Technology Alliance

the **economic impact** of technology-based industries in washington state

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may 2010

a **technology alliance** report

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May 2010

A Report Prepared for the
Technology Alliance
Seattle, WA

Executive Summary

Technology-based industries continue to be at the forefront of the development of the Washington economy. They account for the largest share of employment, business activity, and labor income of any major sector in the state's economic base. Other key industries include natural resource-based sectors such as agriculture and food products, forest products, and services including tourism and transportation.

This study defines technology-based businesses as those with a strong proportion of their labor force in research and development (R&D) related occupations. This definition is consistent with recent analyses by the U.S. Bureau of Labor Statistics of measures of "high-tech" industries. In this study, the industries considered to be technology-based or "high-tech" have, with limited exceptions, at least 15.6% of their employment in R&D related occupations, equivalent to twice the state average for all industries. In Washington State in 2009, technology-based industries had an average of 42% of their employment in these occupations. In other industries just 3% of employment was in these occupations.

State of Washington Employment Security Department (ESD) data benchmarked against the last half of the year 2008 and the first half of the year 2009 (herein after referred to as the year 2009) were used to estimate employment industries included in this study. These industries employed 381,546 people in Washington State in the year 2009 (this includes estimates of university and federal research employees; it excludes self-employed people not covered by the ESD). Through multiplier effects, a total of 1.21 million jobs were created due to technology-based industries, which is 41.7% of total covered (non-proprietor) employment in Washington State. Similar percentages of overall Washington State business activity (sales, labor income, and tax revenues) are associated with the industries included in this study.

Economic impacts of industries included in this study are relatively high due to the wages paid in these industries. Technology-based industries support an average of 3.17 jobs for each direct wage and salary job, compared to 2.84 jobs for all industries. Labor income (wages and salaries, supplements to wage and salaries, and proprietors' income) in technology industries averaged $110,145 in 2009, a figure 91% above the state average of $57,654. Technology-based businesses contribute strongly to the export-base of Washington State, as 75% of their sales are out-of-state, compared to an economy-wide average of 40%.

There has been rapid growth in technology-based industries compared to overall economic activity. Employment has expanded from 96,000 private sector jobs in 1974 to 372,110 private sector jobs in 2009, an increase of 296%. This compares to statewide increase in covered employment of 210% over the same time period. In 2009 there were 9,436 public sector and Federal research related jobs in Washington State, bringing total technology-based employment to 381,546. Total technology based employment has grown from 6.7% to 13.2% of total state covered employment over the 1974-2009 time

period, indicating that technology-based industries have made a growing contribution to the economic base of the state.

The concentration of technology-based industries in Washington State is well above the national average. Based on 2007 data, the latest year for which data are available to make national comparisons with the definitions of technology-based industry used in this study, Washington State has employment in these industries 37% above the national average. Our aerospace and software/computer services sectors are the primary contributors to this high index.

If we exclude aerospace – historically our largest technology-based industry and still our largest employer – Washington is 20% above the national average, up from 17% in 2005. Washington's non-aerospace technology-based industries have grown in recent years at a faster pace than those of the nation as a whole. Waste remediation activity in Washington State has a concentration over twice the national average, largely due to activities at Hanford, while research and development has a concentration 40% above the national average. The concentration of technology based industries overall in Washington State increased slightly from the previous Technology Alliance economic impact study released in 2008, from 35% to 37% above the national average.

Research and development expenditures in Washington State, an important indicator of technology-based industry, outpaced the United States over the time since the last study. R&D activity in Washington State as a share of Gross State Product in 2004 was 4.9%, compared with the national average of 2.7%. We have especially strong receipts and expenditures by business and non-profits, while university and college research receipts are similar to the national average. Business accounts for the largest share of R&D dollars in Washington State (84% in 2007). Washington's concentration of total R&D receipts places us 7th in the U.S. in terms of dollars received, and 4th when the size of R&D expenditures is indexed by Gross State Product. Washington's concentration of business R&D and of federally funded research and development centers ranks 4th in the U.S., while we rank 5th in "other non-profits." For comparison, Washington is the 13th most populous state in the United States.

