Minnesota Technology, Inc.

Our Competitive Nature:
Minnesota's Technology Economy

June 2002

www.minnesotatechnology.org

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Minnesota Technology, Inc. (MTI), the state's technology–based economic development organization, is the resource for information about Minnesota's technology community and contributes to the growth of our economy by working with companies to apply/develop technology for a competitive edge.

MTI is grateful to its distinguished steering committee for guidance in creating this report. The members of the steering committee were:

Paul Duncan	Vice President Minnesota High-Tech Association
Jay Hare	Partner, Technology Practice PriceWaterhouseCoopers
Bob Isaacson	Director, Office of Analysis and Evaluation Minnesota Department of Trade and Economic Development
Tobias Madden	Regional Economist Federal Reserve Bank, Ninth District
Tom Stinson	Chief Economist State of Minnesota
Lyle Wray	Executive Director The Citizen's League

The opinions expressed in this report are expressly those of Minnesota Technology, Inc.

MTI would also like to express thanks to Jonathan Fernands (principal analyst and drafter of this report), Sabeen Altaf, Amy Dolin, Alison Hunter, Roger Hurd, Karen Jeal and Janis Rannow for their assistance with this report.

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To obtain a full copy of *Our Competitive Nature: Minnesota's Technology Economy* visit www.minnesotatechnology.org, or call (612) 373-2900.

Section 1

Executive Summary

Our Competitive Nature: Minnesota's Technology Economy

During much of the past two years, Minnesotans have debated whether our technology community was positioned to compete in the new economy of the 21st century. The primary concern was that Minnesota would not be prepared to create the high wage jobs of the future.

This report was prepared in order to provide public policy leaders with a framework for understanding Minnesota's technology economy and is intended to be used as a baseline for future evaluation of our state's competitiveness.

The discussions about Minnesota's technology competencies were fueled in the Spring of 2000 in a study by the Milken Institute, which ranked the Twin Cities as the 32nd largest technology region in the country. This and other reports ranking states in the budding new economy were published in the midst of the Internet/dot.com mania when traditional definitions of technology were being cast aside.

In most of these studies, the evaluation of a region's *technology* strengths was being defined based on the number of individuals/companies involved in the information technology and telecommunication fields. This approach artificially limited the definition of a technology economy since it did not take into account other sectors of the economy such as biomedical, agricultural and many advanced manufacturing industries.

Minnesota's Technology Economy

In defining the scope and diversity of Minnesota's technology economy, we have used both quantitative and qualitative criteria. Rather than simply using published industry and employment data, which is often more than two years old, we have looked at recent economic indicators such as income growth and unemployment rates and compared Minnesota to other leading regions. In addition, we conducted interviews with 12 local technology industry leaders to obtain their views of the local technology economy.

In Section I, we have defined Minnesota's technology economy as encompassing three broad sectors—advanced manufacturing &

electronics; information technology; and life sciences (including medical technology). We also defined the technology economy as one that includes firms that are intensive *users* of technology, not just *producers*. For the purposes of this report we did not include Minnesota's rich, technology-intensive agricultural sector.

Our research indicates that the advanced manufacturing, information technology and life science sectors include close to 2,500 technology-intensive companies with more than five employees. This includes some 1,300 firms in advanced manufacturing industries, 850 in information technology and 300 in life sciences.

It is important to note that the smallest of these sectors, life sciences, (in terms of firms and employees) is the most productive sector per employee. In fact, the number of Minnesota's medical device employees ranks second only to California.

In Section II, comparisons between the Twin Cities area (most reports analyze metropolitan areas rather than states) and other leading technology metros reflect our region's strong and diverse technology-based makeup. Our top ten technology companies, for example, include six advanced manufacturing companies, two information technology companies and two life science companies. In contrast, metropolitan areas that we are frequently compared to, such as Boston, Denver and San Jose, are far less diverse—their top ten lists are composed largely of companies in a single sector of the technology economy.

Economic indicators also seem to substantiate this strength. In February of 2002, unemployment in the Twin Cities was lower than that of other comparable metropolitan areas: Atlanta, Austin, Boston, Denver, San Jose, and Seattle. Per capita personal income data is also revealing. Despite the talk of the new wealth created in nouveau-tech metros such as Atlanta and Austin, the Twin Cites' per capita income is higher than in those two areas. On the other hand, Twin Cities per capita income rates are behind San Jose, Boston and almost on par with Denver.

Section III summarizes interviews with Minnesota experts in venture capital, advanced manufacturing, life sciences and information technology. The interviews were an effort to reconcile the quantitative information with real life perceptions from the business community. These business leaders generally agreed that Minnesota's technology economy is competitive.

Confirming what most national studies indicate, these business leaders felt good about doing business in Minnesota. They cited the states' excellent workforce, and would not move their companies to another state. While some taxes were an issue, it was often the intangibles—the outdoors, family culture, and clean living—that kept these executives committed to Minnesota. In addition, there was some optimism concerning the future of biotechnology and related industries in Minnesota—particularly where it pertained to complementing the established medical device firms and agricultural sectors.

But there was caution about the future, with some indicating their belief that the technology community is at a crossroads. One major topic of concern among the business leaders was the lack of "industrial replacement" in our economy and the fact that the large technology firms were not spinning off new companies at the same rate as in the past.

Conclusions

Our research arrived at a number of conclusions:

The first conclusion is that within the research community there is no clear, objective definition of what constitutes a technology economy. Among the myriad of national studies, no two agree on what industries comprise the technology sector. As a result, policy makers are left to interpret rankings from various groups that vary substantially *and* view technology industries differently.

For example, in the same calendar year, rankings were provided that could lead one to believe that the technology economy in Minnesota is excellent, average, or poor. The intent of this report is to provide a broader perspective on our technology economy, rather than picking specific indices or data points on which to base conclusions. We hope it is of value to public officials and business leaders by providing a base understanding of the Minnesota technology economy that can be used to develop informed policy decisions.

A second conclusion is that the old adage that Minnesota's economy does well because it is diversified also holds true when looking at the technology economy. Now that all the talk about a dot.com economy has subsided, Minnesota is once again viewed as a leading center for

innovation and technology and most rankings have the Twin Cities ranking among the top ten metropolitan regions in the country.

Our third conclusion confirms the industry concern that we are not creating the next generation of technology industry leaders rapidly enough.

Our research indicates that of the 2,500 technology companies in the state, some 25% said they began doing business after 1990. What is worrisome is that, despite the growth of our nation's technology sector during the past decade, only two of these companies, Zomax and MedSource Technologies, have reached the $100 million sales level (which is still regarded as a "small" firm by most analysts).

So the Minnesota industry profile is one mainly dominated by $1 billion + companies and firms with less than $100 million in sales; we essentially lack a 'middle class' of firms that can position themselves to become industry leaders.

The Future

While it is clear that Minnesota's technology economy has performed very well during the past decade and has a strong establishment, it is less clear where we go from here—do we stay in the top 10, move up, or move down?

One perspective in the community is that the industry sectors in which we are strong will continue to grow, with industry leaders such as Medtronic, 3M and ADC Telecommunications leading the way.

A second view is that our technology community is slowly eroding and becoming less competitive. This is the view of an increasing number of executives in our business community. Because the available macroeconomic data is two to three years away, this assertion is difficult to prove, though anecdotal insights abound.

Some of these include:

- Venture Capital—The issue over the apparent dearth of venture capital availability in Minnesota persists (dot.com mania notwithstanding.) One side claims there is not enough invested locally, the other that there are not enough "good" deals. Others limit the deficiency to "seed" level funding.

- Global Competition—Our large corporations are not growing within Minnesota. Medtronic is moving a portion of its electronic manufacturing processing to Phoenix—while 3M, which had expanded in Austin, Texas, is now moving its high-end optical business from there to Singapore.

- High-wage jobs—Not only are large companies outsourcing programming to countries such as India and China, but small firms such as Softbrands (f/k/a Fourth Shift) are also following suit—eliminating high paying technology jobs in Minnesota.

In developing policies for the future, the perspective of industry executives deserves serious attention, because it is their companies that are competing everyday in an increasingly turbulent global economy. Public officials should also note that the issues these executives are talking about are different from those of previous years—it is no longer primarily government regulation, worker's compensation and high taxes.

The concern is now about the availability of long-term investments to support a future technology infrastructure: K-12, higher ed., regional R& D capacity, transportation and quality of life issues.

Our business leaders have already raised the cautionary flag. Foolish is the reader who complacently sets aside a positive report on our technology economy. Instead we must address our shortcomings and strategize around our strengths. For in a fast-paced, competitive world economy, the region that stands still will merely be a stepping stone for other regions busily implementing their own strategies.

Introduction

A healthy technology sector is important to the overall health of regional economies. Think tanks, public policy organizations and trade associations regularly issue reports ranking the technology attributes of regional economies. In many instances, these reports paint a confusing picture of Minnesota's technology health. A paper recently released by the University of Minnesota's Humphrey Institute of Public Affairs detailed this problem.[1] In reports ranking high–tech metro areas, "Minneapolis/St. Paul is 9 in a NASDAQ/American Electronics Association study, 10 in a Progressive Policy Institute Study, but 32 in a Milken Institute Study," reported the Humphrey Institute paper.

The disparity between these reports stems from the fact that they use different criteria in their analysis. For instance, the AEA uses *occupational* data, and includes only the technology manufacturing, communication services, software and computer-related device industries when evaluating regional technology economies. On the other hand, the Milken Institute uses *industrial output* data when issuing their regional technology rankings.

In response to this confusion, MTI has developed criteria that defines Minnesota's technology infrastructure. We believe our methodology better reflects Minnesota's diverse technology makeup.

The purpose of this report, therefore, is to develop Minnesota's own technology baseline. With that information, policy makers can synthesize the myriad of technology reports, articles, and rankings and make policy decisions based on a single standard.

The report's methodology drew upon Minnesota Technology's 12-year experience serving Minnesota's technology community. The bulk of Minnesota's technology industry lies in three main umbrella categories: advanced manufacturing, information technology and life sciences. Minnesota's technology baseline was developed from the perspective of these three categories.

As this paper goes to press, the national economy continues to emerge from a short recession, which substantially affected technology industries. Minnesota's three umbrella categories were each affected to varying degrees. The life science umbrella was affected the least, information technology posted mixed results, and advanced manufacturing took the hardest hit.

[1] Markusen, Ann, et al. High–Tech and I-Tech: How Metros Rank and Specialize. August 2001.

Companies under the information technology umbrella have continued to struggle throughout the economic downturn. Demand in Minnesota's software and application development sectors has slowed, reflecting national trends. However, on a positive note, demand is expected to grow in late 2002. Companies will start to see new orders as the economy continues to rebound. On the other hand, the telecommunications sector continues to underperform. The effects of the regulatory environment and wholesale overbuilding of the fiber optic network will continue to have a negative impact on telcom for the immediate future.

Minnesota's advanced manufacturing companies were most impacted by the recession. Considerable alarm was raised with announcements that a downturn in manufacturing had a substantial effect on jobs and triggered substantial per capita wage loss. For the first time since 1958, it was reported, Minnesota's wages had fallen from year-earlier levels.

In a recent conversation addressing this topic, Minnesota State Economist and Steering Committee Member Tom Stinson, clarified the situation. As Stinson explained, Minnesota's manufacturing is still outperforming the national averages for manufacturing from an output standpoint. Massive job loss in the Minnesota manufacturing industries contributed to an overall lowering of wages. However, manufacturing in Minnesota still has substantial ground to cover before it returns to pre-2001 employment levels.

For Future Consideration…

Although this report's main function is to characterize Minnesota's existing technology economy, it's also a good opportunity to flag issues for further consideration.

Minnesota's technology economy is strong and has the potential to grow. Yet Minnesota's technology economy will grow only marginally unless policy makers and industry leaders address certain opportunities.

Growth Plateauing
Small-and mid-sized technology companies often face strategic change that results in the net outflow of business—and business influence—from Minnesota. The result is the erosion of Minnesota's ability to generate the kinds of activities and initiatives that keep us on technology's cutting edge.

ZoneTrader is a Plymouth-based firm that manages auctions of corporate assets via the Internet. Recently, ZoneTrader was bought by Culver City, CA-based DoveBid, a privately-held company with a similar business model. After the sale, ZoneTrader became a division of DoveBid. No layoffs are expected as a result of the sale. However, the company will retain its headquarters in California—creating a small vacuum of business influence that the former ZoneTrader once had in Minnesota's IT community.

This situation highlights the critical juncture at which mid-sized technology companies frequently find themselves. Having proven their worth as a small- or mid-sized company, strategic change must frequently be made—in ownership, personnel, products, and technology—to continue to grow into the ranks of the larger companies. Often, this means control of a Minnesota company goes out of state. Witness the lack of $100 million to $1 billion technology companies in Minnesota. The role the public sector may play in nurturing companies like ZoneTrader into large, Minnesota-based companies is worthy of further examination.

Minnesota's Technology Clusters

The concept of working with clusters has become "politically incorrect" in Minnesota, because detractors have equated government assistance to clusters with a government-controlled economy.

According to London's *The Financial Times*, "clusters" is a term given to geographically concentrated sets of companies working in the same industry or sector. Through dependence and competition, companies in a cluster form a critical mass from which all companies can draw upon and grow. Silicon Valley is perhaps the most conspicuous example of a cluster developing into an industrial force. With clusters, the whole is greater than the sum of its parts.

Michael Porter, Harvard professor and author of *The Competitive Advantage of Nations*, attests that clusters emerge in an environment that supports and sustains them. As summarized in MTI's *State Science & Technology Initiatives FY 2001* (available at www.minnesotatechnology.org), many state and regional governments have made investments to accelerate the development or maturing of clusters. Furthermore, the National Governors Association has included involvement with clusters at the state level as an integral part of the *National Governors Association Vision for 2001-2002* report.

To be successful, such government involvement in clusters must follow *the lead of industry*, rather than be the dictate of government. Investing limited public resources requires criteria, and often the greatest impact can be achieved through collaboration with existing strategic economic strengths. Certainly such an investment is warranted only when there is substantial leadership and investment from the industrial players themselves. With this in mind, Minnesota may want to consider a more collaborative relationship with the following recognized clusters:

- Medical Devices
- Telecom/Wireless Communications
- Storage Networking

New Technology Industries

Given Minnesota's unique industrial and academic competencies in the areas of advanced manufacturing, information technology and life sciences, several vanguard industries have real potential to thrive in the state. Proactive steps ought to be taken from the State's public and private sector leaders in order to capitalize on these unique opportunities.

- **Nanotechnology** is a technology that uses devices made out of individual atoms and molecules. Using these devices will allow for a new type of manufacturing by using the fundamental building blocks of nature—inexpensively and in almost any arrangement—to assemble themselves into virtually any type of product.

- **Biocatalysis** is a technology that efficiently develops chemical process methods utilizing the power of enzyme-catalyzed reactions. When coupled with its scientific applications, the biocatalysis industry can be an integral part of a multidisciplinary approach to a drug discovery program. McKinsey & Company has estimated that the biocatalysis industry could have $470 billion in sales by 2010.

- **Bioinformatics** is an industry that joins the once separate industries of bioscience and information technology. This industry has proliferated largely due to the massive amounts of information generated from projects like the human genome project that require analysis and dissemination made possible only through information technology. *Business Week* projects that bioinformatics could be a $43 billion market by 2004.

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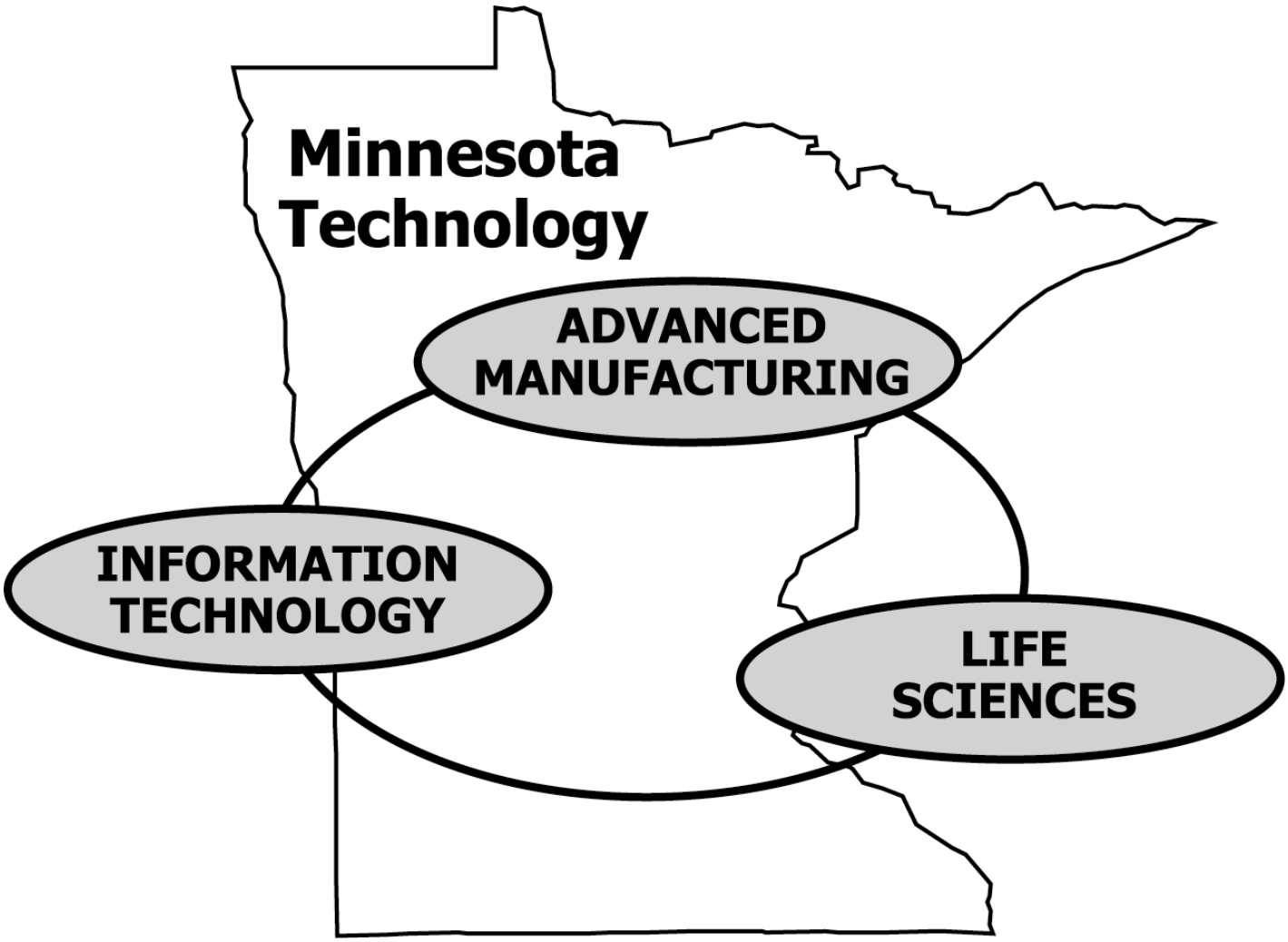
Section I

Definition of Minnesota's Technology Economy


Minnesota Technology
ADVANCED MANUFACTURING
INFORMATION TECHNOLOGY
LIFE SCIENCES

Minnesota Technology, Inc.'s definition of the technology sector is based on our 12-year history of service and involvement with Minnesota's technology economy.

The definition was developed after we examined the disparate criteria used to compile information in widely read regional technology rankings and to resolve the conflicting opinions of economists, business media and analysts concerning what sets of industries and factors constitute a technology economy.

For example, the American Electronic Association uses *occupational data* — including only the technology manufacturing, communication services and software and computer related device sectors — while the Milken Institute uses *industrial output data* when evaluating and ranking regional technology.

In response to these disparities and to be more reflective of Minnesota's technology economy, a company must do one or more of the following to be included in Minnesota Technology, Inc.'s definition:

- Make a technology–intensive **product**
- Provide a technology–intensive **service**
- Conduct technology **R&D** on products or process technology
- Use a technologically advanced **process** in its operations

Analysis of these companies made it clear that there are 42 distinct technology industries in Minnesota. These 42 technology industries fall into 13 clusters under 3 primary umbrella categories. This created an organizational hierarchy that stratifies the composition of the Minnesota technology economy.

Organizational Hierarchy: A Meaningful Taxonomy

- All Minnesota Companies
  - ↳ Minnesota's Technology Sector
    - ↳ Primary Technology Umbrella Categories (3)
      - ↳ Technology Clusters (13)
        - ↳ Technology Industries (42)

Our data for the classification process is based on the Federal Government's North American Industrial Classification System (NAICS). Under NAICS, economic data is compiled on each American company by industry classification and totaled. The Government then provides the aggregate economic information by industrial classification.

MTI used the NAICS coding to compile data on Minnesota's technology hierarchy. The end product is a retrofit version of NAICS, tailored to the Minnesota technology economy (Minnesota's technology NAICS descriptions can be found in Appendices C-E). Therefore, instead of replicating the U.S. classification of the entire economy with umbrellas like Finance/Insurance/Real Estate, Wholesale Trade, Construction, and so on—MTI has classified the technology segment of the Minnesota economy under the three most prominent umbrellas:

- Advanced Manufacturing
- Information Technology
- Life Sciences

The data used in this study is derived from the U.S. Census Bureau's 1997 Economic Census, 1999 County Business Patterns, and the 1999 Annual Survey of Manufacturers (Geographic Series).

FINDINGS: Minnesota Technology Economy

Industry	NAICS codes	Sales/Receipts/ Shipments/ (1000's)	Sales/Receipts/ Shipments/ (1000's)	Percent Change '97-'99	Total Employ-ment	Total Employ-ment	Percent Change '97-'99	Total Establish-ments	Total Establish-ments	Percent Change '97-'99
		1997	**1999**		**1997**	**1999**		**1997**	**1999**	
Automation and Manufacturing Technology	3327	$1,424,111	$1,376,867	(3.32)%	13,212	12,634	(4.37)%	714	713	(0.14)%
Chemicals and Advanced Materials	325, not 3254	$2,113,982	$2,006,528	(5.08)%	6,914	6,677	(3.43)%	197	203	3.05%
Computer and Telcom Hardware	3341, 3342	$4,836,026	$5,034,702	4.11%	17,722	21,275	20.05%	110	100	(9.09)%
Electronics and Components	334 not 3341, 3342, or 3346	$6,115,736	$6,054,009	(1.01)%	38,068	35,908	(5.67)%	363	357	(1.65)%
Engineering, Environmental, Physiological Testing and Services	54171, 54133, 54138, 6215	$1,217,723	†	†	11,241	14,385	27.97%	1106	1277	15.46%
Photonics, Optics and Lasers	333314, 333315	$49,885	†	†	740	777 ‡	4.7%	23	27	17.39%
Application Development, IT Services	5415, 61142	$2,565,085	†	†	23,316	25,653	10.02%	2371	3014	27.12%
Internet Application Development	514191	$81,930	†	†	904	1749 ‡	93.47%	80	118	47.50%
Software	5112	$665,809	†	†	4,053	4,103	1.23%	279	248	(11.11)%
Telecommunications	5133	$3,751,512	†	†	15,177	15,803	4.12%	612	686	12.09%
Biotechnology	325413, 325414	$92,101	†	†	824	880	6.80%	18	16	(11.11)%
Medical Devices and Equipment	33911, 334510, 334516, 334517	$5,829,328	†	†	22,845	25,172	10.19%	368	373	1.36%
Pharmaceuticals	3254	$712,764	$751,940	5.50%	2,114	1,974	(6.62)%	42	42	0.00%
Technology Totals		$29,455,992	†		157,130	164,464‡		6,283	7,174	
MN All		$318,482,387*	†		2,271,671*	2,338,642*		124,039*	137,305*	
Percentage of Minnesota All		9.25%	†		6.92%	7.03%		5.07%	5.22%	

Source: U.S. Census Bureau † Data Unavailable * Non Farm

Minnesota Technology Economy Highlights

In 1997, Minnesota technology companies accounted for 9.2% of the business done[2] in Minnesota, employed 6.9% of Minnesota workers, and represented 5% of Minnesota's establishments. In 1999, those figures remained largely unchanged (not all revenue data was available for 1999.)

Highlights:

- Minnesota exported $5.8 billion of technology products in 1998—equal to 65% of all the state's manufactured exports for that year.
- Minnesota's average technology industry wage for 1999 was $55,118. In contrast, the state's average private sector wage for 1999 was $33, 517—a 64.4% difference.

Advanced Manufacturing

Advanced manufacturing is the largest technology umbrella in the state, consisting of over 20 separate industries organized into six clusters. Advanced manufacturers are involved in the production of electronics, chemicals, machined products, and telecommunications/computer equipment; and providing testing/measurement, photonic/laser and engineering/environmental services.

Highlights:

- In 1999 there were 2,697 firms under the advanced manufacturing umbrella.
- In 1999 there were 92,406 employees working in advanced manufacturing.
- 1997 revenues from shipped goods in the advanced manufacturing umbrella exceeded $15 billion—accounting for over 4.9% of the business done in Minnesota.
- The engineering, environmental, and physiological testing and measurement sector grew substantially from 1997 to 1999, adding 27% more jobs and 15% more establishments during that period.
- From 1997 to 1999, computer and telecommunications hardware manufacturing employment increased 20%.

[2] "Business done" includes the total sales, shipments, receipts, revenue or business done by businesses. Receipts do not include sales and other taxes collected directly from customers of clients and paid directly to a local, state or federal tax agency.

Information Technology

The information technology umbrella consists of nine industries organized into four clusters. Information technology is comprised of application development/IT services, software, Internet applications, and telecommunication services.

