquiry and areas of possible application continue to emerge.

Rationale: Nanotechnology deals with materials at a molecular level. UNH's Center for High-Rate Nanomanufacturing (funded by NSF) and Dartmouth's Center for Nanomaterials (funded by NSF and DOD) are building state-of-the-art infrastructure for nanoscale manufacturing and research in New Hampshire. Nanotechnology, like biotechnology, is multi-disciplinary in nature and draws on knowledge from chemistry, biology, physics, mathematics, engineering, computer science, and many other disciplines. The challenge is that nanotechnology is in its infancy and commercialization and economic opportunity continue to emerge and will take time to develop.

The Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology Council's Committee on Technology has released its 2004 Strategic Plan for the Federal R&D program in nanotechnology.

The document contains the vision, goals and plans for specific activities by which the goals will be accomplished by the 22 agencies participating in the NNI. The budget for these activities was about $1 billion in 2004.

"New R&D areas of focus are planned for the next five years, including increased support for active nanostructures and nanosystems, promoting technological innovation and multidisciplinary nanotechnology platforms, and addressing sustainability using the life-cycle approach," according to Mihail C. Roco, NSET Chair.

Emerging Technologies

1. Precision Engineering

Theme: Focus is on the integrated design and manufacturing of micro systems. Research areas include precision motion control, micro robotic manipulation, micro sensor assembly and packaging, and distributed sensor architectures. Sensor technology represents a major thrust.

Rationale: Precision engineering is becoming a strategic national issue as more product engineering moves off shore. New Hampshire has a manufacturing base that would benefit from the application of precision engineering technology. The current R&D focus is on the integrated design and manufacturing of micro systems. The key goal is to reduce costs and time to market by developing modular sensor architectures and a generic packaging platform for a broad array of industrial, medical, and homeland security applications. This includes machining of advanced materials directed at the development and application of new, cost-effective machining solutions for materials such as ceramics and composites.

2. Optics

Theme: The application of optics technology to sensors and controls and to manufacturing processes

Rationale: There are a large number of fields where the application of optics technology, tools and devices is growing. Industries involved in the application of optics technology include, biotechnology, defense, astronomy, aerospace, consumer electronics, healthcare, security and telecommunications.

Key optics technologies include fiber optics, lasers and semiconductors, metrology instrumentation, precision fabrication, modeling software, positioning equipment, microscopes and telescopes, image processing and thin film coatings.

Currently, there are a number of optics firms in New Hampshire and several are engaged in research programs. The most interesting applications and research include the ground wind project at UNH's Institute for the Study of earth, Oceans and Space and defense and homeland security applied research involving SBIR projects with several New Hampshire companies.

3. Bio-refining

Theme: Biorefining's principal objective is to maximize the extraction of marketable co-products naturally contained in crop or plant matter through use of its proprietary technology. (Part of text taken from web page of Biorefining, Inc.)

Rationale: The pulp and paper industry is engaged in research to restructure the pulp and papermaking process to derive product streams from wood before it is pulped and from the waste stream that result from the paper and pulp making process. New Hampshire has a pulp and paper industry located largely in the northern part of the state that could benefit from this technology.

Institutional Themes

1. Collaboration and Networking

Theme: Improving communication and collaboration among academic institutions and research centers and building collaboration and communication between academic researchers and the business sector.

Rationale: A primary objective of the applied research in nanotechnology is to produce products and solutions that benefit business and society. The transfer of technology and ideas from the academic research centers to the product design and production processes of the business sector will be facilitated by a high level of communication, networking and collaboration.

2. Interdisciplinary Research

Theme: Research institutions across the nation are finding it necessary to reorganize the way they traditionally provide education and conduct research and bring together expertise from different disciplines in order to be effective. Johns Hopkins, for example, is merging its departments of biological chemistry, biomedical engineering, biophysics and biophysical chemistry, molecular biology and genetics, molecular cell biology, neuroscience, pharmacology, molecular sciences and physiology. They are moving these departments under one umbrella organization in order to cut across traditional departmental lines, and foster the collaboration necessary for effective post-genomic research and development.

Rationale: New Hampshire's scientific community is moving in the same direction. Dartmouth College's neuroscience program and the Hubbard Center for Genome Studies at the University of New Hampshire are developing collaborative settings for the "cross fertilization" of ideas and research.

3. Technology Transfer

Theme: Improving the technology transfer infrastructure to increase the commercialization of research discoveries.