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Acknowledgements

The author would like to express his thanks to the following for their assistance with this study. John Haws and Tim Norris at the Washington State Employment Security Department kindly provided county-level estimates of covered employment for the industries included in this study. Ta-Win Lin at the Washington State Office of Financial Management helped get deflators for use with the 2002 Washington input-output model for the year 2009. Mark Boroush at the National Science Foundation provided more current data on Research and Development at the state level than when this project was undertaken. Kristin Osborne of the Technology Alliance helped with various logistics and copyediting related to this report, and the preparation of a brochure based upon it for use by the Technology Alliance. Derik Andreoli, a graduate student in geography at the University of Washington, helped produce the maps included with this report. I also wish to thank Susannah Malarkey of the Technology Alliance for assistance in conceptualizing the technical approach to this latest study.

I. Introduction

This report is the sixth estimate of the magnitude of employment, business activity, and income stemming from a major segment of the Washington State economy—our technology-based industries—commissioned by the Technology Alliance. A relatively high level of employment in research-related computing, scientific, and engineering occupations is the basis for defining the industries included in this study. While primarily in the private sector, some important segments of these technology-based industries are public employers. All segments generate a significant fraction of their business volume out-of-state, and thereby contribute to the economic base of the state. As a group these industries have been growing rapidly, expanding their contribution to the state economy over the past several decades. They are expected to continue this rapid growth trajectory, and they will likely be an even more important component of the state economy in coming years (Employment Security Department, 2009).

This report documents the growth and development of technology-based industries in the Washington economy up to the year 2009, as well as their impact on the aggregate state economy in the year 2009. Similar studies were released by the Technology Alliance in 1997, 1998, 2001, 2005, and 2008, benchmarked to 1995, 1997, 2000, 2003, and 2007 data, respectively (Beyers and Lindahl 1997; Beyers and Nelson 1998; Beyers and Lindahl 2001; Beyers, Andreoli et al. 2005, Beyers 2008).

Each of these analyses started by defining the industries included in them. This is not an easy task, for terms such as "technology industry," "high technology," and "advanced technology" are frequently used by scholars, the media, political figures, and others interested in this rapidly changing part of our economy. Some of these industries manufacture products, while others are engaged in research that may or may not lead to the production of a product. Some are engaged primarily in long-term research or render services with an ongoing, strong technology factor in their production. It is not easy to define clearly all of the industries that should be considered for inclusion in a study of this type. Section II of this report describes how technology-based industries are defined in this study.

After defining the economic activities covered in this report, and reviewing the importance of research and development activity in the Washington economy, Section III traces the historical development of these industries in Washington State and how their concentration within the state compares to the rest of the nation. As this section documents in detail, the growth of employment in technology-based industries has been steadily shifting, albeit gradually, from a heavy concentration in aerospace to most employment being in service industries. This section also presents information on the geographic distribution of technology-based industries among counties in Washington State, and on the size distribution of technology-based industries in Washington State compared to the U.S. as a whole.

Section IV analyzes the impact of these industries on the Washington State economy. Through the use of the Washington State input-output model, direct and

indirect employment, output, income, and tax effects of technology-based industries are presented. These impacts are then compared to the entire state economy; approximately 42% of total covered employment in Washington State can be attributed to technology-based industries in the year 2009.

II. Defining Technology-Based Industry and Measuring the Importance of R&D Activity in the Washington Economy

Advanced economies continue to have evolution in their economic structure. Through the "Great Recession" we have seen nationally faltering output in many technology-based sectors, as well as the economy as a whole. This report focuses on how the technology based sectors contribute to the Washington economy, and reports longitudinal information on how the contribution of these sectors has changed over time. We know that there has been a shift economy-wide in the composition of what is produced and particularly explosive growth in service-based activities and business activity related to the Internet. The methods by which these goods and services are produced are continually evolving, and there have been changes in the use of labor and capital in the production process.

Each of these dimensions — the mix of industries, the method of production, and the intensity of use of the factors of production — have undergone revolutions in regions such as Washington State, as well as in national economies. As these changes have occurred, industries that are growing and deemed "high technology" have often been singled out as dynamic agents in the process of development in regional economies (Atkinson and Andes 2008; DeVol, Charuworm and Kim 2008). There are numerous challenges involved in defining these industries. Factors considered in alternative definitions of technology-based industries include: the nature of the products or services they produce; characteristics of the production process; the structure of the labor force; the ratio of R&D spending as a fraction of sales revenues; and the length of product life-cycles.