Highlights:

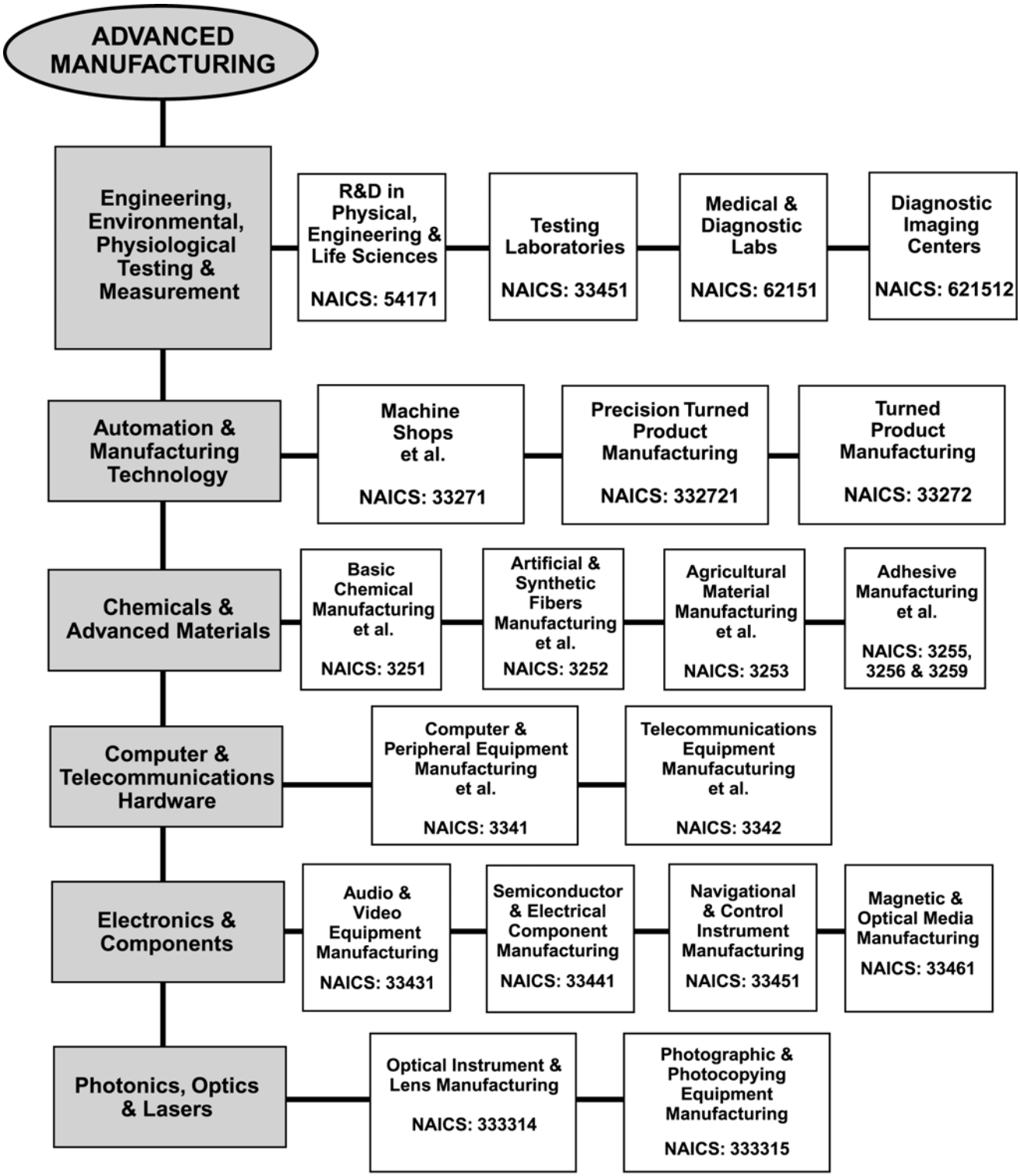
- In 1999, there were 4,066 firms in information technology.
- In 1997 there were 45,559 employees working in information technology.
- In 1997 the information technology umbrella accounted for 2.2% of the business done in Minnesota.
- From 1997 to 1999, the application development/IT cluster added 10% more employees and increased the number of establishments by 27%.

Life Sciences

The Life Science umbrella represents one of Minnesota's best industrial competitive advantages. The umbrella consists of 12 industries organized into three clusters: biotechnology, medical devices and pharmaceuticals.

Highlights:

- In 1999 there were 431 firms in the life sciences.
- In 199 there were 28,026 employees working in the life sciences.
- Representing only 1.1% of the workforce in 1997, life sciences was the smallest technology umbrella, but by percentage, among the most productive, accounting for 2% of the business done in Minnesota.
- From 1997 to 1999 the medical device and equipment cluster increased employment by 10%.


ADVANCED MANUFACTURING
Engineering, Environmental, Physiological Testing & Measurement
R&D in Physical, Engineering & Life Sciences
NAICS: 54171
Testing Laboratories
NAICS: 33451
Medical & Diagnostic Labs
NAICS: 62151
Diagnostic Imaging Centers
NAICS: 621512
Automation & Manufacturing Technology
Machine Shops et al.
NAICS: 33271
Precision Turned Product Manufacturing
NAICS: 332721
Turned Product Manufacturing
NAICS: 33272
Chemicals & Advanced Materials
Basic Chemical Manufacturing et al.
NAICS: 3251
Artificial & Synthetic Fibers Manufacturing et al.
NAICS: 3252
Agricultural Material Manufacturing et al.
NAICS: 3253
Adhesive Manufacturing et al.
NAICS: 3255, 3256 & 3259
Computer & Telecommunications Hardware
Computer & Peripheral Equipment Manufacturing et al.
NAICS: 3341
Telecommunications Equipment Manufacuturing et al.
NAICS: 3342
Electronics & Components
Audio & Video Equipment Manufacturing
NAICS: 33431
Semiconductor & Electrical Component Manufacturing
NAICS: 33441
Navigational & Control Instrument Manufacturing
NAICS: 33451
Magnetic & Optical Media Manufacturing
NAICS: 33461
Photonics, Optics & Lasers
Optical Instrument & Lens Manufacturing
NAICS: 333314
Photographic & Photocopying Equipment Manufacturing
NAICS: 333315

STATISTICAL DATA: Advanced Manufacturing

Industry	NAICS codes	Sales/ Receipts/ Shipments/ (1000's)	Sales/ Receipts/ Shipments/ (1000's)	Percent Change '97-'99	Total Employ-ment	Total Employ-ment	Percent Change '97-'99	Total Establish-ments	Total Establish-ments	Percent Change '97-'99
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Electronics and Components	334 not 3341 or 3342, 3364	$6,115,736	$6,054,009	**(1.01)%**	38,818	36,658	**(5.56)%**	381	377	**(1.05)%**
Photonics, Optics and Lasers	333314, 333315	$49,885	†	**†**	740	777 ‡	**4.7%**	23	27	**17.39%**
Technology Totals		$15,757,463 ‡	†		88,647	92,406 ‡		2,531	2,697	
Minnesota All		$318,482,387*	†		2,271,671*	2,338,642*		124,039*	137,305*	
Percentage of Minnesota All		4.95%	†		3.90%	3.95%		2.04%	1.96%	

Source: U.S. Census Bureau

† Data Unavailable ‡ Estimated *Non-farm

MARKET OVERVIEW

Advanced manufacturing has a rich history in Minnesota. The state's industrial roots are anchored in mining and food processing. From those industrial beginnings, Minnesota manufacturing transitioned into multiple sectors, including technology industries such as chemicals, computers, telecommunication equipment, and machined goods.

Advanced manufacturing is Minnesota's largest technology umbrella, accounting for 4.9% of the state's gross output. However, over much of the last ten years, advanced manufacturing's importance has been lost in the conversation about the new economy.

Despite the hype about the Internet and the IT industry, advanced manufacturing has quietly been an active player in Minnesota's technology economy.

Automation and Manufacturing Technology

The machinery and tools sector of the advanced manufacturing category has historically been a good economic indicator. When companies establish, expand or upgrade production facilities—usually by way of capital expenditures—output from this manufacturing sector surges. Simply then, when the advanced manufacturing sector is doing well, the economy usually follows suit.

Manufacturers of machinery and tools produce goods in two basic categories, standard equipment and custom equipment. Standard equipment carries out uniform tasks such as punching, stamping or bending metal. In contrast, custom machinery used in industries like the transportation, aircraft and chemical industries is more technical, and as a result, more expensive.

According to *Hoover's Online*, the machinery and tool-manufacturing sector experienced 7% annual growth from 1992 to 1999. However, between 1999 and 2000, a combination of rising interest rates, a sluggish Asian economy and a worldwide overcapacity caught up with this sector, and growth rates became anemic. The recent economic downturn has not helped this sector's growth rate either. Analysts predict that the sector will pick up as the economy continues to emerge from the recession and companies increase capital expenditures in anticipation of growing their businesses.

Chemicals and Advanced Materials

The chemical sector accounts for $1.1 trillion dollars in annual global sales. Output from the industry can be broken down into the following divisions:

- Basic and Intermediate Chemicals
- Specialized Chemicals
- Agricultural Chemicals
- Petrochemicals
- Plastics and Fibers
- Paints and Coatings

Not unlike other industry sectors, the chemical sector has undergone significant consolidation in the recent past. The consolidation is attributable to the chemical sector's inherent high cost of doing business due to governmental regulation, intense competition and high energy costs. The result has been a series of mega-mergers and acquisitions within the sector. The new mega-chemical companies that emerged from this period of consolidation have been able to conduct R&D, manage regulation, and offer products more efficiently.

The new chemical sector giants are poised to take advantage of increasing demand for chemical products. Industrialization, a rapidly growing population and increasing standards of living all require output from the chemical industry. With those phenomena occurring at rapid pace, the chemical sector is poised for growth.

Computer and Telecommunications Hardware

The computer manufacturing sector has experienced several trends throughout the last 15 years. Fueled by the Internet, PC demand exploded throughout the 90's, and companies like Gateway and Dell established themselves as top manufacturers through niche marketing.

However, the demand for PC's has slowed due to market saturation and the sluggish economy. While some analysts were predicting that the PC would give way as the preferred information technology interface to PDA's and other wireless devices, those predictions proved to be wrong. Instead, according to *Hoover's Online* "the convergence of devices like cell phones and PDA's with the PC may provide the spark for the PC sector."[3]

The telecommunications equipment manufacturing sector has fallen off its recent robust growth patterns. According to *Hoovers Online*, the industry had over $325 billion dollars in global sales in 1999. However, a combination of the recent U.S. economic downturn, the overbuilding of the U.S. telecommunication infrastructure and the global economic slowdown has slowed industry growth. Developing nations engaged in building telecommunications networks were fostering telecommunication equipment demand. With the global economic downturn, telecommunications industry analysts are pessimistic about the industry's immediate future.

[3] Lower, Josh. *Personal Computers: The Lowdown*, Hoover's Online. www.hoovers.com

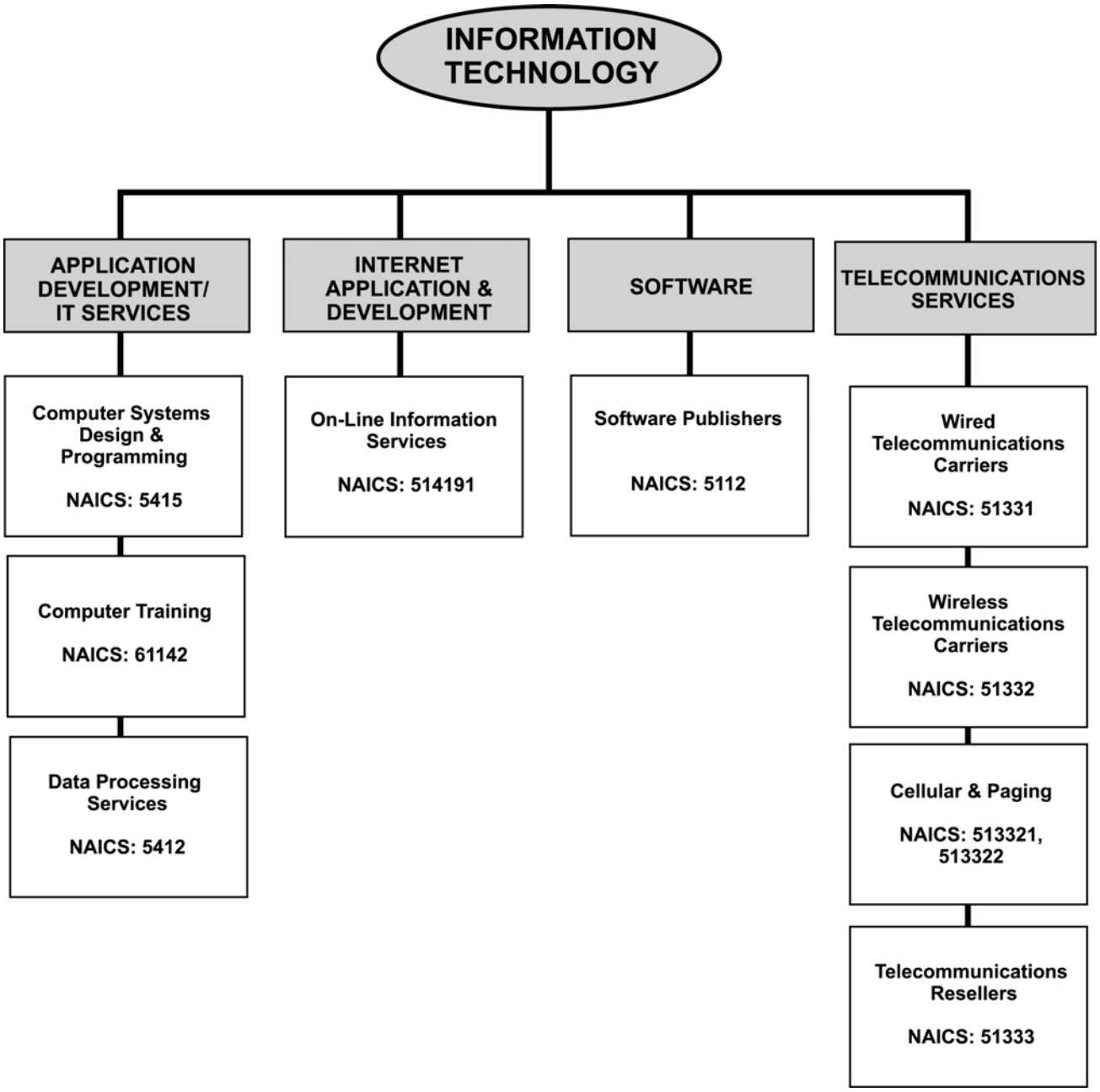
Electronics and Components

Sales of chips manufactured by the semiconductor industry reached $200 billion dollars in 2000. That sales figure represented a 35% increase from 1999—thanks to skyrocketing sales of PC's, cell phones, networking equipment and all manner of mobile and wireless devices.[4]

In addition to chip manufacturing, this sector comprised the manufacturers that make the complex machinery that produce the chips. Minnesota has a particularly strong presence in this manufacturing sector, which is good news; the semiconductor machinery niche is big business, producing $25.5 billion in sales in 1999.

The outlook for the semiconductor industry is bright. Since the 1960's the industry has followed Moore's law—that is, the amount of information storable on a given amount of silicon has roughly doubled every 18 months. That trend is expected to continue for the foreseeable future.

[4] Aiken, Joy. *Semiconductors: The Lowdown*, Hoovers Online. www.hoovers.com


INFORMATION TECHNOLOGY
APPLICATION DEVELOPMENT/ IT SERVICES
INTERNET APPLICATION & DEVELOPMENT
SOFTWARE
TELECOMMUNICATIONS SERVICES
Computer Systems Design & Programming
NAICS: 5415
Computer Training
NAICS: 61142
Data Processing Services
NAICS: 5412
On-Line Information Services
NAICS: 514191
Software Publishers
NAICS: 5112
Wired Telecommunications Carriers
NAICS: 51331
Wireless Telecommunications Carriers
NAICS: 51332
Cellular & Paging
NAICS: 513321, 513322
Telecommunications Resellers
NAICS: 51333

STATISTICAL DATA: Information Technology

Industry	NAICS codes	Sales/ Receipts/ Shipments/ (1000's)	Sales/ Receipts/ Shipments/ (1000's)	Percent Change '97-'99	Total Employ-ment	Total Employ-ment	Percent Change '97-'99	Total Establish-ments	Total Establish-ments	Percent Change '97-'99
		1997	**1999**		**1997**	**1999**		**1997**	**1999**	
Application Development, IT Services	5415, 61142	$2,565,085	†	†	23,316	25,653	**10.02%**	2371	3014	**27.12%**
Internet Application Development	514191	$81,930	†	†	904	1749‡	**93.47%**	80	118	**47.50%**
Software	5112	$665,809	†	†	4,053	4,103	**1.23%**	279	248	**(11.11)%**
Telecommuni-cations	5133	$3,751,512	†	†	15,177	15,803	**4.12%**	612	686	**12.09%**
IT Totals		$7,064,336	†		43,450	45,559‡		3,342	4,066	
Minnesota All		$318,482,387*	†		2,271,671*	2,338,642*		124,039*	137,305*	
Percentage of Minnesota All		2.22%	†		1.91%	1.95%		2.69%	2.96%	

Source: U.S. Census Bureau

† Data Unavailable ‡ Estimated * Non-Farm

MARKET OVERVIEW

The Information Technology sector encompasses application development, software, telecommunications and the Internet. This sector is perhaps the most recognizable technology sector, as the press frequently uses the phrase "information technology" and the word "technology" synonymously. To illustrate this point—refer to the *Wall Street Journal's* take: Katherine Meyer, a reporter for the *Wall Street Journal Online* said, "we…include any computer-related companies, which includes all hardware and software, as well as telecom sectors…Internet-related companies…and fiber-optics," when writing about technology companies."

Application Development/IT Services and Software

The application development/IT services and software sectors are similar in content, but over the last two years, have had dissimilar results regarding their bottom lines. The application development/IT services sector—hired hands that provide system design, custom programming, application development and computer facilities development—has slumped over much of the past two years. At the

same time, the software sector—companies that design and develop prepackaged software—continues to post relatively strong results.

The application development/IT services slump has been characterized by earnings warnings from many of the national and regional players in the industry. Bucking the trend, larger firms resisted the temptation to overemphasize e-commerce in their business plans. As a result, larger firms have managed to produce moderate revenue streams by continuing to offer a balanced portfolio of services during the Internet boom and bust. That foresight has paid off, and many firms anticipate an earnings turnaround in the not-too-distant future.

The recovery in this sector will be largely fueled by renewed spending in "business to business commerce, outsourcing of non-core operations, and upgrad[ing] web-based systems." [5] The nation's largest firms will be well positioned to compete for projects like these and additional web design and consulting work that is forecast to pick up.

This sector has been affected by substantial events of the last two years: Y2K and 9-11. After experiencing a glut of business spurred by Y2K preparations, the industry suffered through a significant slowdown concurrent with the national economic slowdown. Fifteen months ago the computer services industry was looking towards recovery in the latter half of 2001. However, the tragic events of 9-11 and the subsequent economic fallout have pushed back projections of recovery to late 2002. At that time, analysts say, large corporate America will begin to focus on capital expenditures designed to upgrade IT systems with continued focus on network integration into the Internet.

The software sector continues to grow, albeit not at the pace enjoyed in the late '90s. According to *Hoover's Online*, national revenues in this sector continue to annually approach the $150 billion level.

The relationship between the Internet and the software sector continues to evolve. Today, 12% of software is distributed over the Internet. However, a recent survey of CEO's by the Business Software Alliance indicated that the Internet is taking an increasingly larger role in the software industry. By 2005, according to the survey, the

[5] Blunt, Alexander. *Computer Software: The Lowdown*, Hoover's Online. www.hoovers.com

software CEO's believe that two-thirds of software will be distributed online. The effect this trend will have on the development, distribution and profits of the software sector will continue to evolve.

Analysts have also identified software sector developments that read like alphabet soup—future trends with ASP's, ERP, and CRM will have lasting effects on the sector. According to *Hoover's Online,* the increasing prominence of application service providers (ASP) is a "potentially disruptive" force in the sector. On a fee-per-use basis, ASP's allow businesses to use software hosted at offsite data centers. This trend is especially appealing to small- and mid-sized businesses that have limited software budgets. Analysts have also observed a shift in demand for software types over the past five years. Demand in enterprise resource planning (ERP) software — "software that integrates back office operations such as accounting, distribution and human resources—has given way to software that helps companies make money, e.g. customer relationship management software (CRM)."[6]

Internet Services

The well-publicized dot-com bust has victimized many virtual companies that either developed Internet sites around their own business plans or developed the web sites of others. Despite the closure of many of the companies, the Internet, of course, has not gone away. In fact, some analysts expect spending on web-related activities to reach the astounding level of $5 trillion dollars in 2005. The vacuum left by the closures has been occupied by a variety of multi-service companies—many of which lay under the IT umbrella. Therefore, in referencing the Internet sector perhaps a more appropriate discussion theme is the relative strength of the Internet service providers (ISP) market.

Nationally, the ISP market remains stable. Taking a look at Minnesota ISP statistics seems to confirm the stable demand for ISP services. According to the *MarketPlace* database, there were 322 Minnesota ISPs in 2000, representing $267 million in sales. Those Minnesota ISP sales numbers are strong—especially in light of the fact that large national carriers annually capture much of Minnesota's personal and corporate ISP business.

Telecommunication Services

[6] Blunt, Alexander. *Computer Software: The Lowdown*, Hoover's Online. www.hoovers.com

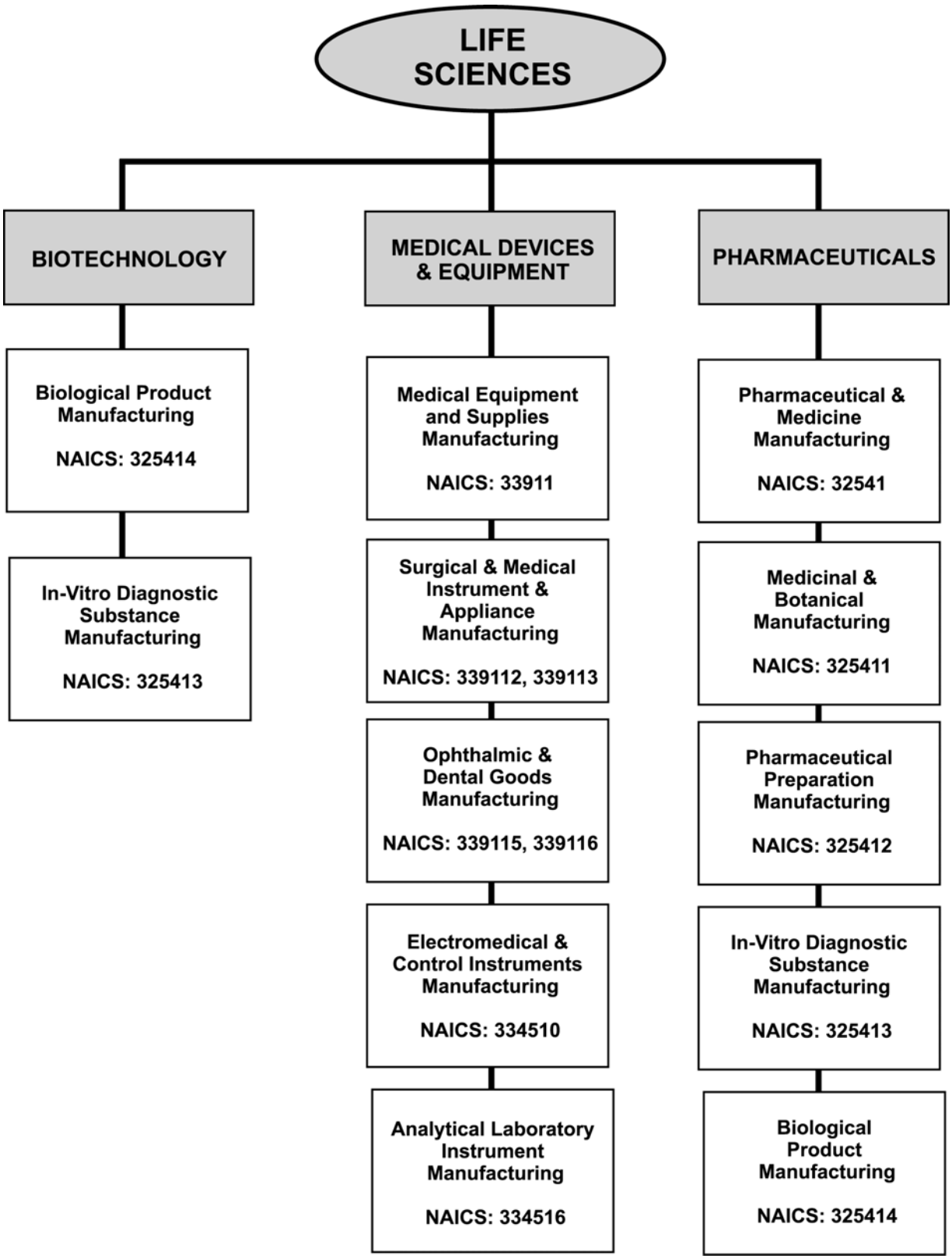
Heralded as a sector of substantial growth in the 90's, the telecommunication services sector has instead come to a standstill during much of the last two years. On June 18, 2001, articles in both *The New York Times* and *The Wall Street Journal* simultaneously attributed the telecommunications slump to overcapacity. In short, too many telecommunications companies buried too much fiber optic cable. Much of that mainline cable goes unused, while many consumers, in some cases less than a mile from the mainline cable, cannot receive service. The connection between the main line and the individual business or consumer is expensive, and with the telecommunications companies losing money, solutions to solve the "last mile" problem are not readily available. This unique scenario—in the case of mainline cable, supply where there is little demand; in the case of the "last mile", demand where there is little supply—contributes to a murky telecommunications sector outlook.

Despite this situation, the telecommunications sector continues to grow slowly. The time frame for that growth, however, is hotly debated. Conventional wisdom among analysts remains that a disruptive event or series of events will eventually build enough inertia to break open current anemic growth cycles. The emergence of the next "killer application" should increase broadband demand. According to *Hoover's Online*, this application could be video conferencing, peer networking, voice-over-Internet protocol, video-on-demand, or new media streaming technologies.

The wireless communication sector has grown at a rapid pace over the years. In 2003, the wireless sector is expected to have over one billion users worldwide. Wireless communication is all about convenience—voice, data and the Internet can be utilized by all manner of wireless phones, computers and sophisticated pagers. However, the eventual unveiling of practical wireless Internet usage will truly make the sector very profitable by making wireless not merely convenient, but necessary.

Similar to the telecommunication services sector, the wireless sector suffers from some confusion regarding infrastructure. According *Hoovers Online*, "competing digital standards have threatened to slow the development of wireless communication standards, where various providers employ all three of the world's major wireless standards." Wireless systems using the Global System for Mobile Communication (GSM) standard offer the best performance, and have been adopted throughout much of Europe and parts of Asia. When the United States arrives at a compromise regarding the GSM

standard—allowing more data/Internet/voice to be transmitted faster, wireless growth is expected to balloon.