Rationale: The need to strengthen technology transfer was mentioned a number of times in the interview process. The growth in research activity, particularly at Dartmouth and UHN, has created the opportunity to increase commercialization and thereby create economic value from new ideas and discoveries. Current tech transfer activities are sparsely staffed and there is a need to think through staffing and the technology transfer processes now in place.

4. Mathematical, Statistical and Computational Tools and Models

Theme: Develop new computer and mathematical tools to enable more precise modeling of phenomena and systems. Such tools would increase knowledge, improve modeling and prediction capabilities and explore potential applications to a variety of problems and systems.

Rationale: The 2004 New Hampshire DEPSCoR proposal contained a technical theme titled "Enhancement and Extension of Computer and Mathematical Modeling Tools" which describes in detail the concept of a "tools project". The limits of research in many fields are expanded when powerful mathematical and computing tools are applied to complex systems and problems.

The widespread use of such tools in numerous fields of research suggests an opportunity to develop a multi-institution research project. This may be an example of

a project that would build connections and collaboration among academic institutions and the business sector based upon common research infrastructure needs.

Possible EPSCoR Projects and Action Steps

1. New Hampshire Science and Technology Directory of Experts

Paula Newton, NH Biotech Council recommended the development of a "Science and Technology Directory for New Hampshire". The two primary components of this directory would be:

- An online searchable database of links to academic researchers who might be possible consultants/collaborators for technology-based companies.

- An online searchable database of instrumentation and other equipment at New Hampshire's universities and colleges that might be made available to technology-based small businesses.

The databases would reside on multiple web sites including the Department of Resources and Economic Development, and academic partners and potentially other existing web sites. EPSCoR could fund an audit of available academic researchers within New Hampshire colleges and universities engaged in ongoing research and development. The initiative would seek to engage participation from as broad a range of researchers, Deans and faculty as possible.

This initiative would also research and catalogue equipment at research institutions in New Hampshire. Obtain participation from institutions making equipment available to technology-based businesses in New Hampshire to fully leverage these assets. NH EPSCoR would work with a web site vendor to coordinate implementation of the online installation and operation of the databases.

2. EPSCoR Graduate Fellowship in Biotechnology and Life Sciences

Paula Newton, President, NH Biotechnology Council suggested that an EPSCoR Graduate Fellowship in Biotechnology and Life Sciences be funded as part of the New Hampshire EPSCoR infrastructure grant. This position would provide support for the growth of a fledgling biotechnology/life sciences network while providing "real world" learning experiences to graduate students and faculty at partner colleges, and universities. The New Hampshire Biotechnology Council has the potential to become a significant catalyst for high technology economic development. However, in order for the program to reach its full potential, strategic invests must be made to build much needed capacity.

3. New England EPSCoR Collaboration

It was suggested that the New Hampshire EPSCoR program reach out to both the Vermont and Maine EPSCoR programs to share resources, networking opportunities, and maximize effectiveness.

Examples - Dave Stewart, President of New Hampshire based Pollyroll is interested in new materials involving polymers. The Vermont EPSCoR Program has a Polymers Industry Group that meets on a regular basis and invites experts from industry to present on new developments, applied research opportunities, etc. New Hampshire EPSCoR may find that there is not enough critical mass in this particular industry in New Hampshire to create a similar initiative. Instead, through close collaboration with neighboring EPSCoR programs, companies like Pollyroll can be directed to a valuable resource in the region. This kind of collaboration can lead to reciprocal services on many levels. The National Science Foundation is strongly encouraging a high level of regional cooperation that creates partnerships that are greater than the sum of their parts.

4. Intellectual Property (IP) Mining Initiative

Establish a pilot program in partnership with an organization like Franklin-Pierce Law Center that focuses on evaluating New Hampshire businesses intellectual property assets and developing "road maps" for licensing, spinning off, donating or otherwise creating value from IP that is currently not utilized or underutilized. There are several national models that could be used for this initiative. John Orcutt, faculty, Franklin Pierce Law Center, has agreed to identify faculty that are specialized in IP issues to support this initiative.

5. Strategic Innovation Services

The Battelle Institute's Technology, Research, and Education Center in Chicago has created a service that quickly identifies federal and other funding opportunities for businesses using a propriety database and methodology developed by Battelle. This service has been established in several states (Hawaii, Utah, and Illinois) with great success. This service is income-generating and has been the key to self-sustainability for several economic development programs and technology incubator programs that have adopted it. EPSCoR could explore ways to facilitate the establishment of such a program in New Hampshire.