Defining Technology-Based Industry

When the Technology Alliance undertook the first study of the economic impact of technology-based industries, a large amount of time was spent deciding upon how to define the industries covered by the study. The first two reports included an appendix that reviewed historically important studies that are not included in this version of the impact analysis. Those interested in these matters can either contact the Technology Alliance or the author to obtain a copy of the earlier studies that include these appendices. Appendix I in the current study describes briefly definitions used in several recent studies of high-technology industries, to give a flavor of the variety of definitions that have been used in recent years.

The definition of "high-tech" has been made more difficult in a world in which information technologies and other advanced technologies influence the way that business is done in every industry. Fishermen and farmers use essentially the same

computer technologies as computer software makers and manufacturers of semiconductor chips to operate their businesses. So, there can be no question but that the nature of production has been altered by modern technologies across the economy, including the public sector.

The analysis of technology-based industries in Washington State used occupational categories considered as R&D intensive by the National Science Foundation (NSF). Table 1 lists examples of these occupational classifications. There were 95 occupations considered to be R&D related in the Employment Security Department (ESD) industry-x-occupation matrix used to define the industries included in this study.

Table 1 Selected Examples of R&D Intensive Occupations

Standard Occupational Category (SOC)	**Occupational Description**
15-1031	Computer Software Engineers, Applications
15-1032	Computer Software Engineers, Systems Software
15-1051	Computer Systems Analysts
15-2031	Operations Research Analysts
17-1011	Architects, Except Landscape and Naval
17-2031	Biomedical Engineers
17-2161	Nuclear Engineers
17-3025	Environmental Engineering Technicians
19-1042	Medical Scientists, Except Epidemiologists
19-2032	Materials Scientists
19-3022	Survey Researchers
19-4011	Agricultural and Food Science Technicians

While it is the case that all industries in the Washington economy now rely on information technologies and other indicators of technology-intensive industry to a greater or lesser extent, there are significant variations in their commitment to staff who try to cause change in the products and services that they provide through their research and development efforts. This study focuses on the industries that have this commitment, and after considerable deliberation and evaluation of approaches taken in studies in other regions, a measure was used that could be defended—at least 15.6% employment in R&D intensive occupations—for most of the industries included in this study.

A threshold of 10% employment in engineering, scientific, and computer related occupations was chosen in the early Technology Alliance economic impact studies as an indicator of industries with a much higher concentration in occupations likely to be related to R&D activities, a figure consistent with that suggested by the Bureau of Labor Statistics as an indicator of high-technology industry (Hecker 1999). The first three studies used industries defined by Standard Industrial Classification (SIC) categories, using a list developed by ESD showing the proportion of industries' employment in R&D occupations. The 2005 and 2008 studies used a spreadsheet obtained from the ESD website that provided estimates of employment by industry and occupation for the years 2003 and 2006, using the North American Industry Classification System (NAICS) rather than SIC code definitions of industries.

The data in these spreadsheets reported significant increases in total employment in R&D intensive occupations, leading to the decision in the 2008 study to increase the percentage of employment in R&D intensive occupations used to define technology-based industries to 14.6%, equivalent to twice the state average for all industries at that time. It should be noted that the Bureau of Labor Statistics has also observed these same trends in occupational structure, and the role they play in developing their current definitions of technology-based industry (Hecker 2005).

The current study has used a 2008 matrix of employment and occupations provided by ESD (Employment Security Department 2010). This matrix defined industries through the use of the 2007 NAICS codes; these codes are slightly different than the original set of NAICS codes first utilized by the federal government in 1997, and modified in 2002. These redefinitions of the NAICS codes posed some minor difficulties in the estimation of employment by industry by state reported upon in Section III of this report. In a few cases the 2002 NAICS codes separated activities (such as ISP's) that were aggregated with broader categories in the 1997 NAICS, and then these categories were recombined with the 2007 NAICS redefinitions. However, the changes in the NAICS codes are a minor issue compared to the more general matter of drawing comparisons between the NAICS scheme and the SIC codes used in the earlier TA studies, as discussed in Section III.