LIFE SCIENCES
BIOTECHNOLOGY
Biological Product Manufacturing
NAICS: 325414
In-Vitro Diagnostic Substance Manufacturing
NAICS: 325413
MEDICAL DEVICES & EQUIPMENT
Medical Equipment and Supplies Manufacturing
NAICS: 33911
Surgical & Medical Instrument & Appliance Manufacturing
NAICS: 339112, 339113
Ophthalmic & Dental Goods Manufacturing
NAICS: 339115, 339116
Electromedical & Control Instruments Manufacturing
NAICS: 334510
Analytical Laboratory Instrument Manufacturing
NAICS: 334516
PHARMACEUTICALS
Pharmaceutical & Medicine Manufacturing
NAICS: 32541
Medicinal & Botanical Manufacturing
NAICS: 325411
Pharmaceutical Preparation Manufacturing
NAICS: 325412
In-Vitro Diagnostic Substance Manufacturing
NAICS: 325413
Biological Product Manufacturing
NAICS: 325414

STATISTICAL DATA: Life Sciences

Industry	NAICS codes	Sales/Receipts Shipments/ (1000's)	Sales Receipts/ Shipments/(1000's)	Percent Change '97-'99	Total Employment	Total Employment	Percent Change '97-'99	Total Establish-mints	Total Establish-mints	Percent Change '97-'99
		1997	**1999**		**1997**	**1999**		**1997**	**1999**	
Medical Devices and Equipment	33911, 334510, 334516, 334517	$5,829,328	†	†	22,845	25,172	10.19%	368	373	1.36%
Pharmaceu-ticals	3254	$712,764	$751,940	5.50%	2,114	1,974	(6.62)%	42	42	0.00%
Biotechnology	325413, 325414	$92,101	†	†	824	880	6.80%	18	16	(11.11)%
Technology Totals		$6,634,193	†		25,783	28,026		428	431	
Minnesota All		$318,482,387*	†		2,271,671*	2,338,642*		124,039*	137,305*	
Percentage of Minnesota All		2.08%	†		1.13%	1.20%		0.35%	0.31%	

Source: U.S. Census Bureau
† Data Unavailable * Non-Farm

MARKET OVERVIEW

Anchored by the medical device industry, Minnesota's life science umbrella, arguably, is the cluster in which the state has the best competitive advantage. A healthy life sciences intellectual and business infrastructure has created a fertile climate for spin-off activity. Despite the recent recession, analysts predict that many industries under this umbrella have substantial growth potential in the immediate future.

Companies in the life sciences cluster routinely factor in government regulatory and reimbursement issues into their day-to-day business operations. With its regulatory power, the Food and Drug Administration can alter the course of a product offering. Approval of a product can yield great returns on the time and financial resources devoted to product research and development. By the same token, however, an FDA non-approval can mean a loss of significant time, money and intellectual capital. As such, companies in this cluster are highly committed to research and development, in some cases spending between eight and ten percent of annual sales on developing new products.

Medical Devices

The medical device industry is poised for continued growth as companies begin to diversify their product offerings. Long known for cardiologic products like pacemakers and stents, medical device companies are now successfully offering products that treat neurological and oncological aliments.

The medical device industry is experiencing increasing levels of success with hybrid devices that simultaneously perform therapeutic processes and administer medication. Minnesota-based companies like Medtronic, St. Jude Medical and Surmodics have all been at the cutting edge of hybrid technologies like these.

Nationally, the industry has been in a consolidation phase. Established medical device companies like Medtronic have diversified their product offerings through acquisitions of smaller medical device firms. By virtue of that process and aggressive R&D, Medtronic and others are constantly able to roll out improved products focused on preventive and less invasive therapies.

Pharmaceuticals

The world's pharmaceutical companies annually sell $300 billion of prescriptive and over-the-counter medicine. The United States is the world's largest consumer of pharmaceuticals. Japan and the European continent, respectively, are the second and third largest pharmaceutical consumers. Increasing life expectancy and quality of life continues to fuel demand for pharmaceuticals. With the population of people older than 65 expected to reach 690 million individuals by 2025, pharmaceuticals are clearly a growth industry.

Overall, production of new pharmaceutical products is largely driven by demand from consumers with chronic, rather than acute ailments. With life expectancy constantly increasing, larger populations exist that require treatments for diseases like cancer and cardio-vascular disease. As a result, the majority of pharmaceutical R&D resources are devoted to prevention or cure of chronic ailments. According to *Hoover's Online,* recent advances in biotechnology have also impacted pharmaceutical R&D processes. For instance, new discoveries derived through the human genome project have already enabled pharmaceutical companies to identify new product opportunities and trim the expense of development.

Recent pharmaceutical industry activity has, like many other industry sectors, gone through a period of consolidation. With so much expense and effort devoted to R&D, larger pharmaceutical companies have merged or been acquired by other pharmaceutical firms. The combined R&D power and larger suite of products have made these mega-pharmaceutical companies powerful and more cost-efficient. However, the mega-pharmaceutical companies' success has not signaled the demise of the small- to mid-sized pharmaceutical companies. To the contrary, smaller- and mid- sized firms – characteristic of pharmaceutical firms found in Minnesota—are developing new products with the hopes of hitting the big time or being acquired by a larger firm.

Biotechnology

The biotechnology industry is an enigma. It's an industry that governments are scrambling to attract to their states or regions. However, to the layperson the biotechnology industry represents threatening products and processes produced by businesses with less than wholesome intentions.

To the contrary, biotechnology is an industry that focuses on improving quality of life by using cellular and molecular processes to make products or solve problems. In short, biotechnology companies use one or a combination of the following technologies to accomplish these goals:

- Cell culture technology
- Biosensor technology
- Genetic modification technology
- Antisense technology
- Protein engineering technology

Thus far, the pharmaceutical and medical industries are the chief beneficiaries of these processes.

The biotechnology industry has been profoundly affected by recent discoveries from the Human Genome Project. From the information gleaned from the genetic research, biotechnology companies are able to develop intricate and powerful therapies at the genetic level. According to *Hoover's Online,* as a result of this research, simultaneous work is being done on developing treatments that focus on the ailments attributed to specific genes and building databases of genes that can be licensed by pharmaceutical companies.

Agricultural applications in biotechnology are another promising growth area, and particularly apply to the Minnesota biotechnology infrastructure. At this time, however, consumers have been slow to warm to the idea of genetically modified food products. Analysts predict that biotechnology applications in agricultural products will gradually be accepted over time. In the short term, markets in developing countries represent the most likely candidates for acceptance of agricultural biotechnology products. When other developed economies do embrace biotechnological agriculture products, companies involved in this sector are likely to be successful

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Section II

Metropolitan and State Comparisons

The premise that industrial technology development in Minnesota has failed to keep pace with other parts of the country was frequently discussed throughout much of 2000 and early 2001. Popular media lauded IT-intensive regions as up and coming, largely over working Minnesota's technology strengths. Some Minnesotans started to find fault with its technology economic makeup, aspiring instead to go after the headlines, IPO's and the "e" everything of the IT-dominated economies of many of the nation's other regions.

During that time however, the Minnesota technology scene was quietly flourishing. The diverse mix of technology industries in the IT, life sciences, and advanced manufacturing sectors continuously churned out record profits and talked about the need for more skilled labor to fuel expansion.

These discrepancies lead Minnesota Technology, Inc. to write, "you would think that in the midst of one of the best economies ever we would take time to celebrate the successes of our business community. Instead, there is a fear that Minnesota is not keeping pace with many other parts of the country." [7] Some local press and business people proclaimed that technology development success stories were occurring everywhere *but* in the Twin Cities.

However, once the bottom fell out and the nation entered into recession, Minnesota's industrial diversity proved to be a strength. Statewide, the healthy life sciences sector softened the blow the IT and advanced manufacturing sectors had been recently dealt. Once a technology has-been, the Twin Cities is now the envy of IT-intensive metro economies of the Pacific Northwest reeling from the after-effects of the recession.

Of course, technology, and in particular IT, are not dead. As technology industries continue to emerge out of the recession, other states and metros are hungry to win back market share lost during the recent downturn. Those regions are poised to once again compete for technology employers and employees. In this report's effort to articulate Minnesota's technology core competencies, this section presents information on the competing state and metro areas—competition Minnesota has frequently been asked to emulate. This data offers compelling information about the technology corporate makeup of Minnesota and other regions—and how we stack up

[7] Koppel, Jacques. Technology & the Minnesota Economy: Is the Grass really Greener? *Minnesota Technology*

against them. In most cases, the data demonstrates, Minnesota compares favorably to the competition.

MTI addressed the issue of Minnesota's competitiveness in a three part series in *Minnesota Technology* magazine. Published in mid-2000, the first article in the series, "Technology & the Minnesota Economy: Is the Grass Really Greener?," MTI addressed, "the fear that Minnesota has not been keeping pace with many other parts of the country." In fact, the article asserted that technology in Minnesota is strong compared to other metros in the country. "From advanced manufacturing to agribusiness and the life sciences, new innovations are creating new companies and helping existing Minnesota firms become more competitive," said the article.

Addressing popular notions of regional technology strength, the article contested the fact that some metros had a pronounced advantage over Minnesota. "Competitiveness", said the article, "is not limited to companies developing new technologies. It also comes about as the result of existing industries exploiting and developing technologies that have been developed all over the globe." Minnesota's technology industries have always been particularly good at adapting and improving new technologies. That adaptiveness has contributed to a strong technology economy. As Minnesota has experienced however, a region that adapts and improves on technology is an infrequent headliner.

MTI presented information attesting to Minnesota's technology strengths. Among some of Minnesota's technology attributes MTI pointed out are the following:

- Minnesota has an unsurpassed quality of life. The Morgan Quinto press, a Kansas-based publishing and research company, has ranked Minnesota's quality of life #1 for four consecutive years.
- Leaders of the Minnesota Business Partnership are looking to play a larger role in the growth of the technology community.
- A rejuvenated Minneapolis Chamber of Commerce has made economic development one of its top priorities.
- Minnesota Planning is looking at ways the state might invest in nanotechnology.
- MnBIO and the University of Minnesota are in the planning stages of constructing a business incubator for companies in the life sciences.
- In Mankato, the Tech Plus incubator facility has already attracted several technology-based companies and initiatives.

- The Northern Tier High Technology Corridor is linking industry and academic resources to promote the region.

The bottom line, the article said, is that despite the hype, the technology industry grass is not necessarily greener in other parts of the country. However, MTI cautioned, these favorable attributes are not meant to lull the Minnesota technology community into contentment. As the article said, "Even if you're on the right track, you must keep moving or the train will run you over."

The following data helps to establish some basic benchmarks with which the Twin Cities can evaluate its relative technology strength. With an accurate idea of where the Twin Cities technology economy compares, the technology community can confidently promote its strengths. Because, as the article concludes, "Minnesota's technology economy is broader and more vibrant than we give it credit for and we should create our own buzz to recognize its contribution. If we don't create our own publicity, no other community will do it for us."

Data

This section presents comparative data and observations at the state and metro level. The information is not meant to provide conclusive evidence of the relative technology health of the regions. Instead, the information contained in the data is snapshot in nature and meant to stimulate discussion by providing information about regions touted as technology hotbeds. Comparisons are presented on per capita personal income, unemployment and technology corporate revenue.

Regarding the per capita personal income and unemployment data, comparisons are made on a metro and on a state basis. Comparisons are made between the Twin Cities and Minnesota and respective metro areas and states. The following six metro/state combinations have been chosen for comparison:

- Atlanta and Georgia
- Austin and Texas
- Boston and Massachusetts
- Denver and Colorado
- San Jose and California
- Seattle and Washington

Principally, the metro and state combinations were chosen for the comparisons due to similarities they share with the Twin Cities and

Minnesota regarding numbers of technology companies, population, and educational attainment.[8] However, the metro and state combinations were also chosen because they are generally considered to be top technology regions in the country.[9] As a result, comparisons with these regions will produce less stunning results than comparisons to metros or states that have an anemic technology economy. The fact that the Twin Cities and Minnesota, respectively, are in the same strata with the leading technology regions is a testament to this region's strength.

The largest technology companies tend to agglomerate around metro regions due to the availability of capital and labor. Therefore, regarding technology corporate revenue, comparisons are made at the metro level only. For simplicity, the 10 largest technology companies in each metro are used in the comparison.

Per Capita Personal Income

Per capita personal income is a broad economic and quality of life indicator. According to the Bureau of Economic Analysis, personal income data is used by government at the federal and state level for numerous economic forecasting functions. At the federal level for example, the distribution of federal funds is annually affected by the estimates of state per capita personal income.

Personal income grew at a rapid pace in technology-intensive metros in the late 90's. During the Internet boom, employees of start-ups reaped the benefits of generous salaries and stock option plans in many metros. Salary levels increased rapidly during those years as many employees job-hopped to the highest-bidding firm. The metro level per capita personal income data reflects this trend—as the most recent data available for metropolitan areas is from 1999. From 1998 to 1999, the data demonstrates, per capita income rose at a furious pace.

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[8] In the cases of San Jose and California, their technology industrial makeup is demonstrably larger than that of the Twin Cities and Minnesota. However, comparison between the two provides compelling information on how Minnesota stacks up with the acknowledged leading technology region.

[9] Given that there may be several technology-intensive metros in a state, the metro that was generally considered the leading state center for technology was chosen for comparison.

At the state level, however, per capita personal income data is available for both 2001 and 2002. These time series data paint a very different picture. Per capita personal income dropped from double-digit growth rates experienced in the late 90's as the technology economy struggled through the dot.com shakeout. Per capita income growth now hovers between one and three percent for most technology oriented states. This trend is expected to continue for the next 12 to 18 months as the economy slowly restarts and moves further away from the recession.

In Minnesota, per capita personal income has been robust throughout much of the last 10 years. Reflecting that trend, an April 2002 report by the U.S Bureau of Economic Analysis revealed that personal income in Minnesota had the 8th highest growth rate nationally.

Observations:

- Between 1992 and 2001, Minnesota's per capita personal income growth was the third best of the seven comparison states. Minnesota's diversified economy helped foster consistent income growth though the dot.com era and into the current economic slowdown.
- At $46,586, San Jose's 2000 per capita personal income far exceeded the other six compassion metros. However, San Jose's prohibitive cost of living made making a living difficult for an "average" wage earner.
- There was a $2,092 difference between the 2000 per capita income of Boston and the Twin Cities. Although Twin Cities residents earned less than Bostonians, Boston's high cost of living arguably makes Minneapolis a more attractive place to live and work.

Per Capita Personal Income by State ($)	1992	2001	Per Capita Personal Income by City ($)	1992	2000	Metro Cost of Living Index *
Massachusetts	24,731	38,845	Boston	25,135	38,758	240
California	22,650	32,678	San Jose	28,685	46,586	366
Washington	21,825	31,582	Seattle	26,390	35,877	108
Minnesota	**21,582**	**32,791**	**Twin Cities**	**24,679**	**36,666**	**90**
Colorado	21,227	32,957	Denver	23,649	37,153	135
Georgia	19,170	28,438	Atlanta	22,509	33,013	115
Texas	19,028	28,486	Austin	19,490	32,039	93

Source: United States Bureau of Economic Analysis *The Cost of Living Index is provided to demonstrate the difference in cost of living for metro areas. The average for cost of living score for American metros = 100. Source: ReloSmart®

Unemployment

Unemployment is a benchmark indicator of a region's economic health. Significant unemployment, of course, is a serious economic ailment. Lost wages as a result of unemployment has a ripple effect—a lower supply of goods and services in combination with lost purchasing power lowers demand and contributes to even more unemployment. Recent spikes in unemployment have been observed in information technology-intensive regions as the technology industry has been particularly hard hit by the recent recession.

In Minnesota, the state's diversified technology economy has held significant unemployment at bay. In a recent Minnesota Department of Economic Security's press release, Governor Ventura maintained optimism about unemployment in Minnesota. "Continuing a pattern that began almost 25 years ago, Minnesota's unemployment rate is still well below the nation's", said the Governor. Most analysts say Minnesota's unemployment trends are likely to continue to stay below the national average.

Observations:

- Due in large part to a diversified economy, Minnesota's unemployment rate increases were the lowest of the seven states and the seven metros. Minnesota's broad economic base including industry clusters in technology, printing, food and kindred products, have helped keep Minnesota's job base stable. Respectively, state and Twin Cities metro area unemployment stood at 4.2% and 4.3% in early 2002.
- IT-intensive Washington State has been particularly hard hit with unemployment. In early 2002, unemployment in Seattle and Washington, stood at 7.1% and 6.8%respectively.
- February 2002 unemployment in San Jose, CA stood at 7.3%, representing a 5.5 percentage point increase from year earlier levels – representing the largest over-the-year unemployment rate increase in the nation.

State Unemployment Rates	Mar-01	Mar-02	% Point Change	Metro Area Unemployment Rates	Feb-01	Feb-02	% Point Change
Minnesota	**3.6%**	**4.3%**	**0.7**	**Twin Cities**	**3.0%**	**4.2%**	**1.2**
Massachusetts	3.1%	4.4%	1.3	Boston	2.6%	4.1%	1.5
Georgia	3.7%	4.6%	0.9	Atlanta	3.1%	4.5%	1.4
Colorado	3.0%	5.6%	2.6	Denver	2.5%	5.9%	3.4
Texas	4.3%	5.8%	1.5	Austin	2.4%	5.3%	2.9
Washington	5.9%	6.8%	0.9	Seattle	4.6%	7.1%	2.5
California	4.8%	6.4%	1.6	San Jose	1.8%	7.3%	5.5

Source: United States Bureau of Labor Statistics

Corporate revenues

Corporate revenues are the single most important determinant of a company's value and stock price. In today's investor savvy climate, a region rife with hot stock companies can attract significant notoriety. Examining the corporate revenues from companies in a given region provides compelling information on that region's economic health. Typically, a region with substantial corporate earnings will benefit from good jobs, entrepreneurialism and innovation, and a positive self-image—inertia that can help a region enjoy prolonged stability.

Metropolitan areas increasingly look upon one another as competitors. State and municipal governments compete for companies by offering tax and other financial incentives to either attract or retain them. This competition manifests itself as reports issued by think tanks and consultants ranking metropolitan areas in everything from quality of life to business vitality.

It is with this competitive environment in mind that corporate data is presented on metros in which technology companies thrive. Corporate revenue data is presented on the top ten technology companies of the Twin Cities and the six comparison metros.

The presentation of corporate revenue data is two-pronged. Corporate revenues are listed for the top ten technology companies of a given metro, providing a snapshot indication of the size of corporate revenue generated per region. Second, each company is categorized by business sector, allowing a quick indication of the metro's general industrial makeup.

To ensure uniformity, the technology companies were identified from lists generated from the leading business journal in each metro. *(The Atlanta Business Chronicle, The Austin Business Journal, The Boston Business Journal, The Denver Business Journal, City Business [Twin Cities], The Silicon Valley/San Jose Business Journal, and the Puget Sound Business Journal are all publications of American City Business Journals, Inc.)*

Observations:

- Twin Cities top ten technology company corporate revenue was larger than that of "new" technology metros like Austin and Denver. However, Twin Cites top ten technology company corporate revenue was also larger than that of Boston – considered one of the first successful technology metros.
- Of the seven metros, the Twin Cities is at the median.
- Twin Cities' top ten technology company corporate revenue total is the 4th largest of the seven.
- Twin Cities top ten technology company corporate revenue was spread over a diverse mix of industry sectors. Conversely, the top ten technology companies in Denver and San Jose, respectively, lie exclusively in the IT sector.
- The Twin Cites was the only metro to place two life sciences sector companies on their top ten technology company list.

STATISTICAL DATA: Technology Company Comparison (2001)

MINNEAPOLIS

COMPANY NAME	SALES	TYPE OF COMPANY	WEB ADDRESS
3M Company	$15.6 billion	Advanced Manufacturing	www.mmm.com
Medtronic Inc	$5.5 billion	Life Sciences	www.medtronic.com
Pentair Inc	$2.3 billion	Advanced Manufacturing	www.pentair.com
Bemis Co. Inc.	$1.9 billion	Advanced Manufacturing	www.bemis.com
ADC Telecommunications Inc	$1.9 billion	Information Technology	www.adc.com
St Jude Medical Inc	$1.7 billion	Life Sciences	www.sjm.com
Imation Corporation	$1.4 billion	Information Technology	www.imation.com
Valspar Corporation	$1.4 billion	Advanced Manufacturing	www.valspar.com
H.B. Fuller Company	$1.3 billion	Advanced Manufacturing	www.hbfuller.com
Donaldson Company Inc.	$1.1 billion	Advanced Manufacturing	www.donaldson.com

Source: *City Business*

ATLANTA

COMPANY NAME	SALES	TYPE OF COMPANY	WEB ADDRESS
IBM Corp. *	$88.7 billion	Advanced Manufacturing	www.ibm.com
BellSouth Corp.	$26.15 billion	Information Technology	www.bellsouth.com
WorldCom Inc.*	$16.05 billion	Information Technology	www.worldcom.com
Cox Communications Inc.	$3.5 billion	Information Technology	www.cox.com
Scientific-Atlanta Inc.	$2.32 billion	Life Sciences	www.sciatl.com
WebMD Corp.	$729.2 million	Information Technology	www.webmd.com
CheckFree Corp.	$459.2 million	Information Technology	www.checkfree.com
National Data Corp.	$352.3 million	Information Technology	www.nationaldata.com
EMS Technologies Inc.	$274.6 million	Advanced Manufacturing	www.ems-t.com
Video Display Corp.	$72.4 million	Advanced Manufacturing	www.videodisplay.com

*** Headquartered elsewhere**

Source: *Atlanta Business Chronicle*

AUSTIN

COMPANY NAME	SALES	TYPE OF COMPANY	WEB ADDRESS
Dell Computer Corp.	$15.64 billion	Advanced Manufacturing	www.dell.com
Southern Union Co.	$1.93 billion	Utility/Adv. Manufacturing	www.southernunionco.com
Cirrus Logic Inc.	$500 million	Advanced Manufacturing	www.cirruslogic.com
ACS Dataline LP	$146 million	Information Technology	www.acsdataline.com
SigmaTel Inc.	$47.4 million	Advanced Manufacturing	www.sigmatel.com
Catapult Systems Corp.	$22 million	Information Technology	www.catapultsystems.com
ClearOrbit Inc.	$16.4 million	Advanced Manufacturing	www.clearorbit.com
EuroSoft Inc.	$13.4 million	Information Technology	www.eurosoft-inc.com
Advanced System Integration Corp.	$12.2 million	Advanced Manufacturing	www.asi-corp.com
NetForce Technology Inc.	11.5 million	Information Technology	www.netforce.com

Source: *Austin Business Journal*

BOSTON

COMPANY NAME	SALES	TYPE OF COPMANY	WEB ADDRESS
Raytheon Co.	$16.8 billion	Advanced Manufacturing	www.raytheon.com
EMC Corp.	$7.09 billion	Information Technology	www.emc.com
NSTAR	$3.19 billion	Utility/Adv. Manufacturing	www.nstaronline.com
Boston Scientific Corp.	$2.67 billion	Life Sciences	www.bostonscientific.com
Thermo Electron Corp.	$2.18 billion	Advanced Manufacturing	www.thermo.com
Analog Devices Inc.	$1.89 billion	Advanced Manufacturing	www.analog.com
Cabot Corp.	$1.65 billion	Advanced Manufacturing	www.cabot-corp.com
Manufacturers' Services Ltd.	$1.52 billion	Advanced Manufacturing	www.msl.com
Teradyne Inc.	$1.44 billion	Advanced Manufacturing	www.teradyne.com
PerkinElmer Inc.	$1.33 billion	Advanced Manufacturing	www.perkinelmer.com

Source: *The Boston Business Journal*

DENVER

COMPANY NAME	SALES	TYPE OF COPMANY	WEB ADDRESS
WorldCom Inc.*	$16.05 billion	Information Technology	www.worldcom.com
Qwest Communications International Inc.	$10.27 billion	Information Technology	www.lci.com
Level 3 Communications	$1.21 billion	Information Technology	www.level3.com
UnitedGlobalCom Inc.	$794 million	Information Technology	www.unitedglobal.com
XO Communications Inc.*	$280.8 million	Information Technology	www.xo.com
Terra Firma	$78.6 million	Information Technology	www.terrasoftsolutions.com
Excel Professional Services Inc.	$31 million	Information Technology	www.team-excel.net
Univance Telecommunications	$30 million	Information Technology	www.univance.com
Image Projections West Inc.	$16.1 million	Information Technology	N/A
ME Engineers Inc.	$15.5 million	Advanced Manufacturing	www.meengineer.com

*** Headquartered elsewhere**

Source: *The Denver Business Journal*

SAN JOSE

COMPANY NAME	SALES	TYPE OF COPMANY	WEB ADDRESS
IBM Storage Systems Division*	$88.7 billion	Advanced Manufacturing	www.storage.ibm.com
Hewlett-Packard Co.	$44.6 billion	Advanced Manufacturing	www.hewlett-packard.com
Compaq Computer Corp.	$36.7 billion	Advanced Manufacturing	www.compaq.com
Intel Corp.	$28.3 billion	Advanced Manufacturing	www.intel.com
Nortel Networks Corp.*	$22.9 billion	Information Technology	www.nortelnetworks.com
Cisco Systems Inc.	$20.2 billion	Advanced Manufacturing	www.ciscosystems.com
Sun Microsystems Inc.	$16.1 billion	Advanced Manufacturing	www.sun.com
Oracle Corp.	$10.8 billion	Advanced Manufacturing	www.oracle.com
JDS Uniphase Corp.	$2.77 billion	Advanced Manufacturing	www.jdsu.com
NEC Corp.*	$2.5 billion	Advanced Manufacturing	www.nec.com

*** Headquartered elsewhere**

Source: *Silicon Valley/San Jose Business Journal*

SEATTLE

COMPANY NAME	SALES	TYPE OF COPMANY	WEB ADDRESS
The Boeing Company*	$28.81 billion	Advanced Manufacturing	www.boeing.com
Microsoft Corporation	$25.3 billion	Advanced Manufacturing	www.microsoft.com
AT&T Wireless	$10.4 billion	Information Technology	www.attws.com
Nintendo of America Inc.	$8.43 billion	Advanced Manufacturing	www.nintendo.com
Puget Energy Inc.	$3.4 billion	Utility/Adv. Manufacturing	www.pse.com
Amazon.com	$2.76 billion	Information Technology	www.amazon.com
Advanced Digital Info. Corp.	$698 million	Information Technology	www.adic.com
Western Wireless	$489 million	Information Technology	www.westernwireless.com
Immunex Corp.	$456.1 million	Advanced Manufacturing	www.immunex.com
New Edge Network	$77.5 million	Information Technology	www.newedgenetworks.com