6. Applied Research – SBIRs, STTRs, etc.

Bioinformatics or information technology related to biotechnology and genomics is an excellent way to spur New Hampshire's biotechnology industry. Gene and medical data analysis is much less costly than data generation and New Hampshire has a competitive advantage in information technology. Bioinformatics is a rapidly growing, interdisciplinary field and would be a good center of excellence to build on given New Hampshire's significant strength in information technology.
Biometrics is a rapidly emerging technology. In labs from BAE Systems to UNH, new systems are being developed using voice recognition, facial recognition, and fingerprint

ID. Also important to homeland security is detection of chemical and biological agents. BAE Systems has developed a chemical vapor detection system called JCAD ChemSentry. Cirtronics is developing an "artificial nose" to detect explosives.

Precision Engineering and Nanotechnologies

A consortium of manufacturing companies in the southwest portion of the state (Upper Connecticut Valley) has proposed the development of a Precision Engineering Center of Excellence. This center would be highly complementary to the life science, biotechnology and medical device industries**.**

7. Promote Education and Scientific Literacy

According to demographic statistics for the state, New Hampshire has the youngest median age in the New England region. The growth in the 5-17 year old population represents an opportunity to do outreach and encourage New Hampshire's young people to pursue knowledge intensive careers. This is a competitive advantage for the state.[10]

Raising the standards for scientific literacy from k-12, and to encouraging greater numbers of majors and greater diversity in the life sciences fields is of critical importance. The James and Joan Leitzel Mathematics, Science and Engineering Education Center recently established a $2 million endowment at the University of New Hampshire to address this issue.

8. Science and Technology Policy Education

The University of New Hampshire College of Engineering and Physical Sciences has provided tutorials on key issues related to bioscience to select members of the state's legislature, and is prepared to provide a broader initiative to better educate the state's 400 legislators and other technology stakeholders. This program could be expanded in partnership with the NH Biotechnology Council, NH Software Association, and NH Technology Council. This could provide vital education and an important networking opportunity for senior policymakers, business people, researchers and educators. The governor and council of chairpersons of house or senate committees could task the Innovation Initiative to perform studies of important issues and to make recommendations.

9. Workforce Development Related to High-Technology

The NH Community Technical College System and state colleges have developed extensive offerings for training opportunities in the life sciences. Support must be provided to ensure the success of programs such as the NH Biotechnology and Education Center and Emerging Technologies Center. These programs provide hands-on, technician level workforce development in close cooperation with private sector partners. This program should be expanded to serve other areas in the state.

10. Regional Collaboration

[10] New Hampshire Finds Investing in Kids Economically Sound, Brad Leighton, The Telegraph, October 24, 2001

New Hampshire might consider linkage with EPSCoR Vermont and Maine to develop regional initiatives, share information, and "dovetail" local strategies to fit within the context of the region.

In 1986 neighboring Vermont launched an EPSCoR (Experimental Research to Stimulate Competitive Research) program funded by the State, partner academic institutions, and the National Science Foundation. As a result of EPSCoR, Vermont has been able to support the research of promising young scientists by tripling external research funding to EPSCoR investigators. This funding resulted in a doubling of publications, presentations, and proposal submissions and the funding of four major instrumentation laboratories established at the University of Vermont. To date, over 100 research projects have been supported at 9 Vermont colleges and universities through EPSCoR's Small College Development Program.[11] Dr. Chris Allen, Director, was interviewed for this study and has agreed to share information and to coordinate the activities of Vermont EPSCoR to create greater opportunities for regional collaboration.

[11] Vermont Technology Council, Paul Hale, Executive Director

APPENDIX 1 – Questionnaire for Interviews

Increasingly, economic growth is driven by technology and knowledge-based economies. The four principal ingredients that are needed to succeed in this arena are: a strong research base, a well-trained and skilled workforce, comprehensive infrastructure (broadband, buildings, labs, communication networks, etc.) and adequate venture capital to finance growth. EPSCoR is designed to serve as one of the tools for strengthening these critical areas.

I. Introduction

1. Are you familiar with the EPSCoR Program and its mission in New Hampshire?

2. Given its mission, what would you recommend as key success metrics/goals for New Hampshire's EPSCoR Program?

II. NH Technology and Research Audit

Industry

1. The following are high-technology industries and research areas in New Hampshire. Which, in your opinion, are key areas that New Hampshire can be competitive in nationally and globally? Are you aware of emerging technology industries/research endeavors that should be added to this list? If so, why?