Shares of employment were calculated for each industry included in the 2008 industry-x-occupation matrix for engineering, scientific and computer related occupations (codes beginning with SOC 15, 17, and 19). These calculations found that 7.81% of total employment in Washington State was estimated to be in these occupations in the year 2008; double this percentage (15.62%) was used as the primary basis for defining technology-based industry in the current study.

A detailed analysis of the distribution of occupations across industries was undertaken to help determine which industries to include in the current study. A measure analogous to the "coefficient of industrial concentration" was used with the state industry-x-occupation matrix to explore which occupations in SOC categories 15, 17, and 19 were broadly distributed across industries, and which were very strongly concentrated in various industries. The expectation was that many of these finely defined occupations would be concentrated in particular industries, while occupations associated with administrative activity would be more widely distributed.

The analysis yielded a much different portrait than expected, with a high degree of concentration in all occupations. Table 2 shows the result, here referred to as "coefficients of occupational concentration." This index takes on a value between 0.0 and 2.0. If an occupation were evenly distributed across all industries, then the index would be zero. If it were all in one industry the index would be two. The data in Table 2 clearly indicate a relatively uneven distribution of the engineering, science, and computer occupations across industries in Washington State. This result led to the conclusion that certain of these occupations should not be excluded from the current definition of technology-based industry, particularly those in occupational categories 15 (computer

science related occupations) that have been the source of much of the employment growth in the three occupational categories presumed to be related to research, which is the hallmark of technology-based industry.

Table 2 Coefficients of Occupational Concentration

15-1 Computer, Database, and Network System Occupations	1.299
15-2 Mathematical Occupations	1.330
17-1 Architects, Cartographers, and Surveyors	1.684
17-2 Engineers	1.418
17-3 Architectural and Engineering Drafters and Technicians	1.410
19-1 Life Scientists	1.432
19-2 Physical Scientists	1.558
19-3 Social Scientists	1.124
19-4 Scientific Technicians	1.436
Average	1.410

The industries that are included in this study after this process of evaluation are listed in Table 3, along with the corresponding percentage of R&D employment. Figure 1 indicates that the majority (66%) of science, computer, and engineering workers are employed in technology-based industries. However, 34% are employed in other industries, the majority in computer-related occupations. Technology-based industries have an average of 41.8% of their workforce in computer, science, and engineering occupations, compared to 3% in other industries in the Washington economy in 2008.

Figure 1 Science and Engineering Jobs in Technology-Based and Other Industries, Washington State 2008