*** Headquartered elsewhere**

Source: *Puget Sound Business Journal*

Statistical Data: Top Twenty Technology Companies Headquartered in Minnesota (2001)

(In Millions of dollars)

	Advanced Manufacturers	$
1	3M Co.	16,079
2	Pentair Inc.	2,615
3	Ecolab Inc.	2,354
4	Bemis Co. Inc.	2,293
5	Valspar Corp.	2,015
6	Alliant Techsystems Inc.	1,610
7	Polaris Industries Inc.	1,512
8	Donaldson Co.	1,120
9	Genmar Holdings Inc.*	1,000
10	Fastenal Co.	809
11	Apogee Enterprises Inc.	808
12	Pemstar Inc.	696
13	Arctic Cat Inc.	564
14	Graco Inc.	472
15	Tennant Co.	423
16	The Cretex Cos. Inc.*	350
17	BMC Industries Inc.	302
18	Navarre Corp.	299
19	Entegris Inc.	285
20	Telex Communications Inc.*	282

	Information Technology	$
1	ADC Telecommunications Inc.	1,885
2	Ceridian Corp.	1,182
3	Imation Corp.	1,176
4	Analysts International Corp.	551
5	Rural Cellular Corp.	441
6	Lawson Software	413
7	MTS Systems Corp.	389
8	Hutchinson Technology Inc.	375
9	Datacard Group*	300
10	Norstan Inc.	273
11	Zomax Inc.	216
12	Computer Network Technology Corp.	187
13	Retek Inc.	179
14	Datalink Corp.	124
15	Digi International Inc.	120
16	HickoryTech Corp.	108
17	Stellent Inc.	96
18	Plato Learning Inc.	74
19	Digital River Inc.	57
20	Ontrack Data International Inc.	55

	Life Sciences	$
1	Cargill Inc.*	49,400
2	Medtronic Inc.	6,137
3	St Jude Medical Inc.	1,347
4	Starkey Laboratories Inc.*	360
5	Chronimed Inc.	359
6	Medsource Technologies	145
7	Innovex Inc.	144
8	Techne Corp.	121
9	Lake Region Manufacturing Co.*	71
10	CNS Inc.	68
11	Rehabilicare Inc.	65
12	Augustine Medical Inc.*	61
13	Disetronic Medical Systems Inc.*	50
14	Medtox Scientific	49
15	Lifecore Biomedical Inc.	32
16	Bio-Vascular Inc.	21
17	Possis Medical Inc.	20
18	Waters Instruments Inc.	19
19	Caire Inc.	18
20	SurModics Inc.	18

* Privately held

Interviews with Minnesota Technology Leaders

Industry and occupational data provide the facts upon which a credible industry analysis is based. However, statistical analysis neither characterizes the *sentiment* of corporate decision makers nor reflects their vision for the future. For the clearest picture of technology—now and to come—MTI recorded the thoughts of several distinguished Minnesota business leaders. Many of their views reflect ideas promulgated by the "Summit on the Minnesota Economy," business coalitions and local business press during the past 18 months. These business leaders comprise the *Our Competitive Nature: Minnesota's Technology Economy* Panel*:*

Life Sciences

- Karen Arnold — Nanomedica, Andover
- Paul Citron — Medtronic, Fridley
- Don Gearhardt — Medical Alley, Minneapolis
- Dale Olseth — Surmodics, Eden Prairie
- Ruth Shuman — Gentra Systems, Minneapolis

Information Technology

- Bob Kill — Ciprico, Plymouth
- Jim Kopp — Wizmo, Eden Prairie

Advanced Manufacturing

- Red Heitkamp — Remele Engineering, Big Lake
- Fred Zimmerman — University of St. Thomas, St. Paul

Venture Capital

- Tony Christianson — Cherry Tree Investments Inc., Edina
- Kris Johnson — Affinity Venture Capital, Minneapolis
- Mac Lewis — Sherpa Partners, Edina

Each interview was conducted separately during October or November 2001. Panel members represent the venture capital community and Minnesota's major technology sectors: information technology, life science, and advanced manufacturing. MTI sought comment on several broad themes throughout the interviews.

Several topics emerged upon which the panelists placed great importance: Minnesota's technology future, the impact of Minnesota's large technology companies as catalysts, area business climate, and our state at a crossroads.

THE FUTURE

Perspectives regarding the future growth of technology in Minnesota varied considerably. However, among many panelists, Minnesota's biotechnology industry sparked much conversation as an area with unrealized potential. The attention to biotech is not uncommon. Many U.S. business leaders also regard the growth of biotech in their regions as an important component of technology success.

On one hand, some felt biotech's future was promising. Ruth Shuman, president and CEO of Gentra Systems, a mid-sized biotech firm specializing in DNA purification, said, "Minnesota can be a biotech industry leader." Shuman believes that Minnesota has the potential to be a biotech player despite the perception that the industry is viable only along the coasts. Shuman said, "Biotechnology is going to emerge into an important *worldwide* industry…there is room for many biotech hubs." Given the fact that we already have a burgeoning biotech industry, there is no reason, Shuman felt, that Minnesota couldn't capture a significant share of the emerging biotech global market. Shuman sees, "real promise."

Others were less optimistic about biotechnology's future in Minnesota. Paul Citron, vice president of science and technology for Medtronic Inc., noted, "biotech and medical devices are distinct technologies converging in some clinically relevant cases." Citron added that biotechnology currently enjoys a "nationwide fervor." If the public and private sectors took careful and coordinated steps to grow biotechnology, especially where it complements the established device industry in our state, then "biotech could be very significant here," as it would leverage this region's position in medical technology.

However, asked whether or not biotech *would* emerge into a significant factor in Minnesota, Citron was less than optimistic. He owed his pessimism to several factors, chief among them the extreme challenge of successfully coordinating a public-private development effort during an economic downturn. Citron also cited a lack of "critical mass of talent, [public] horsepower, and venture capital," as impediments to the growth of a strong biotechnology sector in Minnesota. "They aren't here," said Citron, and the lack of those elements make the probability of biotech enjoying a hub status "relatively low" in view of what's happening elsewhere.

In speaking about industries other than biotechnology, Tony Christianson, managing partner of Cherry Tree Investments Inc., described "several new competencies" in Minnesota. Christianson was excited about the growth of niche technologies in Minnesota, including health information systems and educational information systems. He and other venture capitalists are watching Minnesota companies that provide enabling software in these industries and they are optimistic about the growth potential.

We talked further about the future of IT in Minnesota with President and CEO of Ciprico, Bob Kill. Ciprico is involved in software production and light manufacturing of sophisticated hardware components. As such, Kill benefits from a view of both sides of the IT fence. He said Minnesota has always been very good at *applying* rather than developing technology. Kill said that in the future, Minnesota could maintain a healthy IT industry by focusing on doing what it does best—being a leader in applying information technologies.

CATALYTIC FIRMS

Homegrown firms like 3M, Medtronic, Honeywell, and in its day, Control Data, contributed to technology's success in Minnesota. Companies of their ilk generated the financial resources, research capacity, entrepreneurialism, and business savvy that enabled technology to perpetuate. Many second, third, and even fourth generation Minnesota companies trace their roots to some of Minnesota's technology giants. A 1999 *Star Tribune* article attested to the impact of these catalytic firms in Minnesota, noting that over "70 [spin-offs] can trace their roots to Control Data."[10] Minnesota's catalytic technology firms and subsequent spin-offs were widely discussed by panel members.

To some, the successor to the Control Datas, Medtronics, 3Ms, and Honeywells of Minnesota is not on the horizon. Dale Olseth, current CEO of Surmodics and former chairman and CEO of Medtronic, said as much. As recently as two years ago, Olseth saw some catalytic firm candidates emerging in telecommunications. It looked "like it was going to happen in the telecom industry, but the economy and the [telecom] slowdown" makes it less likely.

[10] "The Control Data Legacy: More Than 70 Businesses Trace Roots to Company." *Minneapolis Star Tribune*, 3 June 1992.

Fred Zimmerman, professor of manufacturing at the University of St. Thomas echoed Olseth's comments. Zimmerman said the energy coming from catalytic firms "isn't happening" now and he doesn't foresee it in the future. "There isn't the industrial replacement happening like what was occurring in the sixties and seventies," said Zimmerman.

Some attribute the spin-off predicament to the unavailability of capital in Minnesota. Mac Lewis, managing partner of the venture capital firm Sherpa Partners, pointed to the difficulties of raising money. Lewis suggested that technology entrepreneurs coming out of catalytic firms have difficulty finding the early round dollars necessary to grow a business in Minnesota. In turn, the lack of capital, according to Lewis, contributes to brain drain. Lewis said, "If you have an idea and you're willing to leave the state to get the company started, you leave. You go where the money is."

On the other hand, some panelists saw the issue of catalyst firms in a different light. Karen Arnold, president of Nanomedica, a life sciences firm, was upbeat in her assessment of smaller spin-offs emerging from catalyst firms. Arnold said that spin-offs were not limited to the largest firms in Minnesota. "I see spin-offs coming from large and medium-sized companies," said Arnold.

Ruth Shuman explained that, for the biotechnology industry, the University of Minnesota is the main source of ideas and innovation. However, she is very happy to see companies like Medtronic and 3M thriving in Minnesota. In a broader sense, Shuman said, "Medtronic and other [catalyst firms] provide good economic stimulus for the state." According to Shuman, a healthy overall technology economy benefits Gentra Systems, too.
Some panelists looked at other assets of Minnesota's catalytic firms. Catalyst firms generate wealth. Aside from money raised through investment banks or venture firms, personal wealth amassed from a productive career at a catalyst firm is an important component of spin-off success.

Paul Citron of Medtronic suggested that the dichotomy between Minnesota's social liberalism and business conservatism played havoc with the touchy issue of wealth creation. He explained that, like it or not, wealth creation was an integral part of the innovation cycle—and a region's economic health. Citron suggested that the Minnesota culture often looks upon creating wealth as an undesirable byproduct of corporate success. "The community has to come to grips with its

financial priorities," said Citron. Comparing Massachusetts' and California's reliance on wealth creation to help fund entrepreneurialism, he said, "I don't see them apologizing."

Mac Lewis and Fred Zimmerman shared similar viewpoints. Suggesting that wealth was an important impetus to the entrepreneurial cycle, Lewis said, "We ought to focus on the retention of folks who have the ability to create wealth—upper and middle management." Lewis also observed that too much of the wealth created in Minnesota was funneled out of the state. Zimmerman also placed significant emphasis on the issue of wealth in Minnesota. When asked about the public sector's role in fostering a vibrant technology economy, he said, "the legislature could conduct a study to determine where Minnesota's wealth comes from—and then nurture that wealth."

While much discussion focused on spin-offs, panelists did not ignore the importance of keeping Minnesota's catalytic firms healthy. A frequent theme was the necessity for successful catalytic firms to consistently focus on innovation. Simply, without new products that respond to customers' needs, the panelists contended, a catalytic firm would lose its edge. Many panelists used the demise of Cray and Control Data to illustrate this point.

Bob Kill spoke about learning from past mistakes. He said, "every time [business] gets into a stay-the-course evolution [in product development] we've paid the price." Kill specifically pointed to Cray and Control Data's failure to adequately fund research and development that led to the downfalls.

Echoing Kill's sentiment, Red Heitkamp talked about research and development and the relentless pursuit to innovate as a must for Minnesota's catalytic technology community. Manufacturing companies frequently operate with low profit margins. Despite that obstacle, he said budgeting for "R&D is a must." Heitkamp added that "technology has never been faster in manufacturing than it is now. We've got to compete."

BUSINESS CLIMATE

Conversation about Minnesota's business climate was animated with strong and varied opinions. In speaking about business climate issues, the panelists focused on workforce, education, infrastructure, taxes, networking, and the availability of capital.

Taxes

Five of twelve panelists felt that Minnesota's tax burden detracted from the business climate. At the least, some panelists indicated taxes dampen growth. Bob Kill, for example, suggested that "the public sector should be more cognizant of business taxes." He asserted that, "creating the right [tax] balance could go a long way toward [reducing] Minnesota's image as a high-cost state."

At the worst, some said taxes cause businesses to flee the state. For example, Karen Arnold indicated a disparity in Minnesota's corporate tax code compared to other states. "There is little [tax] incentive [in Minnesota]—no programs that even compare to Pennsylvania, for example." Another business leader thought that Minnesota's tax burden contributed to the "Brain Drain" phenomena. Mac Lewis said, "tax flight plays a role" in technology personnel and companies leaving the state.

The conversation surrounding Minnesota's tax burden was not all negative. One business saw that paying taxes was not such a big drawback. "We don't worry about the state control [over] taxes," said Red Heitkamp, "it's the cost of doing business in Minnesota." Heitkamp went on to explain that the quality of the things his tax revenue supports—an educated workforce and a good infrastructure—made tax-paying more palatable. Fred Zimmerman said taxes "aren't a deterrent" to Minnesota's technology growth. Furthermore, Zimmerman indicated that any problems regarding the corporate tax code in Minnesota were "manageable."

Education

Minnesota's K-12 public education system received substantial praise from the panelists for preparing students for technology careers. Panelists generally felt that students leave Minnesota schools with good abilities in mathematics, communication, and science. However, not all panelists were pleased with public school career counseling. While careers in information technology and the life sciences were deemed valuable career paths by Minnesota school systems, one panelist felt that careers in manufacturing were treated as second-tier. According to Red Heitkamp, "the high school system almost criticizes manufacturing." Heitkamp believes that educators have many misconceptions about careers in manufacturing. He says, "when students and teachers visit our shop they are amazed at [the complexity of the] math we use."

Much of the education conversation focused on the University of Minnesota, Twin Cities. When asked to name positive things about doing business here, for example, several panelists listed the University as one of Minnesota's most precious assets. Karen Arnold cited the breadth of research and the number of spin-offs that emanate from the University as crucial elements of Minnesota's technology success. Echoing that sentiment, Paul Citron at Medtronic described the University as a "pioneer" and a "source of ideas" that has served the Minnesota technology community for many years.

Despite the many positive statements, the University also received criticism. One common criticism regarded the University's handling of research funding. According to Dale Olseth, the University serves a large research funding constituency—the business community, the legislature, faculty and others. With so many interests to serve, Olseth said that funding all the research requests asked of the University is challenging.

Nonetheless, Paul Citron at Medtronic lamented the University's recent research funding decisions. Citron believes that the University has abandoned research in the areas that made the university a great research institution—medicine and medical devices. Instead, Citron contends the University disproportionately devotes research funds to biotechnology—a trendy research area. He believes that the University would be remiss in not maintaining significant research dollars in medical devices—a growth industry in which Minnesota is already a proven leader.

Workforce

Highly praised was the quality of Minnesota's workforce—lauded for its intelligence, skill, loyalty, and work ethic. For example, Bob Kill said of his staff "they [work in concert] with management, help articulate our vision, and achieve our goals. Our company reaps the benefits of their hard work."

Despite the recent economic downturn, Minnesota technology companies still have a worker shortage. The panelists indicated concern regarding filling employment vacancies, especially for skilled labor. However, as Ruth Shuman pointed out, there were other employment needs. Shuman has had difficulty finding qualified management employees in sales and marketing. Red Heitkamp's company has had difficulty filling management positions. "Finding people who really know the business at the executive level is tough," said Heitkamp.

State Economic Development Spending

Opinions differed regarding the state's economic development efforts. Panelists from the advanced manufacturing and information technology sectors were more satisfied than their counterparts in the life sciences.

For example, some panelists from the life sciences pointed out economic development disparities between Minnesota and other competitor states. Don Gearhardt, executive director of Medical Alley, commented on Minnesota and Wisconsin to illustrate his point. In the last biennium budget cycle, Gearhardt said, "Minnesota passed the $10 million BICI (Biomedical Innovation and Commercialization Initiative)—meanwhile Wisconsin just passed the $340 million Biostar initiative that will build a series of state-of-the-art research complexes at the University of Wisconsin." In the long run, he said, Minnesota's economic development spending policies may take a toll on technology industry development and "there are fast growing areas of the country that will challenge Minnesota's [technology market share]."

Venture Capital

The issue of raising venture capital aroused conflicting opinions. The conversation surrounding venture funds primarily focused on availability. Interestingly, the two groups (venture capitalists and business leaders) did not separate into traditional camps where business people all say there's not enough investment money and venture capitalists all say the good deals will get funded. Instead some from each group said that venture capital availability was good. Others—from both groups—said that the venture capital market was dry.

Of greater interest was the importance of seed funding—early round investment by wealthy individuals in amounts typically below $1 million. This early funding enables a company to bridge the gap between infancy and a first round of venture capital financing. Mac Lewis said that there was a current "lack of seed funding in Minnesota." Lewis went on to explain that in conjunction with a seed fund award, the investor typically counsels—on a formal or informal basis—a company through its first years. Lewis noted that the combination of the loss of capital and business know-how is contributing to a current downturn in tech start-up activity.

However, Lewis does envision seed capital investment making a comeback in the near future. He said that gun-shy investors will emerge from the current bust cycle. "Seed money will come back, and with it will be the perception of [Minnesota companies'] financial liquidity."

Networking

Panelists reflected on the "personality" of Minnesota's business community with pride. Red Heitkamp characterized Minnesota's networking opportunities as an important part of the local business infrastructure. "We stay in Minnesota because of the attributes of the metro area—there is an infrastructure of manufacturing companies. We have to outsource technology, the kind of technology that requires a one-on-one interface—we have that interface right here in Minnesota. It would be too difficult to monitor that type of outsourcing activity in California," said Hietkamp. Dale Olseth said that Minnesota had a history of "linking agents" that enabled the technology economy to grow. The University, the health care system, strong families, and the sense of responsibility in large Minnesota companies all contribute to a healthy exchange of ideas, according to Olseth.

Networking was rooted in the timber, food, and later, the IT and life science clusters in Minnesota. Olseth said that there is an "abundance of leaders in the community—that leadership influenced a lot of innovation in the community." Personal relationships not only helped business ideas circulate, but helped communicate the sentiments of business to the Legislature.

CROSSROADS

Based on the panelists' commentary, the Minnesota technology community is at a crossroads. Over all, panelists were cautious about the future, offering reasons to be both optimistic and pessimistic.

The panelists explained that Minnesota has many positive attributes that can contribute to the continued growth of technology. Bob Kill explained his opinion metaphorically, saying, "it's due to the fact that restaurants are cleaner in Minnesota than in New York or California — people give a little bit more [in Minnesota]." Dale Olseth talked about Minnesota's positive attributes on a larger scale. "We're known as a headquarters state—where decisions are made, where resources are allocated, where decisions relative to the future are made, and

where boards [of directors] reside." Olseth said that this national perception lends credence to the fact that Minnesota is a quality technology location for business.

On the other hand, the panelists pointed out that Minnesota has some areas that need improvement. Fred Zimmerman warned about the future of the manufacturing sector in Minnesota. Currently, "there are not enough companies being created and not enough products being developed, [to keep Minnesota in the top tier of manufacturing states]". To illustrate potential problems in the manufacturing sector, he pointed to the Ford plant in St. Paul. "The Ford plant employs 2,500 people, it is 76 years old, and it has business through 2005. If nothing is done [to encourage the Ford Motor Co.] to keep the plant open—it will go away." Zimmerman also cited the recent downsizing at advanced manufacturing companies like Honeywell, 3M, and Hutchinson Technology as other manufacturing-sector harbingers of further decline.

CONCLUSION

Good or bad though the technology economy may be, the panelists almost universally like Minnesota. When asked whether or not they would move their companies to another state, almost all of the panelists answered "no". The panelists see promise in the things that directly affect business—the University, economic development, and a qualified workforce. However, it was often Minnesota's intangibles that kept panelists committed to Minnesota. The outdoors, family culture and clean living are some of Minnesota's best *business* attributes.

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Analysis of Research and Development Activities Funded by the State During FY 2001

Overview of Minnesota Technology's Reporting Guidelines

Under Minnesota Statutes, state agencies and other organizations are required to notify Minnesota Technology, Inc. of any state funds allocated for science and technology research and development.

This reporting requirement applies only to dollars for which the state of Minnesota is the source; funding allocations from private sector or federal sources are excluded.

To help organizations comply with reporting requirements, Minnesota Technology has adopted specific reporting guidelines. These guidelines are described in the manual entitled *Peer Review and Reporting of State Funded Science and Technology Research and Development,* first distributed in August 1989.

Funding organizations are asked to categorize each R&D project they report into one of nine major research areas. These areas are:

- Agriculture & Food Science
- Transportation & Energy Sciences
- Natural Resources
- Environmental Protection & Waste Management
- Computers, Communications and Microelectronics
- Social Science
- Manufacturing & Engineering
- Human Health
- Physical & Natural Science

Further, because economic development and job creation are particularly important public policy goals, reporting organizations are asked to identify those R&D projects having job creation or economic development as an explicit goal.

Reporting Procedures

- When reporting multi-year projects, Minnesota Technology asked funding organizations to list only the amounts they actually intended to disburse in fiscal year 2001. In past years, some organizations have reported the total allocation for a multi-year project in one fiscal year, usually the year in which the project was initiated. Identifying actual per-year allocations for multi-year projects yields a truer picture of

state-origin R&D expenditures in Minnesota. However, this reporting method, introduced in 1994, makes comparisons between funding levels identified in this report and those contained in reports prior to 1994 invalid.

- This report includes only expenditures for *discrete* research and development projects. No non-project-specific allocations (e.g. lump sum allocations for several projects falling within a general research category or state special appropriation) are included. In past years, a number of state specials were listed as individual projects.

Summary of R&D Expenditures in FY 2001[11]

Reporting organizations allocated a total of $31,885,585 in grants, loans and special appropriations for scientific and technological research and development during FY 2001. In all, 629 projects were funded by 13 organizations. A list of all projects funded in FY 2001 is presented at the end of this report.

- The dominant research category was Agriculture & Food Science, which accounted for 54.3 percent of the total reported R&D expended (Table 1). Transportation & Energy Sciences was the next largest category with 15.9 percent of the funding. Other than Natural Resources with 10.7 percent, each of the remaining categories had less than nine percent of the total.

- The largest funding organization by far was the University of Minnesota's Agricultural Experiment Station which supported 301 research projects in six research categories totaling $21.4 million in funding during FY 2001. This comprised two-thirds of all reported funding. The Minnesota Department of Transportation was the second-largest organizational funder of R&D projects, disbursing over $5 million for 115 transportation and energy projects. The greatest variety of research was funded by the University of Minnesota Graduate School which funded 72 projects for a total of $1.3 million in eight different research categories.

[11] Please note that most of the research conducted at the University of Minnesota is not covered by this report. The University receives most of its funds from the federal government (primarily through the National Science Foundation and the National Institutes of Health) and from contracts with private firms. This report provides information solely on funds allocated by the State of Minnesota.

- Only a half-dozen research and development projects supported by state funds are oriented toward economic development as a primary goal. In general, projects tend to support research designed to advance the state of knowledge in a scientific discipline or topical area. Table 3 lists the projects having an economic development goal.[12]

- There were 275 new projects launched in FY 2001 by reporting organizations[2]. Disbursements for these projects totaled $14.3 million.

- Nearly 96% of all projects from reporting organizations[2] underwent some type of peer review process prior to final selection.

- A complete list of all FY 2001 projects appears at the end of the report.

[12] The University of Minnesota did not report whether its projects had economic development as a primary goal, were new this year, or were peer reviewed. University of Minnesota projects are not included in summary statements about these projects.

Table 1.
State-Supported Science and Technology Research and Development Amount of Funding by Research Category - Fiscal Year 2001

Research Category	Major State-Funded Sources[13]	Category Funding (All Sources)	Percent of Total R&D Funding[14]
Agriculture & Food Sciences	Minnesota Agricultural Experiment Station	$17,301,791	54.3
Transportation & Energy Sciences	Minnesota Department of Transportation	$5,059,337	15.9
Natural Resources	Minnesota Agricultural Experiment Station, Minnesota Department of Natural Resources – Division of Lands and Minerals	$3,405,431	10.7
Environmental Protection & Waste Management	Minnesota Agricultural Experiment Station	$2,824,750	8.9
Social Sciences	Minnesota Agricultural Experiment Station, University of Minnesota Graduate School	$1,724,377	5.4
Physical & Natural Sciences	Minnesota Agricultural Experiment Station, University of Minnesota Graduate School	$870,384	2.7
Human Health	University of Minnesota Graduate School	$439,300	1.4
Manufacturing & Engineering Sciences	University of Minnesota Graduate School, Minnesota State University – Winona, Minnesota Technology, Inc. (MIN-Corp.)	$141,708	0.4
Computers, Communications & Microelectronics	University of Minnesota Graduate School	$118,507	0.4
TOTAL		**$31,885,585**	**100.1**

[13] A "major source" is considered a source contributing more than 20% of the funds disbursed in a particular research category. Therefore, a source may be listed for more than one category. For each category, sources are listed in order of reported funding.
[14] The total does not sum to 100.0% due to rounding.