- **Biotechnology, Bioinformatics and Life sciences (biomanufacturing)**
- **Healthcare/Medical Devices**

- **Information technologies/ Data processing**
- **Sustainable (Environmental) Technologies**
- **Agri/Aquaculture**
- **Software Products and Services**
- **Homeland Security/Defense**
- **Precision Engineering/ Advanced Manufacturing**
- **Nanotechnologies/ New materials**
- **Optics**
- **Space Science Technologies**
- **Internet Forensics / Information Security**

Academic/Government

What are the major academic research agendas and programs of faculty and other researchers and/ or plans for centers of excellence in a various science and technology fields?

- **What are the strengths and weaknesses of each potential cluster identified?**

- **Resources needed?**

- **Describe negative and/or positive characteristics to assist in a gap analysis with respect to the education, knowledge, and skill sets possessed by the New Hampshire's workforce**

- **Describe Current opportunities and challenges?**

- **Are there regulatory issues that hamper growth in knowledge-based industries/research in the state?**

- **Are there infrastructure gaps that create barriers to research and development?**

- **Are there leadership or organizational gaps that hinder progress?**

In assessing science and technology-based industries and research activities in New Hampshire, who are the key business, academic and government leaders that should be interviewed for this strategy?

Suggested Interview List (see attached draft list)

APPENDIX 2 – EPSCoR Project Interview List

Name	Affiliation
Gordon Leversy	Keene State University
Jack Dugan	Monadnock Econ Development
Jeffery Sohl	UNH
Ross Gittell	UNH
Tom Wisbey	NH Community Tech College
Leslie Barber	NHCTC-Stratham/Pease
April Bellafiore	NHCTC-Stratham/Pease
Susan DeMauro	NHCTC-Stratham/Pease
Jenne Furfari	NHCTC-Stratham/Pease
Jim Barbison	NHCTC-Stratham/Pease
Valerie Mahar	NHCTC-Stratham/Pease
Sonia Wallman	NHCTC-Stratham/Pease
Bill Trumble	UNH
Steve Bollander	UNH
Janice Kitchen	SBDC
Hollis McGuire	SBDC
Jesse Devitte	Borealis Ventures
Art Greenberg	UNH
David Bartlett	UNH
John Hamilton	NH Community Loan Fund
John Croiser	BIA of New Hampshire
David A. Juvet	BIA of New Hampshire
Martin Wybourne	Dartmouth College
Roger D. Sloboda	Dartmouth College
Fred Kocher	New Hampshire High Tech Council
Douglas Pearson	NSS Corp
Joe Scotti	
Erle B. Pierce	Verizon
Robert Dalton	UNH
Stuart Arnett	Dept of Resources and Economic Development
Jac Cuddy	Mt Washington Valley Economic Council
Gregg Fairbrothers	Dartmouth Entrepreneurial Network
Daniel Thompson	Capital Technology Group, Inc.
C.Davis Farmer	The Ulysses Group
Christopher Allen	Vermont EPSCoR/University of Vermont
Steve Epstein	Grafton County Economic Development Council
Michael King	North Country Council
Jeffrey Hayes	North Country Council
Peter Riviere	Coos Economic Development Corporation
Jill Michaels	Community Investments
Lenard Chalux	Moore Nanotechnology Systems
Paula Newton	NH Biotechnology Council
Steve Kahl	Center for the Environment, Plymouth State University
Julie Gufstafson	Amoskeag Business Incubator, Southern NH University
Ian Baker	Center for Nanomaterials, Dartmouth College
David Stewart	Polyroll
John Orcutt	Franklin Pierce Law Center

Appendix 3 – Academic Institutions in New Hampshire

- Antioch New England Graduate School
- Chester College of New England
- Colby-Sawyer College
- Daniel Webster College
- Dartmouth College
- Franklin Pierce College
- Franklin Pierce Law Center
- Granite State College (formerly the College for Lifelong Learning)
- Keene State College
- Magdalen College
- New England College
- New Hampshire Institute of Art
- Plymouth State University
- Rivier College
- Saint Anselm College
- Southern New Hampshire University
- Thomas More College of Arts
- University of New Hampshire - Main Campus
- University of New Hampshire - Manchester
- Upper Valley Teacher Institute