Table 2.
Six R&D Projects in FY 2001
With an Economic Development or Job Creation Goal

Project Title	Recipient(s)	Funding Organization	Amount
Small Business Development Center	Moorhead, MN	Minnesota State University - Moorhead	$51,291
Collaborative Rural Nurse Practitioner	Winona State University, Winona, MN	Minnesota State University - Winona	$16,313
MJSP Red Wing Shoe Co. (MJSP cash contribution)	Winona State University, Winona, MN	Minnesota State University - Winona	$15,003
Measuring & sensoring device for liquid applications	Sensor Measurement, Redwood Falls, MN	Minnesota Technology, Inc. (MIN-Corp.)	$15,000
Ultra-Miniature Transformer and Inductor Design and Manufacturer	BH Electronics Inc.	Minnesota Technology, Inc. (Technology Partnership Fund)	$6,803

Agricultural Utilization Research Institute

Summary by Research Category	FY 2001
Agriculture & Food Science	$ 655,708

Recipient	Project Title	FY 2001
Agra Resources Cooperative	Value Added Soybean Processing—Feasibility and Business Plan	$ 73,469
ARK Bedding Inc.	Poultry Bedding Research Study	$ 10,000
Central MN Ethanol Cooperative	Dry Distillers Grain Soluables (DDGS) and Carp Fertilizer	$ 24,999
Environmental Dust Control	Soybean Soapstock as a Dust Suppressant	$ 5,059
Greener Pasture	Liquid Compost	$ 4,000
Mississippi Topsoil	Composting poultry processing waste into usable topsoil	$ 2,997
MN Canola Council	Impact of Crop Rotation on Canola Diseases	$ 13,078
MN Cultivated Wild	Fusarium Head Blight and Common Waterplantain in Cultivated Wild Rice	$ 13,852
MN Forage and Grasslands	Reducing Insecticide Use in Alfalfa	$ 17,280
MN Hybrid Poplar Research Coop.	Hybrid Poplar Tree Project	$ 200,000
National Sunflower Association	NuSun Diet Study	$ 12,500
North Central Feed Products	Micronutrient Content of Forages in Relation to the Soils on Which They are Produced	$ 410
Northharvest Bean	Integrated Bean Root Rot Management	$ 4,860
Red River Valley Sugar Beet	Determination of the effectiveness of using sugar to produce ethanol.	$ 5,971
Redwood Candle Company	Soybean Candle & Lotion Bars Product Refinement & Market Expansion	$ 79,830
Sustainable Farming	On Farm Pesticide Reduction Strategies	$ 7,980
Sweet Beet, Inc.	Value Added Processing of Sugarbeets Co-products	$ 10,583
University of Minnesota	Ag. Residues for Paper Production	$ 1,364
University of Minnesota	Bio-Based Weed Control in Strawberry Using Sheep Wool Mulch	$ 25,955
University of Minnesota	Controlling Kidney Bean Root Rot	$ 16,335
University of Minnesota	Evaluation of Mechanical Cultivation and Flame Weeding	$ 5,584
University of Minnesota	Highly Refined Cellulose Phase II	$ 47,681
University of Minnesota	Management of Black Vine Weevil, Otiorhynchus Sulcatus	$ 5,249
University of Minnesota	New Pest Management Strategies for Strawberry Growers	$ 7,191
University of Minnesota	Reduce Severity of Wild Rice Diseases	$ 3,000
University of Minnesota	Reducing Pesticide Use for a Flea Beetle	$ 6,918
University of Minnesota	Reducing Pesticide Use in Snap Beans	$ 15,111
University of Minnesota	Reducing Pesticide Use in Sweet Corn Production through Integrated Pest Management	$ 22,619
University of Minnesota	Weed Competitiveness in Sweet Corn	$ 11,834
	Subtotal	$ 655,708

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Minnesota Agricultural Experiment Station

Summary by Research Category	FY 2001
Agriculture & Food Science	$ 15,013,793
Environmental Protection & Waste Management	$ 2,663,558
Natural Resources	$ 1,902,289
Social Science	$ 1,190,368
Physical & Natural Science	$ 582,560
Human Health	$ 61,749

Recipient	Project Title	FY 2001
A Saari Csallany, COAFES - Food Science and Nutrition, St. Paul, MN	Studies on the Secondary Oxidation of Various Lipids and Edible Fats in Vitro and in Vivo	$ 70,924
Alan G Smith, Horticultural Science, St. Paul, MN	Molecular Analysis of Floral Gene Expression	$ 74,648
Alan Ryan Ek, Forest Resources, St. Paul, MN	Modeling and Estimating Forest Regeneration, Growth, and Change	$ 49,937
Alan Stephen Polasky, Applied Economics, St. Paul, MN	Benefits and Costs of Resource Policies Affecting Public and Private Land	$ 4,416
Albert H Markhart, Horticultural Science, St. Paul, MN	Plant and Root Response to Environmental Stress	$ 54,992
Alfredo DiCostanzo, Animal Science, St. Paul, MN	Factors Affecting Biological and Economic Efficiency of the Beef Cattle Enterprise	$ 712,679
Andrew J David, Forest Resources, St. Paul, MN	Development and Implementation of Genetically Improved Aspen	$ 27,131
Andrew J David, Forest Resources, St. Paul, MN	Development of Larch as An Alternative Conifer for Reforestation	$ 9,081
Andrew J David, Forest Resources, St. Paul, MN	Optimization of Forest Genetic Resources Through Integration of Tree Improvement and Silvicultural Processes	$ 180,697
Ann Carla Ziebarth, Design, Housing, & Apparel, St. Paul, MN	Housing and the Rural Workforce	$ 34,400
Ann M Fallon, Entomology, St. Paul, MN	Development of Molecular Approaches to Predicting and Monitoring Insecticide Resistance	$ 110,838
Anne Kapuscinski, Fisheries and Wildlife, St. Paul, MN	Influence of Fisheries Management Practices on Genetic Resources of Fish Populations	$ 18,589
Anuradha Subramanian, Biosystems and Agricultural Engineering, St. Paul, MN	Biosynthesis of PRRS Viral Glycoproteins in Transgenic Animals	$ 40,428
Benham E L Lockhart, Plant Pathology, St. Paul, MN	Diagnosis, Epidemiology and Control of Plant Diseases Caused by Badnaviruses	$ 66,168
Benjamin H Senauer, Applied Economics, St. Paul, MN	Food Demand, Nutrition and Consumer Behavior	$ 45,933
Bert E Stromberg Jr, Veterinary Pathobiology, St. Paul, MN	Control of Animal Parasites in Sustainable Agricultural Systems	$ 14,040
Beverly R Durgan, Agronomy and Plant Genetics, St. Paul, MN	Weed Management Strategies for Small Grain Production Systems	$ 32,874
Billie J Wahlstrom, Rhetoric, St. Paul, MN	Distance by Design: Developing and Implementing An Integrated Plan for Technology Enhanced and Distance Learning in Coafes	$ 32,203
Brian Alwyn Crooker, Animal Science, St. Paul, MN	Regulation of Nutrient Use in Food Producing Animals	$ 418,367
Brian L Buhr, Applied Economics, St. Paul, MN	Economic Analysis of Livestock Industry Marketing, Prices, Production and Policy	$ 87,310
Bruce Nord Wilson, Biosystems and Agricultural Engineering, St. Paul, MN	Development and Application of Comprehensive Agricultural Ecosystem Models	$ 71,438
Burle G Gengenbach, Agronomy and Plant Genetics, St. Paul, MN	Biochemical and Developmental Genetics of Higher Plants	$ 23,976

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Carl Jay Rosen, Soil, Water, & Climate, St. Paul, MN	Improving Plant Nutrient Use Efficiency	$ 190,226
Carlisle Ford Runge, Applied Economics, St. Paul, MN	Environmental and Trade Competitiveness Issues in Agriculture	$ 81,723
Carol Elizabeth Windels, NWROC, Crookston, MN	Biocontrol of Soil-And-Residue-Borne Plant Pathogens	$ 40,100
Carol Elizabeth Windels, NWROC, Crookston, MN	Sugarbeet Disease Control and Fertility Management	$ 301,630
Charles J Clanton, Biosystems and Agricultural Engineering, St. Paul, MN	Agricultural Waste Management-Water Quality Beneath Manure Storages	$ 181,764
Charles Robert Blinn, Forest Resources, St. Paul, MN	Balancing Harvesting Practices and Environmental Protection Needs	$ 24,154
Cheryl F Smith, CHE - Food Science and Nutrition, St. Paul, MN	Examination of Nutritional Status and Dietary Behavior for Minority Populations	$ 57,562
Christian A Thill, Horticultural Science, St. Paul, MN	Breeding Potato Cultivars and Germplasm for Yield, Quality and Disease Resistance	$ 300
Christian A Thill, Horticultural Science, St. Paul, MN	Develop Potato Varieties and Germplasm with Improved Yield, Stability, Quality, Disease Resistance	$ 100,071
Cindy Bow San Tong, Horticultural Science, St. Paul, MN	Changes in Quality of Horticultural Crops During Growth and Storage	$ 45,452
Clive Frank Reece, Soil, Water, & Climate, St. Paul, MN	Water and Solute Transport in the Vadose Zone of Minnesota Outwash Soils: Monitoring and Mechanisms	$ 58,844
Craig Alan Hassel, CHE - Food Science and Nutrition, St. Paul, MN	A Multicultural Investigation of Food as Medicine	$ 24,669
Craig C Sheaffer, Agronomy and Plant Genetics, St. Paul, MN	Forage Protein Characterization and Utilization for Cattle	$ 9,302
Craig C Sheaffer, Agronomy and Plant Genetics, St. Paul, MN	Legumes in Cropping Systems	$ 117,871
Daniel D Gallaher, CHE - Food Science and Nutrition, St. Paul, MN	Role of N-3/N-6 Polyunsaturated Fatty Acids in Health Maintenance	$ 48,988
Daniel F Detzner, Family Social Science, St. Paul, MN	Intergenerational Relationships in Southeast Asian Refugee Families	$ 27,716
Daniel J Philippon, Rhetoric, St. Paul, MN	Rhetoric, Ethics, and the Environment: Case Studies From Minnesota	$ 15,369
Daniel Josep Osullivan, COAFES - Food Science and Nutrition, St. Paul, MN	In Vivo Regulatory Systems in Lactic Acid Bacteria: Bacteriophage Resistance & Bacteriocin Production	$ 67,201
Daniel L Erkkila, Forest Resources, St. Paul, MN	Understanding and Assessing Forest-Based Tourism in Minnesota	$ 64,997
Dario Menanteau, Social Work, St. Paul, MN	Patterns of Adaptation and Acceptance of Hispanics in American Communities	$ 1,736
Dario Menanteau, Social Work, St. Paul, MN	Professionalism Among Social Workers: Linkages Among Family, School, and Community	$ 79,472
David Andow, Entomology, St. Paul, MN	Ecology and Management of European Corn Borer and Other Stalk-Boring Lepidoptera	$ 67,989
David Andow, Entomology, St. Paul, MN	Frequency of Alleles for Resistance to Bacillus Thuringiensis Toxin in European Corn Borer	$ 250
David Andow, Entomology, St. Paul, MN	Natural Enemies and Resistance Management of BTCorn	$ 250
David E Smith, COAFES - Food Science and Nutrition, St. Paul, MN	Physico Chemical Properties of Dairy Macromolecules in Food Systems	$ 95,913
David F Grigal, Soil, Water, & Climate, St. Paul, MN	Sustainability of Forest Production—Soil Physical Properties	$ 1,926
David George Pitt, Landscape Architecture, St. Paul, MN	Design and Evaluation of Sustainable Patterns of Regional Land Use Development	$ 29,671
David H Macdonald, Plant Pathology, St. Paul, MN	Persistence of Heterodera Glycines and Other Regionally Important Nematodes	$ 75
David H Macdonald, Plant Pathology, St. Paul, MN	Soybean Cyst Nematode	$ 21,636
David K Wildung, NCROC, Grand Rapids, MN	Developing Cultural Systems to Improve Horticultural Crop Production	$ 143,675

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
David Willard Ragsdale, Entomology, St. Paul, MN	Aphid Alert: Virus and Vector Surveillance and Management Strategies for Potato	$ 200
David Willard Ragsdale, Entomology, St. Paul, MN	Interference of Late Blight Fungicides with Entomopathogens of Myzus Persicae	$ 135
David Willard Ragsdale, Entomology, St. Paul, MN	Management of Insects and Insect Vectors of Plant Pathogens in Potato	$ 69,429
Delane E Welsch, Applied Economics, St. Paul, MN	Impact Analysis and Decision Strategies for Agricultural Research	$ 8,117
Denise A Guerin, Design, Housing, & Apparel, St. Paul, MN	Development of An Interior Material Rating System for Environmental Conservation	$ 35,294
Deon Dean Stuthman, Agronomy and Plant Genetics, St. Paul, MN	Oat Breeding and Genetics	$ 138,120
Dietmar Walter Rose, Forest Resources, St. Paul, MN	Minnesota's Forested Landscapes: Balancing Productivity and Environmental Quality	$ 41,800
Donald B White, Horticultural Science, St. Paul, MN	The Biology and Utilization of Turfgrasses	$ 70,845
Donald Jiann-Tyng Liu, Applied Economics, St. Paul, MN	An Economic Analysis of U.S. Livestock Sector Facing Demand and Supply Structural Changes	$ 52,516
Dorothy H Anderson, Forest Resources, St. Paul, MN	Environmental, Social & Managerial Conditions Affecting the Quality of Recreation Experience	$ 18,411
Dorothy H Anderson, Forest Resources, St. Paul, MN	Methods and Procedures for Benefits-Based Management of Recreation and Nonrecreation Resources	$ 75,697
Douglas J Weiss, Veterinary Pathobiology, St. Paul, MN	Critical Components of Host Immune Response in Johne'S Disease	$ 32,740
Douglas N Foster, Animal Science, St. Paul, MN	Advanced Technologies for the Genetic Improvement of Poultry	$ 127,687
Earl E McDowell, Rhetoric, St. Paul, MN	Human Communication Practices Related to Teaching Technical Communication	$ 43,598
Edward A Nater, Soil, Water, & Climate, St. Paul, MN	Biogeochemistry and Ecological Risk Management of Trace Chemical Constituents	$ 188,339
Edward B Radcliffe, Entomology, St. Paul, MN	Potato Insects: Biological and Cultural Control	$ 99,743
Eileen V Carey, Forest Resources, St. Paul, MN	Net Primary Productivity and Carbon Sequestration Potential of Lake States Forests	$ 66,970
Elizabeth Anne Dyck, Agronomy and Plant Genetics, St. Paul, MN	Research in Organic Farming Systems in the Northern Corn Belt	$ 18,180
Elizabeth Br Lightfoot, Social Work, St. Paul, MN	Accessibility to Social Service Agencies in Rural Minnesota	$ 20,627
Elizabeth E Davis, Applied Economics, St. Paul, MN	Rural Labor Market Behavior and Outcomes: the Role of Work Support Policies and Economic Changes	$ 16,288
Elizabeth Jane Parks, CHE - Food Science and Nutrition, St. Paul, MN	Quantification of Fatty Acid and Triglyceride Flux	$ 41,111
Elmer Lyle Schmidt, Wood and Paper Science, St. Paul, MN	Reduced Wood Deterioration with Focus on Control and Application of Wood-Inhabiting Fungi	$ 61,683
Emily Esther Hoover, Horticultural Science, St. Paul, MN	Sustainable Production Systems for Fruit Crops	$ 121,411
Ervin Albert Oelke, Agronomy and Plant Genetics, St. Paul, MN	Canola and Wild Rice Production	$ 11,086
Ervin Albert Oelke, Horticultural Science, St. Paul, MN	Center for Alternative Plant and Animal Products	$ 202,795
Federico Ponce de leon, Animal Science, St. Paul, MN	Identification of a Recipient Genome for the Generation of a Chicken Radiation Hybrid Cell Panel	$ 18,598
Francesca J Cuthbert, Fisheries and Wildlife, St. Paul, MN	Geo-Referenced Conservation Databases: Integrating Biodiversity Conservation & Sustainable Development	$ 64,001
Francis L Pfleger, Plant Pathology, St. Paul, MN	Plant Biodiversity: Impact on and Interactions with Arbuscular Mycorrhizal Fungi	$ 36,067
Francisc Diez-Gonzalez, COAFES - Food Science and Nutrition, St. Paul, MN	The Impact of Cattle Diet on the Fecal Shedding of Food-Borne Pathogens	$ 57,063

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Gary A Reineccius, COAFES - Food Science and Nutrition, St. Paul, MN	Controlled Release of Encapsulated Food Flavor	$ 57,784
Gary J Muehlbauer, Agronomy and Plant Genetics, St. Paul, MN	Molecular Genetics of Barley and Wheat	$ 215,833
Gary Lee Malzer, Soil, Water, & Climate, St. Paul, MN	Improving Crop Nutrition and Ground Water Quality Through Efficient Fertilizer Use	$ 85,723
Gary Robert Sands, Biosystems and Agricultural Engineering, St. Paul, MN	Investigating Drainage Design and Management Alternatives for Meeting Both Env. and Agro. Objectives	$ 65,105
George Heimpel, Entomology, St. Paul, MN	Biological Control of Insect Pests in Minnesota: Principles and Implementation	$ 52,878
George Heimpel, Entomology, St. Paul, MN	Insect Response to Plant Diversity: Effects of Weed-Suppressing Cover Crops	$ 180
George R Spangler, Fisheries and Wildlife, St. Paul, MN	Ecology and Management of Fishery Research of Large Lakes	$ 75,589
George W Rehm, Soil, Water, & Climate, St. Paul, MN	Improving Farm Profitability Through More Precise Fertilizer Use	$ 98,833
George Wilson Morse, Applied Economics, St. Paul, MN	Rural Economic Development: Alternatives in the New Competitive Environment	$ 24,568
Georgiana May, Plant Biology, St. Paul, MN	The Genetic Basis of Compatibility Between Corn, Zea Mays, and the Pathogen, Ustilago Maydis	$ 1,090
Gerald C Shurson, Animal Science, St. Paul, MN	Evaluation of New Nutritional Technologies for Situation Dependent Diet Formulation in Swine	$ 551,957
Glenn D Pederson, Applied Economics, St. Paul, MN	Financing Agriculture and Rural America: Issues of Policy, Structure and Technical Change	$ 44,576
Glenn Olger Titrud, Biosystems and Agricultural Engineering, St. Paul, MN	Sand Plain Research Farm-Operations	$ 120,484
Graham Clifford Lamb, NCROC, Grand Rapids, MN	Methods to Increase Reproductive Efficiency in Cattle	$ 161,663
Gregg A Johnson, Agronomy and Plant Genetics, St. Paul, MN	Characterizing Weed Population Variability for Improved Weed Management Decision Support System to Reduce Herbicide Use	$ 89,423
Gregg A Johnson, Agronomy and Plant Genetics, St. Paul, MN	Integrated Weed Management Strategies	$ 92,176
Gregory J Cuomo, WCROC, Morris, MN	Pasture Management/Ecology	$ 275,478
Gyles Wade Randall, Soil, Water, & Climate, St. Paul, MN	Characterizing Nitrogen Mineralization and Availability in Crop Systems to Protect Water Resources	$ 15,193
Hans M Gregersen, Forest Resources, St. Paul, MN	Identifying, Measuring, and Capturing Forest Values in An Economic Context	$ 10,039
Harold D Grotevant, Family Social Science, St. Paul, MN	Relationships in Adoptive Families	$ 52,806
Harold M Pellett, Horticultural Science, St. Paul, MN	Breeding, Evaluation & Selection of Hardy Landscape Plants	$ 107,768
Harold M Pellett, Horticultural Science, St. Paul, MN	Plant Germplasm and Information Management and Utilization	$ 27,489
Helen Q Kivnick, Social Work, St. Paul, MN	Vital Involvement Practice: Promoting Life Strengths Among Frail Elders	$ 28,077
Henry W Schafer III, COAFES - Food Science and Nutrition, St. Paul, MN	Antioxidant and Antimicrobial Properties of Phenolic Compounds From Food Plant Cultivars	$ 1,562
Howard Hoganson, Forest Resources, St. Paul, MN	Economic Modeling Methods for Forestwide Planning and Timber Supply Analysis	$ 150,263
Hugh Chesterjones, SROC, Waseca, MN	Management Systems for Improved Decision Making and Profitability of Dairy Herds	$ 59,242
Ian Vance Macrae, Entomology, St. Paul, MN	Site Specific IPM in Small Grain, Oil Seed, and Sugarbeet Cropping Systems	$ 109,619
Ira Robert Adelman, Fisheries and Wildlife, St. Paul, MN	Effects of Environmental Estrogens on Fish	$ 79,785
J Schottel, Biochemistry, Molecular Biol, & Biophys, St. Paul, MN	Biochemistry and Genetics of Potato Infection by Streptomyces Scabies	$ 6,608

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
James A Perry II, Forest Resources, St. Paul, MN	Management of Forest Water Quality in a Landscape Perspective	$ 22,801
James Alfred Cooper, Fisheries and Wildlife, St. Paul, MN	Ecology, Behavior, and Management of Nuisance Canada Goose Populations	$ 2,628
James Allan Anderson, Agronomy and Plant Genetics, St. Paul, MN	Wheat Breeding and Genetics	$ 430,577
James Angelo Percich, Plant Pathology, St. Paul, MN	Etiology and Management of Soil Borne Pathogens of Vegetable Cropping Systems	$ 142,903
James Angelo Percich, Plant Pathology, St. Paul, MN	Integrated Management of Wild Rice Diseases	$ 88,348
James Crawford Bell, Soil, Water, & Climate, St. Paul, MN	Land Resource Assessment, Interpretation, and Delivery for Minnesota Landscapes	$ 142,356
James Edward Kurle, Plant Pathology, St. Paul, MN	Management and Control of Diseases of Soybeans	$ 23,810
James Gary Linn, Animal Science, St. Paul, MN	Applied Nutrition and Feeding Management of Dairy Cattle	$ 525,349
James Harold Orf, Agronomy and Plant Genetics, St. Paul, MN	Soybean Breeding and Genetics	$ 283,603
James J Luby, Horticultural Science, St. Paul, MN	Breeding & Genetics of Fruit Crops for Cold Climates	$ 262,813
James L Anderson, AES Administration, St. Paul, MN	Agricultural Impacts on Water Quality	$ 77,159
James Louis Bowyer, Wood and Paper Science, St. Paul, MN	Assessment of Changing Raw Material Needs and Life Cycle Environmental Impacts of Alternative Raw Materials	$ 68,128
James R Mickelson, Veterinary Pathobiology, St. Paul, MN	National Animal Genome Research Program	$ 14,766
James Vernon Groth, Plant Pathology, St. Paul, MN	Genetics of Diversity in Obligately Pathogenic Fungi of Agricultural and Native Plants	$ 89,654
James W Maddock, Family Social Science, St. Paul, MN	The Ecology of Sexual Abuse/Violence in Families	$ 9,614
Jane F Gilgun, Social Work, St. Paul, MN	Patterns in the Development of Violent Behaviors	$ 33,465
Jay Steven Coggins, Applied Economics, St. Paul, MN	Market-Based Control of Environmental Quality	$ 29,907
Jean Delores Kinsey, Applied Economics, St. Paul, MN	Economic Impacts of Changing Consumers' Expenditure Patterns on Food, Food Services and Agribusiness	$ 89,728
Jean W Bauer, Family Social Science, St. Paul, MN	Family Economic Well-Being: Self-Sufficiency Goals for Low-Income and Public Assistance Families	$ 34,803
Jean W Bauer, Family Social Science, St. Paul, MN	Rural Low-Income Families: Tracking Well-Being and Functioning in the Context of Welfare Reform	$ 1,852
Jeffrey Dean Apland, Applied Economics, St. Paul, MN	Decision Making for Agricultural Firms Considering Risk and the Environment	$ 32,992
Jeffrey H Gillman, Horticultural Science, St. Paul, MN	Increasing Production Efficiency and Long Term Health of Nursery Grown Crops	$ 38,756
Jeffrey L Edleson, Social Work, St. Paul, MN	Understanding the Links Between Woman Battering and Child Abuse: A Study of Child Protection Cases	$ 49,035
Jeffrey L Gunsolus, Agronomy and Plant Genetics, St. Paul, MN	Weed Management Strategies for Corn and Soybean Production Systems	$ 107,166
Jeffrey R Crump, Design, Housing, & Apparel, St. Paul, MN	Housing Policy in Minnesota	$ 21,377
Jeffrey S Miller, Plant Pathology, St. Paul, MN	Epidemiology of Potato Pathogens	$ 20,047
Jeremiah E Fruin, Applied Economics, St. Paul, MN	Agricultural and Rural Transportation Systems Analysis and Database and Model Development	$ 39
Jeremiah E Fruin, Applied Economics, St. Paul, MN	Competitiveness and Value-Added Markets in the U.S. Grain and Oilseed Industry	$ 36,854
Jerry Beker, Social Work, St. Paul, MN	Studies in Residential Youthwork	$ 34,744
Joann F Lamb, Agronomy and Plant Genetics, St. Paul, MN	Genetics and Breeding of Alfalfa for New Uses, Forage Quality, and Persistence	$ 70,841

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Joanne Bubolz Eicher, Design, Housing, & Apparel, St. Paul, MN	Dress, Identity and Cultural Heritage Among Minnesota Immigrants	$ 48,930
Joanne L Slavin, CHE - Food Science and Nutrition, St. Paul, MN	Defining a Desirable Dietary Fiber Intake	$ 63,168
Jochum Jan Wiersma, Agronomy and Plant Genetics, St. Paul, MN	Small Grains Production and Management	$ 67,615
Joellen Feirtag, COAFES - Food Science and Nutrition, St. Paul, MN	Evaluation, Improvement and Application of ATP Bioluminescence Technology as a Rapid On-Site Method	$ 3,835
John Alexander Lamb, Soil, Water, & Climate, St. Paul, MN	Management of Nutrient Sources in Minnesota Cropping Systems	$ 241,327
John Deen, Veterinary Medicine Administration, St. Paul, MN	Development of Integrated and Sustainable Animal Production Systems	$ 7,455
John E Erwin, Horticultural Science, St. Paul, MN	Impact of Temperature and Light on Flowering	$ 67,581
John F Moncrief, Soil, Water, & Climate, St. Paul, MN	Management of Eroded Soils for Enhancement of Productivity and Environmental Quality	$ 42,529
John F Moncrief, Soil, Water, & Climate, St. Paul, MN	Utilization of Waste for Sustainable Agricultural Production Systems	$ 81,575
John Little Nieber, Biosystems and Agricultural Engineering, St. Paul, MN	Modeling Preferential Flow Processes in Variably-Saturated Porous Media	$ 98,508
John M Shutske, Biosystems and Agricultural Engineering, St. Paul, MN	Injury Prevention and Health Promotion Research for Production Agriculture	$ 25,993
John V Carter, Horticultural Science, St. Paul, MN	Mechanisms of Environmental Stress Resistance & Injury in Plants	$ 7,290
John W Osborn Jr, Animal Science, St. Paul, MN	Nutritional Determinants of Cardiovascular Disease	$ 101,915
Jon F Powell, Plant Pathology, St. Paul, MN	Epidemiology of Turfgrass Diseases	$ 53,460
Jonathan Chaplin, Biosystems and Agricultural Engineering, St. Paul, MN	Development and Testing of Dry Fertilizer Sensors and Machinery for Precision Agriculture	$ 54,365
Jonathan E Wheaton, Animal Science, St. Paul, MN	Hormonal Control, Enhancement and Diagnosis of Ovarian Function in Farm Animals	$ 94,440
Joseph R Sowokinos, Horticultural Science, St. Paul, MN	Biochemical/Molecular Factors Controlling Potato Processing Quality During Growth & Storage	$ 147,356
Kakambi V Nagaraja, Veterinary Pathobiology, St. Paul, MN	Reduce Preharvest Salmonella Enteritidis/Poultry: Fimbrial Protein Based Live Recombinant Vaccine	$ 243
Karen Anne Mesce, Entomology, St. Paul, MN	Regulation of Ecdysis-Producing Neurons in Insects and Other Invertebrates	$ 77,736
Kathryn Kay Rettig, Family Social Science, St. Paul, MN	Decision Making Integral to Relationship-Ending Transitions	$ 32,382
Kenneth Norman Brooks, Forest Resources, St. Paul, MN	Hydrologic Response of Watersheds to Changes in Forest Cover, Agroforestry, Wetlands, and Riparian Systems	$ 58,411
Kenneth R Ostlie, Entomology, St. Paul, MN	Corn Rootworms, Resistant Transgenic Corn and Weedy Grasses: A Recipe for Resistance Evolution?	$ 250
Kenneth R Ostlie, Entomology, St. Paul, MN	Management Strategies for European Corn Borer, Corn Rootworms, and Stand-Reducing Insects in Corn	$ 32,710
Kenneth R Ostlie, Entomology, St. Paul, MN	Population Impacts of Corn Rootworm Control Strategies: Developing Tools for Resistance Management	$ 200
Kenneth William Easter, Applied Economics, St. Paul, MN	The Impact of Land and Water Management Decisions on Minnesota'S People and Their Environment	$ 86,464
Kent D Olson, Applied Economics, St. Paul, MN	Indicators of Financial Viability of Minnesota Family Farms	$ 34,359
Kent Martin Reed, Veterinary Medicine Administration, St. Paul, MN	Enhance Animal Genetic Diversity and Biological Performance	$ 23,911
Keum Hwa Choi, Clinical and Population Sciences, St. Paul, MN	Development of Rapid Detection Method to Screen Generic Species of Foodborne Pathogens in the Vertical Food Chain	$ 11,597
Kevin A Janni, Biosystems and Agricultural Engineering, St. Paul, MN	Environmental and Air Quality Assessment and Control of Livestock Facilities	$ 131,569

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Kevin Paul Smith, Agronomy and Plant Genetics, St. Paul, MN	Barley Breeding and Genetics	$ 213,519
Kewen Yin, Wood and Paper Science, St. Paul, MN	Modeling and Control Using On-Line Data	$ 49,052
Kim Kp Johnson, Design, Housing, & Apparel, St. Paul, MN	Impact of Technology on Rural Consumer Access to Food and Fiber Products	$ 27,589
Klaus J Puettmann, Forest Resources, St. Paul, MN	Management of Mixed Species Forest Stands	$ 22,637
KURT LEONARD, Plant Pathology, St. Paul, MN	Rust Diseases of Cereals	$ 3,611
Larry Dean Jacobson, Biosystems and Agricultural Engineering, St. Paul, MN	Animal Manure and Waste Utilization, Treatment, and Nuisance Avoidance for a Sustainable Agriculture	$ 155,004
Larry L McKay, COAFES - Food Science and Nutrition, St. Paul, MN	Application of Genetic Engineering Techniques for Dairy Starter Culture Improvement	$ 113,888
Laura J Gurak, Rhetoric, St. Paul, MN	A Rhetorical Analysis of Internet Communication: Social and Cultural Implications	$ 325
Lawrence Phili Wackett, Biochemistry, Molecular Biol, & Biophys, St. Paul, MN	Use of NMR Spectroscopy in Agricultural Research	$ 7,452
Leeson James Alexander, Veterinary Medicine Administration, St. Paul, MN	Development of Molecular Diagnostics	$ (2,100)
Leonard C Ferrington, Entomology, St. Paul, MN	Chironomidae as Indicators of Reference Conditions of Aquatic Habitats in North Central Hardwood Forest Region	$ 18,657
Leslie B Hansen, Animal Science, St. Paul, MN	Genetic Enhancement of Health and Survival for Dairy Cattle	$ 421,935
Linda J Brady, CHE - Food Science and Nutrition, St. Paul, MN	Bifidobacteria, Fermentable Carbohydrate, and Colon Health	$ 54,511
Linda Lee Kinkel, Plant Pathology, St. Paul, MN	Ecology of Microbes in Relation to Plant Disease, Biological Control, and Competitive Interactions	$ 63,369
M E Elhalawani, Animal Science, St. Paul, MN	Reproductive Performance of Turkeys	$ 173,142
Marcia Hathaway, Animal Science, St. Paul, MN	The Effect of Growth Factors on the Processes of Skeletal Muscle Growth in Meat-Producing Animals	$ 75,313
Margaretha Ve Rudstrom, Applied Economics, St. Paul, MN	Impacts of Structural Change in the Dairy Industry	$ 98,062
Margaretha Ve Rudstrom, WCROC, Morris, MN	Financial Performance of Rotationally Grazed Dairies in Minnesota	$ 130,551
Marilyn J Bruin, Design, Housing, & Apparel, St. Paul, MN	Housing, Neighborhood, and Community Environments of Low-Resource Families with Young Children	$ 26,304
Marilyn R Delong, Design, Housing, & Apparel, St. Paul, MN	Apparel Products in the 21St Century	$ 71,978
Mark Lee Brenner, Horticultural Science, St. Paul, MN	Role of Endogenous Hormones on Fruit Growth	$ 121
Mark S Umbreit, Social Work, St. Paul, MN	Impact of Restorative Justice	$ 27,395
Mark Stephe Rutherford, Veterinary Medicine Administration, St. Paul, MN	Porcine Reproductive and Respiratory Syndrome (PRRS): Mechanisms of Disease and Methods for the Detection, Protection and Elimination	$ 17,433
Mark W Seeley, Soil, Water, & Climate, St. Paul, MN	Impact Climate and Soils on Crop Selection and Management	$ (14,667)
Mark W Seeley, Soil, Water, & Climate, St. Paul, MN	The Monitoring and Analysis of Climate in the Upper Midwest	$ 26,187
Marla M Reicks, CHE - Food Science and Nutrition, St. Paul, MN	Identification of Factors Predicting Consumption of Selected Dietary Constituents	$ 46,949
Marla S Spivak, Entomology, St. Paul, MN	Behavior, Stock Improvement, and Conservation of Bee Pollinators in Northern Climates	$ 65,115
Marlene Sue Stum, Family Social Science, St. Paul, MN	Health Care Decisions in Later Life: A Family Perspective	$ 35,756
Marshall D Stern, Animal Science, St. Paul, MN	Metabolic Relationships in Supply of Nutrients for Lactating Cows	$ 27,978

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Marshall D Stern, Animal Science, St. Paul, MN	Methods for Achieving Optimal Protein Utilization in Ruminants	$ 148,237
Marvin E Bauer, Forest Resources, St. Paul, MN	Remote Sensing Inputs to Inventory and Analysis of Natural Resources	$ 55,635
Mary H Meyer, Horticultural Science, St. Paul, MN	Using Native and Ornamental Grasses in the Landscape	$ 20,616
Mary M Lay, Rhetoric, St. Paul, MN	Rhetorical and Feminist Analyses of Reproductive Technologies	$ 12,365
Melvin Jay Baughman, Forest Resources, St. Paul, MN	Financial Incentives & Approaches for Management of Nonindustrial Private Forest Lands	$ 3,524
Michael A Schmitt, Soil, Water, & Climate, St. Paul, MN	Nitrogen Fertilizer Management Using Soil Nitrogen Tests and Improved Manure and Legume Management	$ 6,771
Michael E White, Animal Science, St. Paul, MN	Regulation of Factors Affecting Muscle Growth in Meat Animals	$ 118,945
Michael L Baizerman, Social Work, St. Paul, MN	Youth Voluntarism: Developing Youth and Civic Capacity	$ 59,068
Michael Murtaugh, Veterinary Pathobiology, St. Paul, MN	Gene Discovery in Avian Pathogens	$ 9,835
Mindy Susan Kurzer, CHE - Food Science and Nutrition, St. Paul, MN	Dietary Regulation of Sex Hormone Synthesis and Metabolism	$ 55,216
Mitchell S Abrahamsen, Veterinary Pathobiology, St. Paul, MN	Enteric Diseases of Swine and Cattle: Prevention, Control and Food Safety	$ 18,129
Mrinal Bhattacharya, Biosystems and Agricultural Engineering, St. Paul, MN	Improvement of Thermal and Alternative Processes for Foods	$ 42,185
Nancy Jo Ehlke, Agronomy and Plant Genetics, St. Paul, MN	Alternative Forage and Turf Grass Breeding, Genetics and Seed Production	$ 154,532
Nancy Jo Ehlke, Agronomy and Plant Genetics, St. Paul, MN	Forage Crop Genetics and Breeding to Improve Yield and Quality	$ 29,142
Neil Owen Anderson, Horticultural Science, St. Paul, MN	Breeding and Genetics of Floricultural Crops: Old, New Crop Development, Germplasm Enhancement, Invasiveness Potential	$ 173,396
Nevin Dale Young, Genetics, Cell Biology and Development, St. Paul, MN	Plant Molecular Genetics Institute	$ 168,467
Nevin Dale Young, Plant Pathology, St. Paul, MN	Genomics of Cyst Nematode Resistance in Soybean	$ 75,720
Nicholas R Jordan, Agronomy and Plant Genetics, St. Paul, MN	Crop/Weed Ecology of Agricultural Diversification	$ 110,908
Nicholas R Jordan, Agronomy and Plant Genetics, St. Paul, MN	Management Methods to Aid Adoption of Integrated Weed Management	$ 900
Pamela Jane Smith, Applied Economics, St. Paul, MN	International Aspects of Intellectual Property Rights in Agriculture	$ 46,622
Paul B Addis, COAFES - Food Science and Nutrition, St. Paul, MN	Functional Foods: Fiber-and Antioxidant-Enriched Foods	$ 36,686
Paul C Rosenblatt, Family Social Science, St. Paul, MN	Family Systems and Family Realities	$ 33,691
Paul Max Porter, Agronomy and Plant Genetics, St. Paul, MN	Diversifying the Corn-Soybean Cropping System	$ 84,963
Paul Ronald Bloom, Soil, Water, & Climate, St. Paul, MN	Chemistry, Biology and Morphology of Wet Soils	$ 133,695
Paul V Bolstad, Forest Resources, St. Paul, MN	Measuring & Modeling Component & Whole-System Productivity & Co2 Flux at Local to Regional Scales	$ 25,938
Paul Vernon Ellefson, Forest Resources, St. Paul, MN	State Forest Resource Programs: Analysis of Policy Options & Program Administration	$ 54,501
Paul W Glewwe, Applied Economics, St. Paul, MN	Determinants of Education and Nutrition Outcomes in Developing Countries	$ 45,911
Pauline Elsbeth Boss, Family Social Science, St. Paul, MN	Family Boundary Ambiguity in Alzheimer'S Disease and Other Situations of Unclear Loss and Change	$ 30,655
Pen Hsiang Li, Horticultural Science, St. Paul, MN	Plant Cold Hardiness	$ 113,620

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Peter Albion Jordan, Fisheries and Wildlife, St. Paul, MN	Relationships Between Wild Ungulates & Natural Vegetation: Ecological & Management Aspects	$ 14,657
Peter B Reich, Forest Resources, St. Paul, MN	Forest Response to Environmental Change: An Approach to Multiple Interactions	$ 26,628
Peter David Ascher, Horticultural Science, St. Paul, MN	Gene Action in Angiosperms	$ 2,169
Peter David Ascher, Horticultural Science, St. Paul, MN	Genetics and Improvement of Garden Flowers	$ 5,400
Peter H Graham, Soil, Water, & Climate, St. Paul, MN	Improving the Capacity for Nodulation and Nitrogen Fixation of Crop, Pasture and Prairie Legumes	$ 85,387
Peter W Sorensen, Fisheries and Wildlife, St. Paul, MN	Identification and Functional Characterizations of Sex Pheromones in Cyprinid Fish	$ 43,579
Priscilla A Gibson, Social Work, St. Paul, MN	Raising a Vulnerable Generation: African American Grandmother Caregivers Preparing Their Grandchildren to Succeed in the 21St Century	$ 14,314
Ralph W Holzenthal, Entomology, St. Paul, MN	Entomological Systematics and Museum Maintenance Program	$ 147,598
Raymond M Newman, Fisheries and Wildlife, St. Paul, MN	Trophic Relations in Freshwater Systems	$ 58,900
Rex Eugene Lovrien, Biochemistry, Molecular Biol, & Biophys, St. Paul, MN	Enzymology of Forage Processing	$ 17,563
Rex Eugene Lovrien, Biochemistry, Molecular Biol, & Biophys, St. Paul, MN	Gas Chromatography-Mass Spectrometer Operation	$ 75,291
Rex N Bernardo, Agronomy and Plant Genetics, St. Paul, MN	Adaptation of Corn Hybrids	$ 100,317
Richard J Zeyen, Plant Pathology, St. Paul, MN	Cooperative Electron Optics Facility	$ 128,033
Richard J Zeyen, Plant Pathology, St. Paul, MN	Genetic Engineering Cereal Crops for Fungal Disease Resistance	$ 17,243
Robert A Blanchette, Plant Pathology, St. Paul, MN	Biology, Control, and Biotechnological Uses of Forest Microbes	$ 86,829
Robert Allen Stine, Natural Resources Administration, St. Paul, MN	Dynamics, Management, and Sustainable Use of Northern Forest Ecosystems	$ 168,238
Robert J Jones, Agronomy and Plant Genetics, St. Paul, MN	Physiology of Corn Kernel Development	$ 105,856
Robert M Brambl, Plant Biology, St. Paul, MN	Biochemistry of Fungi: the Heat Shock Response	$ 7,868
Robert Philip King, Applied Economics, St. Paul, MN	Management Information Systems for Firms in the Food System	$ 50,009
Roger D Eliason, Soil, Water, & Climate, St. Paul, MN	Elemental Analysis of Biological Materials, Soil, Water and Waste Materials	$ 43,589
Roger D Moon, Entomology, St. Paul, MN	Biology and Management of Muscid Flies Associated with Livestock and Poultry in Minnesota	$ 68,656
Roger Kent Jones, Plant Pathology, St. Paul, MN	Pathology of Small Grains, Sugarbeets, and Potatoes	$ 30,313
Roger Lee Becker, Agronomy and Plant Genetics, St. Paul, MN	Weed Management in Disturbed and Undisturbed Systems	$ 197,329
Ronald L Phillips, Agronomy and Plant Genetics, St. Paul, MN	Molecular Cytogenetics in Plant Improvement	$ 199,269
Rongsheng Ruan, Biosystems and Agricultural Engineering, St. Paul, MN	Advanced Sensing and Control Technology for Biological, Agricultural and Food Engineering	$ 40,065
Royce Gary Fulcher, COAFES - Food Science and Nutrition, St. Paul, MN	Structure/Function Relationships in Cereal Grains and Their Influence on Processing and Quality	$ 22,165
Ruth Dillmacky, Plant Pathology, St. Paul, MN	Management and Control of Diseases in Small Grains	$ 369,338
S Goyal, Veterinary Medicine Administration, St. Paul, MN	Enhance the Health and Well-Being of Animals	$ 65,597
S K Maheswaran, Clinical and Population Sciences, St. Paul, MN	Bovine Respiratory Disease: Risk Factors, Pathogens, Diagnosis and Management	$ 21,965

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Sagar V Krupa, Plant Pathology, St. Paul, MN	Atmospheric Deposition: Transported Versus Local Air Pollutants & Their Effects on Crops	$ 67,793
Sagar V Krupa, Plant Pathology, St. Paul, MN	Characterization and Mechanisms of Plant Responses to Ozone in the Northeastern U.S.	$ 4,002
Sally Noll, Animal Science, St. Paul, MN	Improving Turkey Production Performance	$ 41,974
Sandra K Beeman, Social Work, St. Paul, MN	Social Support, Social Networks, and Family Violence	$ 21,210
Sandra Michele Godden, Clinical and Population Sciences, St. Paul, MN	Effect of Pasteurizing Waste Milk on Health and Performance in Dairy Calves with Emphasis on Johne'S Disease and Salmonellosis	$ 8,519
Satish Chander Gupta, Soil, Water, & Climate, St. Paul, MN	Tillage and Nutrient Source Interactions on Non-Point Source Pollution From Surface and Subsurface Drainage Systems	$ 67,265
Scott Joseph Wells, Clinical and Population Sciences, St. Paul, MN	Use of Molecular Epidemiology to Describe the Clonal Diversity of Mycobacterium Avium Subsp. Paratuberculosis	$ 7,826
Scott M Ogrady, Animal Science, St. Paul, MN	Mechanisms of Ion Transport Across Porcine Endometrium	$ 102,969
Senyu Chen, SROC, Waseca, MN	Managing Plant-Parasitic Nematodes in Sustainable Agriculture with Emphasis on Crop Resistance	$ 169,914
Sharon M Danes, Family Social Science, St. Paul, MN	Family Business Viability in Economically Vulnerable Communities	$ 792
Sharon M Danes, Family Social Science, St. Paul, MN	Family Business: Work and Family Integration	$ 38,527
Simo Sarkanen, Wood and Paper Science, St. Paul, MN	Lignin Biosynthesis, Biodegradation and Derivative Plastics	$ 62,071
Sita R Tatini, COAFES - Food Science and Nutrition, St. Paul, MN	Elimination of Escherichia Coli and Salmonellae From Ready to Consume Acid Foods	$ 71,602
Sridharan Ramaswamy, Wood and Paper Science, St. Paul, MN	Papermaking Processes: Investigations on Optimizing Current Water Removal Processes and Developing New and Improved Processes	$ 53,378
Stanley C Stevens, Applied Economics, St. Paul, MN	Rural Minnesota Grain and Oilseed Price Collection and Analysis	$ 21,334
Steve Robert Simmons, Agronomy and Plant Genetics, St. Paul, MN	Decision Making for Diversified Cropping Systems	$ 27,951
Steven J Seybold, Entomology, St. Paul, MN	Interactions Among Bark Beetles, Pathogens, and Conifers in North American Forests	$ 7,331
Steven James Taff, Applied Economics, St. Paul, MN	Economic Analysis of Limited Property Rights Transfer	$ 24,774
Steven John Severtson, Wood and Paper Science, St. Paul, MN	Development of New Chemistries for Improving the Papermaking Process	$ 79,174
Susan Mar Galatowitsch, Horticultural Science, St. Paul, MN	Restoration of Wetland Vegetation	$ 71,508
Terrance Michae Hurley, Applied Economics, St. Paul, MN	Profitability and Adoption of New Technology and Implications for Agricultural Policy	$ 31,094
Terry Lee Roe, Applied Economics, St. Paul, MN	Private Strategies, Public Policies, and Food System Performance	$ 116,238
Theodore P Labuza, COAFES - Food Science and Nutrition, St. Paul, MN	Physical Chemistry of Foods: Relationships of Water Activity, Temperature and Oxygen to Quality	$ 95,888
Thomas E Burk, Forest Resources, St. Paul, MN	Growth Modeling and Information Delivery Tools for Ecosystem Management	$ 59,140
Thomas F Stinson, Applied Economics, St. Paul, MN	Public Sector Impacts on State Economic Growth	$ 28,126
Timothy J Kurtti, Entomology, St. Paul, MN	Virulence and Host Specificity Mechanisms in Insect Pathogenic Protozoa: Microsporidia	$ 70,628
Timothy M Smith, Wood and Paper Science, St. Paul, MN	Industrial Marketing Communications in the Forest Products Industry	$ 59,791
Ulrike W Tschirner, Wood and Paper Science, St. Paul, MN	Environmentally Friendly Pulping and Bleaching Processes	$ 59,789

Minnesota Agricultural Experiment Station – Continued

Recipient	Project Title	FY 2001
Vera Krischik, Entomology, St. Paul, MN	Resistance Traits in Woody Landscape Plants Against Abiotic and Biotic Stress	$ 33,772
Vernon R Eidman, Applied Economics, St. Paul, MN	Strategic Management of Agribusiness Firms	$ 31,685
Vincent A Fritz, SROC, Waseca, MN	Genetic Manipulation of Sweet Corn Quality and Stress Resistance	$ 19,968
Virginia S Zuiker, Family Social Science, St. Paul, MN	Self Employment Among the United States Hispanic Householders Population	$ 29,026
Walter D Svedarsky, NWROC, Crookston, MN	Management and Landscape Composition Effects on Vegetation and Birds in Northern Tallgrass Prairie	$ 123,850
Willard L Koukkari, Plant Biology, St. Paul, MN	Oscillations in the Response of Plants to Stress Agents	$ 41,347
William A Head, WCROC, Morris, MN	Biological Events that Characterize Ewe/Lamb Production Unit	$ 232,904
William Dale Hutchison, Entomology, St. Paul, MN	Development of Pest Management Strategies for Forage Alfalfa Persistence	$ 2,529
William Dale Hutchison, Entomology, St. Paul, MN	IPM and BTSweet Corn: Efficacy and Benefits to Resistance Management	$ 72,966
William Dale Hutchison, Entomology, St. Paul, MN	Minnesota Pesticide Impact Assessment Program	$ 225
William F Wilcke, Biosystems and Agricultural Engineering, St. Paul, MN	Marketing and Delivery of Quality Cereals and Oilseeds	$ 44,738
William H Bradshaw, Social Work, St. Paul, MN	Bridging the Gap Between Science and Practitioner: the Mental Health Research Dissemination Project	$ 24,599
William J Doherty, Family Social Science, St. Paul, MN	Fathers and Mothers Parenting Together	$ 43,574
William R Dayton, Animal Science, St. Paul, MN	Molecular Mechanisms Regulating Skeletal Muscle Growth and Differentiation	$ 98,366
Yang Da, Animal Science, St. Paul, MN	Genetic Improvement of Cattle Using Molecular Genetic Information	$ 2,491
Yosef Cohen, Fisheries and Wildlife, St. Paul, MN	Growth and Succession in Forested Ecosystem Simulations	$ 83,325
Zata M Vickers, CHE - Food Science and Nutrition, St. Paul, MN	Factors Affecting Food Acceptability and Methods of Assessment	$ 52,008
	Subtotal	$ 21,414,317

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Minnesota Department of Agriculture, Agricultural Development Division

Summary by Research Category	FY 2001
Agriculture & Food Science	$ 741,431

Recipient	Project Title	FY 2001
Andy Hart, Elgin MN	Soil conservation of canning crop fields	$ 9,000
Buckwheat Growers Assoc.	Flour corn as an alternative crop - The benefits of using corn flour	$ 4,500
Carlton County Extension	Pasture aeration and its effects on productivity using a variety of inputs.	$ 7,050
Dakota County SWCD, Farmington, MN	Using Liquid Hog Manure as Starter Fertilizer and Maximizing Nutrients of Bedded Swine Manure	$ 10,800
Dan Miller, Spring Valley, MN	Potassium Rate Trial on an Established Grass/Legume Pasture. Determining Economic Rates	$ 4,464
Dan Persons, Kensington MN	Programmatic approach to pasture renovation for cell grazing	$ 3,760
Dave Minar, New Prague, MN	Potential for Medicinal Plants for Rotational Grazing	$ 4,000
Dave Serfling, Preston, MN	High Value Pork Production for Niman Ranch Using a Modified Swedish System	$ 3,690
Don Reding, Redwood Falls	Viability of wine quality grapes as an alternative crop for the family farm	$ 4,000
Douglas County Extension	Apple bagging	$ 7,150
Faribault County SWCD	Replacing Open Tile Intakes with Rock Inlets in Faribault Cty	$ 4,500
Frank Schiefelbein, Jr, Kimball, MN	Harvesting beef cattle as a sustainable agricultural product	$ 3,025
John Fisher-Merritt, Wrenshall, MN	Rootcellaring and Computer-Controlled Ventilation for Efficient Storage of Organic Vegetables in a Northern Market	$ 5,000
Leo Seykora, Owatonna, MN	Woolly Cupgrass Research	$ 3,000
Linda Ward	Heating and Eating: A Strawbale Greenhouse as a Source of	$ 5,100
Mark Simon, New Prague, MN	High quality - low input forages for winter feeding lactating cows	$ 6,000
Marvin Jenson, Evansville, MN	In-Field Winter Drying and Storage of Corn: An Economic Analysis of Costs and Returns	$ 3,600
Meierhofer Farms, Belgrade, MN	Turkey litter - More is not always better	$ 2,500
Melissa Peteler/Cathy Friend, Zumbrota, MN	Sustainable weed control in a commercial vineyard	$ 1,600
Michael Reese, Hancock, MN	Integrated Demonstration of Native Forb Seed Production	$ 3,600
Nathan Converse, Motley, MN	Development of Eastern Gamagrass Production	$ 2,400
Pat Bailey, Altura, MN	A project to evaluate the benefits of compost teas to the small market gardener	$ 9,150
Patty Dease, South Haven, MN	Development and continuation of a community based sustainable organic growers' coop and marketing system	$ 3,500
Peter Schilling, Gaylord, MN	Adding value for the small producer via natural production methods and direct marketing	$ 3,425
Peter Seim, Ramsey, MN	Adoption of green manure to deter quackgrass and maximize soil temperature and biology	$ 3,300

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Minnesota Department of Agriculture, Agricultural Development Division - Continued

Recipient	Project Title	FY 2001
Ralph Stelling, Millville, MN	Forage Production to maintain a mature animal per acre for 12 months	$ 5,550
Raymond Rauenhorst, Easton, MN	Aerial seeding winter rye into no-till corn and soybeans	$ 5,640
Red Lake County Extension	Niger Project for Northwest MN	$ 3,600
Robert Schelhaas, Edgerton, MN	Mechanical Tillage to Promote Aeration, Improve Water, Infiltration, and Rejuvenate Existing Forage	$ 6,020
Stearns County SWCD, Waite Park, MN	Promotion of Best Management Practices Using a Paired Watershed Demonstration	$ 11,250
Steven Stassen, Kerkhoven, MN	Farrowing: Crates vs. Pens vs. Nestboxes	$ 4,200
University of Minnesota	Can Canola Control Weeds in Strawberry Fields?	$ 4,955
University of Minnesota	Can New Perennial Grasses Extend MN's Grazing Season	$ 22,500
University of Minnesota	Deep zone tillage and crop rotation as an integrated	$ 14,500
University of Minnesota	Enhancements of On-Farm Alfalfa Grazing for Beef and Dairy Heifer Production	$ 11,700
University of Minnesota	Evaluation of IPM Programs Using Expected Utility and Risk Analysis	$ 20, 888
University of Minnesota	Implementing vegetable IPM: Value of on-farm research	$ 25,192
University of Minnesota	New Tools for Apple Scab Decision -Making	$ 1,854
University of Minnesota	Odor Emissions Reduction through Anaerobic Digestion	$ 6,250
University of Minnesota	Organic blueberry production	$ 6,995
University of Minnesota	Reducing livestock/poultry odor and nutrient seepage	$ 272,350
University of Minnesota	Risk Efficiency and Value of Vegetable IPM Programs	$ 15,000
University of Minnesota	Selectin for Pesticide Resistance in Parasitoids of Green Peach Aphid	$ 7,404
University of Minnesota	Soil quality and rainfall simulation	$ 1,829
University of Minnesota	Stakeholders feedlot air quality monitoring project	$ 54,000
University of Minnesota	Sustainable agriculture information exchange	$ 117,600
University of Minnesota	Wool Mulching Systems for Specialty Crops	$ 14,378
Wabasha County SWCD	Manure Calibration and Demonstration	$ 8,550
Wright County Extension	Biological seeding of legumes through horses	$ 2,000
	Subtotal	$ 741,431

Minnesota Department of Natural Resources, Division of Lands and Minerals

Summary by Research Category	FY 2001
Natural Resources	$ 860,234

Recipient	Project Title	FY 2001
Cliffs Mining Services	Borehole Geophysics	$ 27,500
Cliffs Mining Services	Testing of Fine Screening Devices	$ 18,500
David Hopstock	Ore Liberation	$ 21,072
In-house research	Hydrology of Pit Mergers	$ 66,419
National Steel Pellet Co	Quantifying Greenball Oversize	$ 9,600
University of Minnesota	Aggregate Mapping (MGS)	$ 29,504
University of Minnesota	Bedrock Geology Eagle's Nest	$ 55,684
University of Minnesota	Chemistry of Agglomeration—Phase II	$ 28,184
University of Minnesota	Chemistry of Agglomeration—Phase III	$ 65,196

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Minnesota Department of Natural Resources, Division of Lands and Minerals **- Continued**

Recipient	Project Title	FY 2001
University of Minnesota	Drilling Data—Phase II	$ 67,392
University of Minnesota	Duluth Complex Geology and Potential	$ 66,216
University of Minnesota	Duluth Complex Mineral Separations	$ 21,710
University of Minnesota	Ilmenite Processing High Pressure Rolls	$ 6,800
University of Minnesota	Indexing of Mineral Exploration Data (MGS)	$ 36,217
University of Minnesota	Industrial Mineral Technical Reference	$ 24,785
University of Minnesota	Mercury Removal Using Wet Scrubbers and Minerals	$ 17,773
University of Minnesota	Oxidized Taconite—Itasca County	$ 20,269
University of Minnesota	Preparation of Certified Mercury Standards	$ 17,882
University of Minnesota	Relationship of PGEs & Stratigraphy	$ 55,155
University of Minnesota	Simulation Center—Phase III	$ 102,536
University of Minnesota	Static Liquifaction	$ 6,509
University of Minnesota	Valuation of State Owned Land in BWCA	$ 28,081
University of Minnesota	VMS Occurrences Vermilion District	$ 67,251
	Subtotal	$ 860,234

Minnesota Department of Natural Resources, Fisheries Division

Summary by Research Category	FY 2001
Natural Resources	$ 290,064

Recipient	Project Title	FY 2001
Dr. Anne Kapuscinski, University of Minnesota, St. Paul, MN	Diagnostic Genetic Markers at the Species and Subspecies Level	$ 30,000
Dr. David Fulton and Dr. Bruce Vondracek, University of Minnesota, St. Paul, MN	Constraints and Opportunities for Quality Trout Angling Experiences in Southeastern Minnesota	$ 95,064
Dr. David Fulton and Dr. William Gartner, University of Minnesota, St. Paul, MN	The Economic Impact and Social Benefits of Cold Water Angling in Minnesota	$ 50,000
Dr. David Fulton, University of Minnesota, St. Paul, MN	Evaluating Decision-Processes: Case Studies of Fisheries Issues	$ 25,000
Dr. David Fulton, University of Minnesota, St. Paul, MN	Trends on Fisheries Issues in Minnesota	$ 30,000
Dr. David Willis, South Dakota State University, Brookings, SD	Food Habits of Young-of-the-year Walleye	$ 11,500
Dr. George Spangler University of Minnesota St. Paul, MN	A Proposal to Evaluate the Restoration of Fishery Productivity to Red Lakes, Minnesota	$ 18,000
Dr. Malcom Butler, North Dakota State University, Fargo, ND	Population Studies of Aquatic Macroinvertebrates and Aquatic Macrophytes	$ 10,500
Dr. Ray Newman, University of Minnesota, St. Paul, MN	Effects of Forest Harvest Practices on Fish Communities and Population in Logged and Unlogged Reaches of Coldwater Streams	$ 7,000
Dr. S. Weisburg, University of Minnesota, St. Paul, MN	Statistical Consulting	$ 13,000
	Subtotal	$ 290,064

Minnesota Department of Natural Resources, Forestry Division

Summary by Research Category	FY 2001
Natural Resources	$ 328,900

Recipient	Project Title	FY 2001
Andrew David, North Central Research and Outreach Center,Grand Rapids, MN	White Pine Blister Rust	$ 120,800
JoAnn Hanowski and Gerald Niemi, NRRI	Wildlife Species: Response to Forest Harvesting and Management in Riparian Stands and Landscapes.	$ 55,700
Lee Frelich, University of Minnesota, St. Paul, MN	White Pine Natural Regeneration	$ 45,500
Alan Ek, University of Minnesota, St. Paul, MN	Urban and Community Forestry Program	$ 37,500
Klaus Puettmann, University of Minnesota, St. Paul, MN	Impact of Harvesting on Regeneration, Productivity, and Floristic Diversity of Quaking Aspen and Northern Hardwoods	$ 25,500
Jim Perry and Charlie Blinn, University of Minnesota, St. Paul, MN	Riparian Area Dynamics	$ 21,500
Steven Seybold, University of Minnesota, St. Paul, MN	Spruce Budworm Populations and Damage	$ 13,000
Klaus Puettmann, University of Minnesota, St. Paul, MN	White Pine Regeneration and Outreach	$ 5,000
	Subtotal	$ 328,900

Minnesota Department of Transportation

Summary by Research Category	FY 2001
Transportation & Energy	$ 5,052,534

Recipient	Project Title	FY 2001
Advanced Inform Consultant	Mn/DOT Library Cataloging	$ 630
Castle Rock Consultants	INV744: Local Road Research Board Web Site Maintenance	$ 500
Castle Rock Consultants	Local Road Research Board (LRRB) Web Site Enhancements	$ 42,000
Charles Jahren	Best Practices for Maintaining and Upgrading Aggregate Roads in Australia	$ 3,334
Dan Krivit and Associates	"Recycled Glass and Shingles" Presentation	$ 500
Dan Krivit and Associates	Using Scrap Shingles as a Road Construction Material - Implementation and Expansion	$ 4,083
Darlene Gorrill	Editing/Writing Services	$ 43,900
Darlene Gorrill	LRRB Outreach Activities	$ 9,950
Darlene Gorrill	Preparation of Mn/DOT's 1999-2000 Transportation Research Biennial Report	$ 3,925
Darlene Gorrill	Spring Load Restrictions Brochure	$ 2,950
Dawn Mathers	Graphic Design Services for Mn/DOT's 1999-2000 Transportation Research Biennial Report	$ 9,455
Editware	Video Services Section Training	$ 3,100
In-House	Deer/Vehicle Collisions	$ 50,832
Iowa State University	Measuring the Public Value of Aesthetic Considerations	$ 21,348
Iowa State University	Office of Research Services (ORS) Web Site Enhancements	$ 11,875
Kittelson & Associates	INV645: Roundabout Training	$ 22,000
MTE Services, Inc	Mn/ROAD Pavement Mixture Testing	$ 15,800
Parsons Trans. Group Inc.	Major Fork Study	$ 9,765

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Minnesota Department of Transportation - Continued

Recipient	Project Title	FY 2001
Simpson, Gumphertz & Heger	Devlopment of a Research Program for Thermoplastic Culvert Under Highway Vehicle Loading.	$ 14,196
SRF Consulting Group, Inc.	INV645: Implementation of Research Findings (2001-2002)	$ 83,546
SRF Consulting Group, Inc.	INV645: Interactive CD-ROM Development: "Geosynthetics - Use in Streets and Highways"	$ 3,000
Stantec Consulting. Inc.	Pavement Management System (PMS) Maintenance and Support	$ 12,688
Susan Henderson	INV645: Workforce Strategic Planning Summit Follow-up—Enrollment Conference and Luncheon	$ 4,925
The Garrity Group, Inc.	Transportation and Regional Growth Study—Communications Plan and Tools	$ 5,000
Transportation Policy Institute	Opportunities Assessment of External Funding for Research	$ 5,000
University of Florida	Evaluation of Water Flow through Pavement Systems—Phase II	$ 22,500
University of Minnesota	A Survey of Segmental Concrete Block Retaining Walls Along Roads	$ 4,620
University of Minnesota	Agricultural Transportation Database Consortium Support and Extensions	$ 25,146
University of Minnesota	Analysis Tools and Rapid Screening Data for Distortional Fatigue in Steel Bridge Girders	$ 28,700
University of Minnesota	Assistance in Validating the Mn/ROAD Database	$ 20,499
University of Minnesota	Attributes and Amenities of Highway Systems that are Important to Tourists	$ 42,801
University of Minnesota	Building Our Way Out of Congestion? Highway Network Design for the Twin Cities	$ 10,000
University of Minnesota	Calibration of Earth Pressure Cells	$ 4,000
University of Minnesota	Capacity Analysis for Dynamic Bottlenecks and Alternative Concepts for Coordinated Ramp Metering Operations.	$ 2,600
University of Minnesota	Characteristics of Erosion Control Measures and Their Impact on Erosion	$ 40,000
University of Minnesota	Climatological Characterization of Snowfall and Snowdrift in Minnesota	$ 12,400
University of Minnesota	Context-Sensitive Design Curriculum Development and Training	$ 3,600
University of Minnesota	Context—Sensitive Design Training	$ 165,850
University of Minnesota	Delineation of the Stiff Layer and Groundwater Conditions from FWD Data	$ 42,971
University of Minnesota	Design/Development Principles for Livable Suburban Arterial Roadways	$ 4,800
University of Minnesota	Driver Behavioral Response in Incipient Accident Conditions - Phase II	$ 1,180
University of Minnesota	Dynamic Estimation of Freeway Weaving Capacity for Traffic Management and Operations—Phase II	$ 10,625
University of Minnesota	Effect of Increasing Truck Weight on Steel and Prestressed Bridges	$ 200,000

Minnesota Department of Transportation - Continued

Recipient	Project Title	FY 2001
University of Minnesota	Effects of Vision Enhancement Systems (VES) on Older Drivers' Ability to Drive Safely at Night & in Inclement Weather	$ 400
University of Minnesota	Employment of the Traffic Management Laboratory (TRAMLAB) for Evaluating Ramp Control Strategies in the Twin Cities	$ 106,000
University of Minnesota	Enhanced Portable Device for Subgrade and Granular Base Characterization	$ 41,637
University of Minnesota	Environmental Hazard Assessment for Transportation Related Chemicals	$ 76,791
University of Minnesota	Experimental Investigation of the Effect of Vertical Pre-Release Cracks in Prestressed Bridge Girders, Phase II	$ 80,000
University of Minnesota	Fatigue Assessment of Deck Truss of Bridge 9340	$ 5,000
University of Minnesota	Feasibility of a Shipper Panel to Measure Transportation Services	$ 48,179
University of Minnesota	Fine Particle (Nanoparticle) Emissions from Minnesota Transportation	$ 30,000
University of Minnesota	Fine Particle (Nanoparticle) Emissions on Minnesota Highways	$ 15,628
University of Minnesota	GPS-Based Failure Identification System for Intelligent Vehicles	$ 14,750
University of Minnesota	Handling Pedestrian Control Issues at Busy Intersections	$ 6,888
University of Minnesota	Identification of Transportation-Related Barriers Expansion of Minnesota's Share of International Visitation	$ 29,755
University of Minnesota	Image Compression for Storage and Transmission of Digitized Images	$ 7,000
University of Minnesota	Improving the Nodulation and Nitrogen (N2) Fixation of Prairie Legumes Used in Roadside Revegetation in Minnesota	$ 2,344
University of Minnesota	Increasing Native Grass Germination Using Novel Germination Blankets, Soil Treatments, & Cover Crops	$ 28,000
University of Minnesota	Inoculated Legumes and Revegetation/Roadside Plantings	$ 20,659
University of Minnesota	Integration of RTMS and SQL Server to Mn/DOT Next Generation R/WIS	$ 600
University of Minnesota	INV 668: 1998 Minnesota Technology Transfer Program	$ 18,617
University of Minnesota	INV 668: 1999 Minnesota Technology Transfer Program	$ 69,000
University of Minnesota	INV 700(2): Field Investigation of an Integral Abutment Bridge—Phase II	$ 34,000
University of Minnesota	INV 700:Field Performance of an Integral Abutment Bridge	$ 48,336
University of Minnesota	INV 725: Efficary of Erosion Control Blankets and Soil Stabilizers	$ 6,669
University of Minnesota	INV 727: Investigating the Effects of Traffic Calming Strategies on Driver Behavior	$ 15,000
University of Minnesota	INV 747: Best Practices for the Design and Construction of Low Volume Roads	$ 66,000

Minnesota Department of Transportation - Continued

Recipient	Project Title	FY 2001
University of Minnesota	INV668: 2000 Minnesota Technology Transfer (T2) LTAP Program	$ 131,250
University of Minnesota	INV668: 2001 Minnesota Technology Transfer (T2)/LTAP Program	$ 260,701
University of Minnesota	INV733: Vehicle/Pedestrian Collision Model for Neighborhood Traffic Control	$ 2,000
University of Minnesota	INV734: Field Measurement of Granular/Base Drainage Characteristics	$ 43,666
University of Minnesota	INV739: Low Temperature Cracking of Asphalt Concrete Pavements	$ 21,667
University of Minnesota	INV742: Materials Evaluation and Mix Design Procedures for Cold In-Place Recycling of Asphalt Pavements	$ 72,000
University of Minnesota	INV754: Traffic Supplement to Low Volume Road Best Practices Manual	$ 24,997
University of Minnesota	INV757: Designing Pavement Drainage Systems	$ 15,000
University of Minnesota	INV758: Properties and Aggregate Potential of Coarse Taconite Tailings	$ 20,000
University of Minnesota	INV759: Impact of Roughness Elements on Reducing the Shear Stress Acting on Soil Particles	$ 9,000
University of Minnesota	INV760: Reducing Crashes at Controlled Rural Intersections	$ 30,000
University of Minnesota	INV761: Eliminating Driver Forward Blindspots at Rural Intersections	$ 5,000
University of Minnesota	INV763: Effectiveness of In-Lane Rumble Strips	$ 15,000
University of Minnesota	INV764: Investigation of Factors Related to Surface-Initiated Cracks in Flexible Pavements	$ 10,000
University of Minnesota	INV776: Improve the Design of Roadside Ditches to Decrease Transportation-Related Surface Water Pollution	$ 50,000
University of Minnesota	ITS Institute Match Funding	$ 250,000
University of Minnesota	Live Load Stresses in Steel Curved Girder Bridges	$ 13,540
University of Minnesota	Load Testing of Instrumented Pavement Sections	$ 400,000
University of Minnesota	Minnesota Guidestar Support—FY2000-2001	$ 178,850
University of Minnesota	Minnesota Value Pricing	$ 646,500
University of Minnesota	Northstar Workshop "Connecting the Minnesota Safety Agenda"	$ 55,000
University of Minnesota	Operating Costs of Automobiles and Trucks for Economic Analysis	$ 33,359
University of Minnesota	Physical and Mechanical Properties of Innovative Concrete Mixtures	$ 47,585
University of Minnesota	Planning Technical Assistance Program	$ 15,000
University of Minnesota	Population Density and Travel in the U.S. Cities	$ 5,000
University of Minnesota	Reducing Risk Taking at Highway At-Rail Grade Crossings with Supplemental Visual Warnings	$ 15,000
University of Minnesota	Refinement and Validation of the Washington Hydraulic Fracture Test	$ 20,910
University of Minnesota	Signal Operations Research Laboratory for Development and testing of Advanced Control Strategies—Phase II	$ 45,500
University of Minnesota	Sites/Environmental Correlations in Northeastern Minnesota	$ 59,111

Minnesota Department of Transportation - Continued

Recipient	Project Title	FY 2001
University of Minnesota	Testing of PCC Pavement Design and Rehabilitation Features	$ 61,994
University of Minnesota	The Economic Value of Minnesota's Transportation Network	$ 7,297
University of Minnesota	The Effects of Fire Versus Mowing on Prairie Plant Communities	$ 50,000
University of Minnesota	The Value of Time for Freight Movements	$ 15,930
University of Minnesota	Traffic Flow Modeling, Simulation, and Signal Timing Plans Evaluation of the Miller Hill Corridor	$ 2,587
University of Minnesota	Transportation and Regional Growth—Administration	$ 44,530
University of Minnesota	Transportation and Regional Growth— Education/Public Involvement	$ 52,500
University of Minnesota	Transportation and Regional Growth–Part I, Twin Cities Regional Dynamics (Phase I, II, III)	$ 39,513
University of Minnesota	Transportation and Regional Growth–Part III, Full Transportation Costs and Cost Incidence	$ 8,000
University of Minnesota	Transportation and Regional Growth - Part IV, Transportation Financing Alternatives	$ 50,979
University of Minnesota	Transportation and Regional Growth—Part V, Urban Design: Transportation & Urban Growth -Connectivity	$ 67,222
University of Minnesota	Transportation and Regional Growth—Part V, Urban Design: Transportation, Enviroment and Urban Growth: Tansit – Suppo	$ 160,000
University of Minnesota	Transportation Related Costs of Different Regional Land Use Scenarios	$ 29,000
University of Minnesota	Transportation Technologies for Sustainable Communities	$ 62,500
University of Minnesota	Use of Adhesives to Repair Out of Plane Bending at Stiffener to Web Connection	$ 30,612
University of Minnesota	Use of FRP Sheets to Retrofit (Strengthen) Pier Caps	$ 30,000
University of Minnesota	User-Centered Auditory Warning Signals in Snowplows	$ 15,625
University of Minnesota	Wireless Transmission of Image and Video Data	$ 5,000
UW-Madison	Element Unit and Failure Costs and Functional Improvement Costs for Use in the Mn/DOT Pontis Bridge Management System	$ 25,762
	Subtotal	$ 5,052,534

Minnesota Pollution Control Agency

Summary by Research Category	FY 2001
Environmental Protection & Waste Management	$ 145,000

Recipient	Project Title	FY 2001
US Geological Survey	Deformed Frog Research	$ 95,000
US Geological Survey	Emerging Toxics research	$ 50,000
	Subtotal	$ 145,000

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Minnesota Racing Commission

Summary by Research Category	FY 2001
Agriculture & Food Science	$ 805,000

Recipient	Project Title	FY 2001
N/A	University of Minnesota, Clinical & Population Sciences, College of Vet. Medicine	$ 765,000
N/A	MERC	$ 40,000
	Subtotal	$ 805,000

Minnesota State University - Moorhead

Summary by Research Category	FY 2001
Social Science	$ 74,137
Physical & Natural Science	$ 10,668
Human Health	$ 9,384

Recipient	Project Title	FY 2001
Moorhead, MN	Community Training thru Life Routines	$ 80
Moorhead, MN	German Jewish Refugees in Midwest	$ 1,300
Moorhead, MN	Learning By Doing	$ 9,384
Moorhead, MN	Learning By Doing	$ 12,592
Moorhead, MN	MultiCultural Education Preparation	$ 7,007
Moorhead, MN	Pine Point Teacher Preparation	$ 1,867
Moorhead, MN	Small Business Development Center	$ 51,291
Moorhead, MN	Teacher Preparation of Science/Math	$ 763
Moorhead, MN	Teacher Research Network of Science/Math	$ 9,905
	Subtotal	$ 94,189

Minnesota State University - Winona

Summary by Research Category	FY 2001
Human Health	$ 69,725
Manufacturing Engineering	$ 43,349

Recipient	Project Title	FY 2001
Winona State University, Winona, MN	MERC Grant	$ 53,412
Winona State University, Winona, MN	MJSP Red Wing Shoe Co. (Red Wing Shoe Co. cash contribution)	$ 28,346
Winona State University, Winona, MN	Collaborative Rural Nurse Practitioner	$ 16,313
Winona State University, Winona, MN	MJSP Red Wing Shoe Co. (MJSP cash contribution)	$ 15,003
	Subtotal	$ 113,074

MIN-Corp (originally Minnesota Technology, Inc.)

Summary by Research Category		FY 2001
Manufacturing Engineering		$ 33,750
Computers, Communications & Microelectronics		$ 12,500
BrenLin, Herman, MN	Septic tank cover and piping system	$ 18,750
Dayport, Mankato, MN	Software tools to integrate video into web sites	$ 12,500
Sensor Measurement, Redwood Falls, MN	Measuring & sensoring device for liquid applications	$ 15,000
	Subtotal	$ 46,250

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Minnesota Technology, Inc. (Technology Partnership Fund)

Summary by Research Category	FY 2001
Transportation & Energy	$ 6,803

Recipient	Project Title	FY 2001
BH Electronics Inc.	Ultra-Miniature Transformer and Inductor Design and Manufacturer	$ 6,803
	Subtotal	$ 6,803

University of Minnesota, Graduate School

Summary by Research Category	FY 2001
Social Science	$ 459,872
Human Health	$ 298,442
Physical & Natural Science	$ 277,156
Computers, Communications & Microelectronics	$ 106,007
Agriculture & Food Science	$ 85,859
Manufacturing Engineering	$ 64,609
Natural Resources	$ 23,944
Environmental Protection & Waste Management	$ 16,192

Recipient	Project Title	FY 2001
Aerospace Engineering & Mechanics	Simulating turbulent flows in complex geometries	$ 17,527
Agronomy & Plant Genetics	Caribbean, Mexican, and other exotic populations for improving Minnesota corn	$ 17,692
Animal Science	Statistical and computational methods for animal genomics	$ 18,693
Applied Economics	Microeconomic analysis of the determinants of student achievement in primary school in the Philippines	$ 17,992
Astronomy	Assessing the amplitude of lensing-induced quasar-galaxy correlations	$ 16,192
Biochemistry, Medical School	Function of snRNP proteins in splicing	$ 21,512
Biochemistry, Medical School	Pioneer peptide synthesis system	$ 21,250
Biology	Chemical induction of body defenses in the water flea, Daphnia	$ 25,900
Chemical Engineering	Measurement of dispersion in two-dimensional heterogeneous porous media	$ 17,161
Chemical Engineering	Reactivity and thermal stability of electrolytes for lithium batteries	$ 23,000
Chemical Engineering & Materials Science	Coercivity engineering in magnetic heterostructures	$ 16,192
Chemistry	Acquisition of a Purifier Unit for an Inert Atmosphere Glove Box	$ 9,225
Chemistry	High-speed microdialysis assays for novel neuromessengers	$ 17,899
Chemistry	Use of novel substrates to probe the mechanism of Acyl-CoA dehydrogenases	$ 21,250
Chemistry	Watching the nuclear motions that dictate chemical reactions in real time: dipolar and non-dipolar solvation dynamics	$ 16,192
Civil Engineering	Enhanced degradation of chlorinated solvents using surfactants and reducing agents	$ 16,192

University of Minnesota, Graduate School - Continued

Recipient	Project Title	FY 2001
Clinical & Population Sciences	Efficacy and practicality of pasteurizing colostrum as a management tool to control the spread of Johne's disease in Minnesota dairy herds	$ 20,784
Communication Disorders	Speech motor control and spoken word recognition in children with phonological impairments	$ 17,741
Computer Science & Engineering	Efficient representations of formal objects	$ 16,192
Computer Science & Engineering	Self-scaling virtual services	$ 16,192
Cultural Studies & Comparative Literature	Nostalgia and the future: Indian cinema and the politics of sentiment	$ 16,832
Design, Housing & Apparel	Dress and employment issues of somali women refugees	$ 14,232
Economics	Entrepreneurship, default risk, bequests and wealth inequality	$ 16,886
Economics	The economics of innovation: a reappraisal	$ 24,192
Educational Psychology	Meta-analysis of psychometric properties	$ 16,517
Educational Psychology	Native American adolescents' perceptions of parent support	$ 18,992
Educational Psychology	Preliminary analysis of behavioral mechanisms in early aggression	$ 16,192
Electrical & Computer Engineering	Development of a magnetostrictive-Piezoelectric power source for implanable microsystems	$ 24,192
Entomology	Isolation of novel sex-specific, inducible myrcene synthase activity associated with an insect	$ 17,039
Family Practice & Community Health	Structural neuroimaging studies of pedophilia and compulsive sexual behavior	$ 21,243
General College	Salting down composition: intersections of popular and compositional literacy, 1880-1920	$ 8,096
Genetics,Cell Biology & Development/CBS	Regulation of gap junction assembly: function of specific Connexin43 sites	$ 22,525
Geography	Africa's first democrats	$ 26,700
Geological Sciences	Textural and mineralogical evidence for melting in pelitic migmatites, Australia	$ 5,700
History	Before Voltaire: Newtonianism and the birth of the enlightenment in France, 1687-1734	$ 24,142
History	Refugees of the republic: race and nation in the old northwest	$ 25,150
History	Representing the domestic in late imperial China	$ 16,754
History	Sons of the Sierra: Benito Juarez, Porfirio Diaz, and the Zapotee People of Ixtlan Oaxaca, 1855-1911	$ 25,942
History	The transformations of British liberalism 1803-1918	$ 24,474
History	Which way now? Historical paradigms and conflict resolution in Burundi	$ 16,302
Hormel Institute	Flow cytometer	$ 21,250
Hormel Institute	Regulation of cellular N-acylethanolamine levels	$ 19,303
Journalism & Mass Communication	Documentary multimedia: beyond a sum of the parts	$ 26,677
Laboratory Medicine & Pathology	Control of hepatocyte gene expression by cell-matrix and cell-cell adhesion	$ 18,863
Learning Foundations	Software systems in support of high energy physics research	$ 11,875

University of Minnesota, Graduate School - Continued

Recipient	Project Title	FY 2001
Learning Foundations	Teachers' and administrators' perceptions of in-service training regarding parent involvement	$ 17,377
Mathematics & Statistics	Periodic solutions of differential delay equations	$ 16,192
Mechanical Engineering	Direct numerical simulation of turbulent aerosols	$ 16,192
Medicine	Purchase of a flow cytometer remote work station	$ 14,063
Microbiology	Identification and analysis of novel virulence factors in c. albicans	$ 18,275
Neuroscience	Maintenance of stem cells in retina	$ 22,263
Neurosurgery	Encoding of reach-to-grasp in the primary motor cortex	$ 24,413
Nursing	Hmong illness beliefs, behaviors, and care structures	$ 15,818
Nursing	Interactive effects of treatment modality & personal characteristics on health	$ 14,727
Oral Sciences	Analysis of the mechanism of bacterial virus phi29 DNA packaging machine using electron paramagnetic resonance	$ 20,988
Physics & Astronomy	Fluctuation spectroscopy of membrane proteins on the single molecule level	$ 17,167
Physics & Astronomy	Magnetic avalanching with periodic pinning	$ 15,145
Physiology	Molecular physiology of potassium channel gating	$ 26,343
Plant Biology	Identification of functions of higher plant stress proteins	$ 23,944
Plant Biology	Utilization of SPY to identify components of the gibberellin signaling pathway	$ 28,613
Plant Pathology	Assessment of genetic diversity for disease resistance in wild barley	$ 24,985
Political Science	Gender and race in the Cuban revolution	$ 24,796
Public Health	Isolation of escherichia coli from environmental, animal, and human sources in the same geographic area	$ 16,527
Public Health	Nonstationary modelling of spatial datasets	$ 18,863
Rhetoric	Coping with a difficult national past: model and anti-model	$ 5,654
Rhetoric	Virtual peer review: teaching and learning about writing in online environments	$ 9,161
Social Work	Social work with women and girls in historical perspective	$ 8,788
Soil, Water, & Climate	Solute leaching from swine manure applied to a sloping landscape	$ 22,398
Therapeutic Radiology-Radiation Oncology	Physiological factors in hyperthermia	$ 24,561
Veterinary PathoBiology	AngII-neural interactions in cardiovascular control	$ 20,940
Women's Studies	A critical reading of recovered literary Hispanic texts written by women	$ 10,446
Work, Community, & Family Education	The role of human resource development in recruitment advertisements	$ 8,594
	Subtotal	$ 1,332,081
	Grand Total	$ 31,885,585

Appendix

APPENDIX A

A Rankings Snapshot from other Sources

The following is a chart that summarizes rankings, criteria, and bases for rankings for several well-known studies on technology. In all these examples, the studies rank metropolitan areas. The Twin Cites received consistent top ten scores with the notable exception of the Milken Institute study.

Notably, two recent studies conducted by Michigan and Massachusetts—Minnesota's competitors—also recognized Minnesota as a top technology state. "In Benchmarks for the New Michigan" (2002), by the Michigan Economic Development Corporation, Minnesota was ranked as the third most "competitive" state for business. In another example, the Massachusetts Technology Collaborative described Minnesota as a leading technology state along with California, Colorado, Connecticut, New Jersey, and New York in the "Index of the Massachusetts Innovation Economy" (2001).

Comparison of 12 Metro Rankings in Recent High Tech Studies

Organization	U of M, Humphrey Institute	Progressive Policy Institute	Progressive Policy Institute	AEA/NASDAQ	Milken Institute
Author(s)	Markusen, Chapple, Schrock, Yamamoto, Yu	Atkinson, Gottlieb	Atkinson, Gottlieb	--	Devol
Basis for Ranking	Number of High Tech Jobs	Metropolitan New Economy Index	Share of High Tech Jobs	Number of High Tech Jobs	Tech Pole Index
Metro Areas Studied (N)	30	50	50	60	315
Criterion for Inclusion	30 MSAs with fastest absolute job growth 1991-99	Largest Metro Areas (CMSAs)	Largest Metro Areas (CMSAs)	All Metros with 15,000+ HT Jobs	All Metros
Data Used	Economic Census, 1997	Various sources	County Business Patterns, 1997	County Business Patterns, 1998	Bureau of Econ. Analysis, Regional Financial Assoc, 1998
Atlanta	14	11	13	7	10
Austin	18	2	1	16	21
Boston	4	8	4	2	4
Chicago	1	19	15	3	8
Detroit	13	28	33	22	38
Mpls - St Paul	9	10	9	9	32
New York City	5	17	14	8	9
San Diego	15	5	7	21	17
San Francisco	-	1	2	20	22
San Jose	3	*	*	1	1
Seattle	8	3	23	13	5
Washington DC	2	6	8	4	6

* San Jose combined with San Francisco (San Francisco CMSA) for PPI study

Spreadsheet by Ann Markusen, Karen Chapple, Greg Schrock, Daisaku Yamamoto and Pingkang Yu from the University of Minnesota, Humphrey Institute of Public Affairs. Used with Permission.

APPENDIX B

Cyberstates Ranking

Most national comparative rankings for technology are done on a metro basis. However, the American Electronics Association (AEA) publishes a widely read report on state technology rankings, the *Cyberstates* report, as a companion to their *Cybercities* and *CyberEducation* reports.

The *Cyberstates* report uses an employee count in electronics manufacturing (Minnesota ranks 6th,) communication services (Minnesota ranks 21st,) and software services (Minnesota ranks 17th,) to assign technology rankings to the states. From 1994-2000, Minnesota has ranked among the top 13 technology states.

CYBERSTATES RANKINGS

APPENDIX C.2

CYBERSTATES RANKINGS BY HIGH-TECH EMPLOYMENT, 1994 - 2000

	1994	1995	1996	1997	1998	1999	2000
California	1	1	1	1	1	1	1
Texas	3	2	2	2	2	2	2
New York	2	3	3	3	3	3	3
Massachusetts	4	4	5	4	5	4	4
Florida	6	6	6	6	6	5	5
Illinois	5	5	4	5	4	6	6
Virginia	9	9	9	9	9	7	7
New Jersey	7	7	7	7	7	8	8
Pennsylvania	8	8	8	8	8	9	9
Colorado	11	12	12	12	10	10	10
Georgia	13	11	11	10	11	11	11
Ohio	10	10	10	11	12	12	12
Minnesota	12	13	13	13	13	13	13
North Carolina	14	14	14	14	14	14	14
Washington	18	18	17	16	15	15	15

APPENDIX C

Advanced Manufacturing NAICS Descriptions[15]

Engineering, Environmental, and Physiological Testing and Measurement

Medical and Diagnostic Laboratories *NAICS 6215*

This industry comprises establishments known as medical and diagnostic laboratories primarily engaged in providing analytic or diagnostic services, including body fluid analysis and diagnostic imaging, generally to the medical profession or to the patient on referral from a health practitioner.

Testing Laboratories *NAICS 54138*

This industry comprises establishments primarily engaged in performing physical, chemical, and other analytical testing services, such as acoustics or vibration testing, assaying, biological testing (except medical and veterinary), calibration testing, electrical and electronic testing, geotechnical testing, mechanical testing, nondestructive testing, or thermal testing. The testing may occur in a laboratory or on-site.

Research and Development in the Physical, Engineering, and Life Sciences *NAICS 541710*

This industry comprises establishments primarily engaged in conducting research and experimental development in the physical, engineering, or life sciences, such as agriculture, electronics, environmental, biology, botany, biotechnology, computers, chemistry, food, fisheries, forests, geology, health, mathematics, medicine, oceanography, pharmacy, physics, veterinary, and other allied subjects.

Engineering Services *NAICS 541330*

This industry comprises establishments primarily engaged in applying physical laws and principles of engineering in the design, development, and utilization of machines, materials, instruments, structures, processes, and systems. The assignments undertaken by these

[15] Executive Office of the President, Office of Management and Budget. *North American Industry Classification System*, 1997.

establishments may involve any of the following activities: provision of advice, preparation of feasibility studies, preparation of preliminary and final plans and designs, provision of technical services during the construction or installation phase, inspection and evaluation of engineering projects, and related services.

Automation and Manufacturing Technology

Machine Shops *NAICS 33271*

This industry comprises establishments known as machine shops primarily engaged in machining metal parts on a job or order basis. Generally machine shop jobs are low volume using machine tools, such as lathes (including computer numerically controlled); automatic screw machines; and machines for boring, grinding, and milling.

Turned Product and Screw, Nut, and Bolt Manufacturing *NAICS 33272*

This industry comprises establishments primarily engaged in (1) machining precision turned products or (2) manufacturing metal bolts, nuts, screws, rivets, and other industrial fasteners. Included in this industry are establishments primarily engaged manufacturing parts for machinery and equipment on a customized basis.

Precision Turned Product Manufacturing *NAICS 332721*

This industry comprises establishments known as precision turned manufacturers primarily engaged in machining precision products of all materials on a job or order basis. Generally precision turned product jobs are large volume using machines, such as automatic screw machines, rotary transfer machines, computer numerically controlled (CNC) lathes, or turning centers.

Bolt, Nut, Screw, Rivet, and Washer Manufacturing *NAICS 332722*

This industry comprises establishments primarily engaged in manufacturing metal bolts, nuts, screws, rivets, and washers, and other industrial fasteners using machines, such as headers, threaders, and nut forming machines.

Chemicals and Advanced Manufacturing

Basic Chemical Manufacturing *NAICS 3251*

This industry group comprises establishments primarily engaged in manufacturing chemicals using basic processes, such as thermal cracking and distillation. Chemicals manufactured in this industry group are usually separate chemical elements or separate chemically defined compounds.

Petrochemical Manufacturing *NAICS 325110*

This industry comprises establishments primarily engaged in (1) manufacturing acyclic (i.e., aliphatic) hydrocarbons such as ethylene, propylene, and butylene made from refined petroleum or liquid hydrocarbon and/or (2) manufacturing cyclic aromatic hydrocarbons such as benzene, toluene, styrene, xylene, ethyl benzene, and cumene made from refined petroleum or liquid hydrocarbons.

Industrial Gas Manufacturing *NAICS 325120*

This industry comprises establishments primarily engaged in manufacturing industrial organic and inorganic gases in compressed, liquid, and solid forms.

Synthetic Dye and Pigment Manufacturing *NAICS 32513*

This industry comprises establishments primarily engaged in manufacturing synthetic organic and inorganic dyes and pigments, such as lakes and toners (except electrostatic and photographic).

Inorganic Dye and Pigment Manufacturing *NAICS 325131*

This industry comprises establishments primarily engaged in manufacturing inorganic dyes and pigments.

Other Basic Inorganic Chemical Manufacturing *NAICS 32518*

This industry comprises establishments primarily engaged in manufacturing basic inorganic chemicals (except industrial gases and synthetic dyes and pigments).

Alkalies and Chlorine Manufacturing *NAICS 325181*

This industry comprises establishments primarily engaged in manufacturing chlorine, sodium hydroxide (i.e., caustic soda), and other alkalies often using an electrolysis process.

Other Basic Organic Chemical Manufacturing *NAICS 32519*

This industry comprises establishments primarily engaged in manufacturing basic organic chemicals (except petrochemicals, industrial gases, and synthetic dyes and pigments).

Gum and Wood Chemical Manufacturing *NAICS 325191*

This industry comprises establishments primarily engaged in (1) distilling wood or gum into products, such as tall oil and wood distillates, and (2) manufacturing wood or gum chemicals, such as naval stores, natural tanning materials, charcoal briquettes, and charcoal (except activated).

Resin and Synthetic Rubber Manufacturing *NAICS 32521*

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing synthetic resins, plastics materials, and nonvulcanizable elastomers and mixing and blending resins on a custom basis; (2) manufacturing noncustomized synthetic resins; and (3) manufacturing synthetic rubber.

Plastics Material and Resin Manufacturing *NAICS 325211*

This industry comprises establishments primarily engaged in (1) manufacturing resins, plastics materials, and nonvulcanizable thermoplastic elastomers and mixing and blending resins on a custom basis and/or (2) manufacturing noncustomized synthetic resins.

Fertilizer Manufacturing *NAICS 32531*

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing nitrogenous or phosphatic fertilizer materials; (2) manufacturing fertilizers from sewage or animal waste; (3) manufacturing nitrogenous or phosphatic materials and mixing with other ingredients into fertilizers; and (4) mixing ingredients made elsewhere into fertilizers.

Nitrogenous Fertilizer Manufacturing *NAICS 325311*

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing nitrogenous fertilizer materials and mixing ingredients into fertilizers; (2) manufacturing

fertilizers from sewage or animal waste; and (3) manufacturing nitrogenous materials and mixing them into fertilizers.

Paint and Coating Manufacturing *NAICS 325510*

This industry comprises establishments primarily engaged in (1) mixing pigments, solvents, and binders into paints and other coatings, such as stains, varnishes, lacquers, enamels, shellacs, and water repellant coatings for concrete and masonry, and/or (2) manufacturing allied paint products, such as putties, paint and varnish removers, paint brush cleaners, and frit.

Soap and Cleaning Compound Manufacturing *NAICS 32561*

This industry comprises establishments primarily engaged in manufacturing and packaging soap and other cleaning compounds, surface active agents, and textile and leather finishing agents used to reduce tension or speed the drying process.

Soap and Other Detergent Manufacturing *NAICS 325611*

This industry comprises establishments primarily engaged in manufacturing and packaging soaps and other detergents, such as laundry detergents; dishwashing detergents; toothpaste gels, and tooth powders; and natural glycerin.

Other Chemical Product and Preparation Manufacturing *NAICS 3259*

This industry group comprises establishments primarily engaged in manufacturing chemical products (except basic chemicals; resins, synthetic rubber, cellulose and noncellulosic fibers and filaments; pesticides, fertilizers, and other agricultural chemicals; pharmaceuticals and medicines; paints, coatings, and adhesives; soaps and cleaning compounds; and toilet preparations).

Printing Ink Manufacturing *NAICS 325910*

This industry comprises establishments primarily engaged in manufacturing printing and inkjet inks and inkjet cartridges.

Computer and Telecommunications Hardware

Computer and Peripheral Equipment Manufacturing *NAICS 33411*

This industry comprises establishments primarily engaged in manufacturing and/or assembling electronic computers, such as mainframes, personal computers, workstations, laptops, and computer servers; and computer peripheral equipment, such as storage devices, printers, monitors, input/output devices and terminals. Computers can be analog, digital, or hybrid. Digital computers, the most common type, are devices that do all of the following: (1) store the processing program or programs and the data immediately necessary for the execution of the program; (2) can be freely programmed in accordance with the requirements of the user; (3) perform arithmetical computations specified by the user; and (4) execute, without human intervention, a processing program that requires the computer to modify its execution by logical decision during the processing run. Analog computers are capable of simulating mathematical models and comprise at least analog, control, and programming elements.

Electronic Computer Manufacturing *NAICS 334111*

This industry comprises establishments primarily engaged in manufacturing and/or assembling electronic computers, such as mainframes, personal computers, workstations, laptops, and computer servers. Computers can be analog, digital, or hybrid. Digital computers, the most common type, are devices that do all of the following: (1) store the processing program or programs and the data immediately necessary for the execution of the program; (2) can be freely programmed in accordance with the requirements of the user; (3) perform arithmetical computations specified by the user; and (4) execute, without human intervention, a processing program that requires the computer to modify its execution by logical decision during the processing run. Analog computers are capable of simulating mathematical models and contain at least analog, control, and programming elements. The manufacture of computers includes the assembly or integration of processors, coprocessors, memory, storage, and input/output devices into a user-programmable final product.

Computer Storage Device Manufacturing *NAICS 334112*

This industry comprises establishments primarily engaged in manufacturing computer storage devices that allow the storage and retrieval of data from a phase change, magnetic, optical, or magnetic/optical media. Examples of products made by these establishments are CD-ROM drives, floppy disk drives, hard disk drives, and tape storage and backup units.

Computer Terminal Manufacturing *NAICS 334113*

This industry comprises establishments primarily engaged in manufacturing computer terminals. Computer terminals are input/output devices that connect with a central computer for processing.

Other Computer Peripheral Equipment Manufacturing *NAICS 334119*

This industry comprises establishments primarily engaged in manufacturing computer peripheral equipment (except storage devices and computer terminals).

Telephone Apparatus Manufacturing *NAICS 334210*

This industry comprises establishments primarily engaged in manufacturing wire telephone and data communications equipment. These products may be standalone or board-level components of a larger system. Examples of products made by these establishments are central office switching equipment, cordless telephones (except cellular), PBX equipment, telephones, telephone answering machines, and data communications equipment, such as bridges, routers, and gateways.

Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing *NAICS 334220*

This industry comprises establishments primarily engaged in manufacturing radio and television broadcast and wireless communications equipment. Examples of products made by these establishments are: transmitting and receiving antennas, cable television equipment, GPS equipment, pagers, cellular phones, mobile communications equipment, and radio and television studio and broadcasting equipment.

Other Communications Equipment Manufacturing *NAICS 334290*

This industry comprises establishments primarily engaged in manufacturing communications equipment (except telephone apparatus, and radio and television broadcast, and wireless communications equipment).

Electronics and Components

Audio and Video Equipment Manufacturing *NAICS 33431*

This industry comprises establishments primarily engaged in manufacturing electronic audio and video equipment for home entertainment, motor vehicle, public address and musical instrument amplifications. Examples of products made by these establishments are videocassette recorders, televisions, stereo equipment, speaker systems, household-type video cameras, jukeboxes, and amplifiers for musical instruments and public address systems.

Semiconductor and Other Electronic Component Manufacturing *NAICS 33441*

This industry comprises establishments primarily engaged in manufacturing semiconductors and other components for electronic applications. Examples of products made by these establishments are capacitors, resistors, microprocessors, bare and loaded printed circuit boards, electron tubes, electronic connectors, and computer modems.

Electron Tube Manufacturing *NAICS 334411*

This industry comprises establishments primarily engaged in manufacturing electron tubes and parts (except glass blanks). Examples of products made by these establishments are cathode ray tubes (i.e., picture tubes), klystron tubes, magnetron tubes, and traveling wave tubes.

Navigational, Measuring, Electromedical and Control Instruments Manufacturing *NAICS 33451*

This industry comprises establishments primarily engaged in manufacturing navigational, measuring, electromedical, and control instruments. Examples of products made by these establishments are aeronautical instruments, appliance regulators and controls (except switches), laboratory analytical instruments, navigation and guidance systems, and physical properties testing equipment.

Electromedical Instruments Manufacturing *NAICS 334510*

This industry comprises establishments primarily engaged in manufacturing electromedical and electrotherapeutic apparatus, such as magnetic resonance imaging equipment, medical ultrasound

equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment.

Manufacturing and Reproducing Magnetic and Optical Media *NAICS 33461*

This industry comprises establishments primarily engaged in (1) manufacturing optical and magnetic media, such as blank audio tape, blank video tape, and blank diskettes and/or (2) mass duplicating (i.e., making copies) audio, video, software, and other data on magnetic, optical, and similar media.

Software Reproducing *NAICS 334611*

This industry comprises establishments primarily engaged in mass reproducing computer software. These establishments do not generally develop any software, they mass reproduce data and programs on magnetic media, such as diskettes, tapes, or cartridges. Establishments in this industry mass reproduce products, such as CD-ROMs and game cartridges.

Photonics, Optics and Lasers

Optical Instrument and Lens Manufacturing *NAICS 333314*

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing optical instruments and lens, such as binoculars, microscopes (except electron, proton), telescopes, prisms, and lenses (except ophthalmic); (2) coating or polishing lenses (except ophthalmic); and (3) mounting

Photographic and Photocopying Equipment Manufacturing *NAICS 333315*

This industry comprises establishments primarily engaged in manufacturing photographic and photocopying equipment, such as cameras (except television, video, digital projectors, film developing equipment, photocopying equipment, and microfilm equipment).

APPENDIX D

Information Technology NAICS Descriptions[16]

Application Development/IT Services

Computer Systems Design and Related Services *NAICS 5415*

This industry comprises establishments primarily engaged in providing expertise in the field of information technologies through one or more of the following activities: (1) writing, modifying, testing, and supporting software to meet the needs of a particular customer; (2) planning and designing computer systems that integrate computer hardware, software, and communication technologies; (3) on-site management and operation of clients' computer systems and/or data processing facilities; and (4) other professional and technical computer-related advice and services.

Computer Training *NAICS 61142*

This industry comprises establishments primarily engaged in conducting computer training (except computer repair), such as computer programming, software packages, computerized business systems, computer electronics technology, computer operations, and local area network management. Instruction may be provided at the establishment's facilities or at an off-site location, including the client's own facilities.

Data Processing Services *NAICS 5142*

This industry comprises establishments primarily engaged in providing electronic data processing services. These establishments may provide complete processing and preparation of reports from data supplied by customers; specialized services, such as automated data entry services; or may make data processing resources available to clients on an hourly or timesharing basis.

[16] Executive Office of the President, Office of Management and Budget. *North American Industry Classification System*, 1997.

Internet Application and Development

On-Line Information Services *NAICS 514191*

This industry comprises Internet access providers, Internet service providers, and similar establishments primarily engaged in providing direct access through telecommunications networks to computer-held information compiled or published by others.

Software

Software Publishers *NAICS 5112*

This industry comprises establishments primarily engaged in computer software publishing or publishing and reproduction. Establishments in this industry carry out operations necessary for producing and distributing computer software, such as designing, providing documentation, assisting in installation, and providing support services to software purchasers. These establishments may design, develop, and publish, or publish only.

Telecommunications Services

Wired Telecommunications Carriers *NAICS 51331*

This industry comprises establishments engaged in (1) operating and maintaining switching and transmission facilities to provide direct communications via landlines, microwave, or a combination of landlines and satellite linkups or (2) furnishing telegraph and other nonvocal communications using their own facilities.

Wireless Telecommunications Carriers *NAICS 51332*

This industry comprises establishments primarily engaged in operating and maintaining switching and transmission facilities that provide direct communications via airwaves. Included in this industry are establishments providing wireless telecommunications network services, such as cellular telephone or paging services.

Cellular and Paging *NAICS 513321/513322*

This industry comprises establishments primarily engaged in operating cellular telecommunications and paging networks. The establishments

of this industry may also supply and maintain equipment used to receive signals.

Telecommunications Resellers *NAICS 51333*

This industry comprises establishments primarily engaged in purchasing access and network capacity from owners and operators of the networks and reselling wired and wireless telecommunications services to businesses and households. Establishments in this industry resell telecommunications; they do not operate and maintain telecommunications switching and transmission facilities.

APPENDIX E

Life Sciences NAICS Descriptions[17]

Medical Devices and Equipment

Medical Equipment and Supplies Manufacturing *NAICS 33911*

This industry comprises establishments primarily engaged in manufacturing medical equipment and supplies. Examples of products made by these establishments are laboratory apparatus and furniture, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, dentures, and orthodontic appliances.

Surgical and Medical Instrument and Appliance Manufacturing *NAICS 339112/339113*

This industry comprises establishments primarily engaged in manufacturing medical, surgical, ophthalmic, and veterinary instruments, apparatus and appliances. (except electrotherapeutic, electromedical and irradiation apparatus). Examples of products made by these establishments are syringes, hypodermic needles, anesthesia apparatus, blood transfusion equipment, catheters, surgical clamps, and medical thermometers. orthopedic devices, prosthetic appliances, surgical dressings, crutches, surgical sutures, and personal industrial safety devices (except protective eyewear).

Ophthalmic and Dental Goods Manufacturing *NAICS 339115/339116*

This industry comprises establishments primarily engaged in manufacturing ophthalmic goods. Examples of products made by these establishments are prescription eyeglasses (except manufactured in a retail setting), contact lenses, sunglasses, eyeglass frames, dentures, crowns, bridges, and orthodontic appliances customized for individual application and reading glasses made to standard powers.

[17] Executive Office of the President, Office of Management and Budget. *North American Industry Classification System*, 1997.

Electromedical, and Control Instruments Manufacturing *NAICS 334510*

This industry comprises establishments primarily engaged in manufacturing electromedical and electrotherapeutic apparatus, such as magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment.

Analytical Laboratory Instrument Manufacturing *NAICS 334516*

This industry comprises establishments primarily engaged in manufacturing instruments and instrumentation systems for laboratory analysis of the chemical or physical composition or concentration of samples of solid, fluid, gaseous, or composite material.

Pharmaceuticals

Pharmaceutical and Medicine Manufacturing *NAICS 32541*

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing biological and medicinal products; (2) processing (i.e., grading, grinding, and milling) botanical drugs and herbs; (3) isolating active medicinal principals from botanical drugs and herbs; and (4) manufacturing pharmaceutical products intended for internal and external consumption in such forms as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.

Medicinal and Botanical Manufacturing *NAICS 325411*

This industry comprises establishments primarily engaged in (1) manufacturing uncompounded medicinal chemicals and their derivatives (i.e., generally for use by pharmaceutical preparation manufacturers) and/or (2) grading, grinding, and milling uncompounded botanicals.

Pharmaceutical Preparation Manufacturing *NAICS 325412*

This industry comprises establishments primarily engaged in manufacturing in-vivo diagnostic substances and pharmaceutical preparations (except biological) intended for internal and external consumption in dose forms, such as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.

In-Vitro Diagnostic Substance Manufacturing *NAICS 325413*

This industry comprises establishments primarily engaged in manufacturing in-vitro (i.e., not taken internally) diagnostic substances, such as chemical, biological, or radioactive substances. The substances are used for diagnostic tests that are performed in test tubes, petri dishes, machines, and other diagnostic test-type devices.

Biological Product Manufacturing *NAICS 325414*

This industry comprises establishments primarily engaged in manufacturing vaccines, toxoids, blood fractions, and culture media of plant or animal origin (except diagnostic).

Biotechnology

In-Vitro Diagnostic Substance Manufacturing *NAICS 325413*

This industry comprises establishments primarily engaged in manufacturing in-vitro (i.e., not taken internally) diagnostic substances, such as chemical, biological, or radioactive substances. The substances are used for diagnostic tests that are performed in test tubes, petri dishes, machines, and other diagnostic test-type devices.

Biological Product Manufacturing *NAICS 325414*

This industry comprises establishments primarily engaged in manufacturing vaccines, toxoids, blood fractions, and culture media of plant or animal origin (except diagnostic).

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