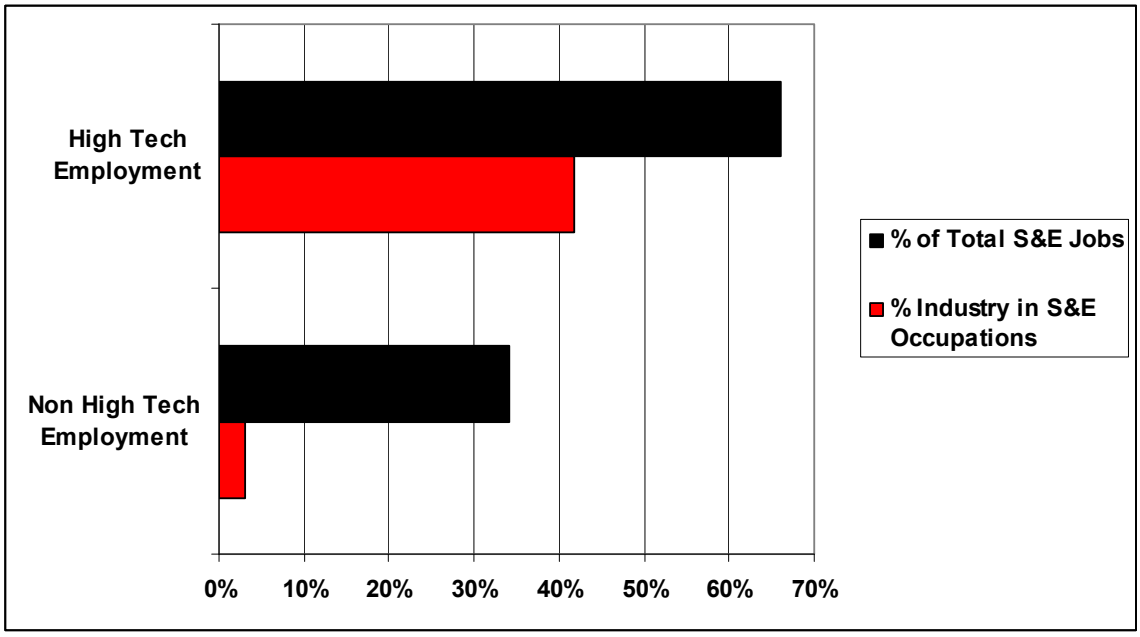

Table 3 Technology-Based Industries in Washington State

NAICS	Industrial Description	%R&D
	Technology-Intensive: R&D Employment Over 30%	
5112	Software Publishers	70.1%
5413	Architectural and Engineering Services	69.8%
5415	Computer Systems Design and Related Services	68.3%
5417	Scientific Research and Development Services	60.6%
5182	Data Processing and Related Services	39.7%
3364	Aerospace	35.2%
5191	Other Information Services	33.7%
	University and Federal Research	(Not covered in ESD data base: see text)
	Other Technology Industries: R&D Employment 11.5%-30%	
334	Computer and Electronics Manufacturing	28.8%
3361	Motor Vehicle Manufacturing	27.6%
5416	Management and Technical Consulting Services	27.2%
4234	Commercial Equipment Merchant Wholesalers	24.0%
517	Telecommunications	19.8%
335	Electrical Equipment	17.4%
325	Chemicals	17.3%
5511	Management of Companies & Enterprises	16.9%
324	Petroleum Refining & Coal Products	16.4%
5629	Remediation and Other Waste Services	15.1%
4541	Electronic Shopping and Mail-Order Houses	13.0%
5622	Waste Treatment and Disposal	11.5%
	All Technology-Based Industries	**41.8%**

Three industries included in Table 3 have less than 15.6% R&D-related employment: electronic shopping and mail-order houses, waste treatment and disposal, and remediation and other waste services. These sectors were included after careful examination of their occupational structure. Electronic shopping and mail-order houses have a very high level of computer-related employment, but relatively small shares of employment in engineering and scientific occupations. Waste treatment and disposal and remediation have relatively high levels of engineering and scientific occupations, but a relatively small share of employment in computer-related occupations.

Two sectors included in the ESD employment-x-occupation matrix had a concentration of employees in research-related occupations, but were excluded from this study. They were the federal government and state government except hospitals, with 21.0% and 16.7% employment in research-related occupations. These two sectors had a large level of employment (55,298 and 63,712, respectively) in this matrix. However, we could not determine what categories of government activity were included in these two sectors, and we have included some activity in government in this study (university research, NOAA, and the Keyport Naval Warfare Research Center). In future studies of this type, it would be useful if the Employment Security Department could categorize the

agency structure of these two sectors, to more precisely isolate where these research-related employees are concentrated.

University and Federal Research

Two categories included in Table 3, university research and federal research organizations, were not defined for inclusion in this study through the use of the industry-x-occupation matrix. University research employment includes full time equivalent (FTE) research-related workers at the University of Washington and Washington State University. The federal research organizations include National Oceanic and Atmospheric Administration (NOAA) agencies in Washington State (except the National Weather Service) and the Naval Undersea Warfare Center at Keyport. Their occupational mix is strongly skewed towards a research and development dominated labor force. In contrast to the measurement of employment for other sectors covered in this study, university research employment measures include only research-related employment. Thus, the teaching, service and extension, housing, fellowship/traineeship, and hospital employment at the two research universities were excluded from employment measures used in this study.

Biotechnology and Medical Technology

Biotechnology and medical technology are not identified separately in the NAICS codes shown in Table 3. Most biotechnology and medical technology employment is encompassed within three NAICS codes included in this study: chemicals manufacturing (NAICS 325), computer and electronic product manufacturing (NAICS 334), and scientific research and development services (NAICS 5417). A portion of medical technology is included in NAICS 3391, an industry that did not meet the criteria for inclusion in this study. The Washington Research Council estimates that 11,609 people were employed in biotechnology and medical technology in Washington State in 2008[1]. Washington Research Council data show 2,490 people employed in drug manufacture (NAICS 3254), 4,127 people employed in electromedical apparatus manufacturing (NAICS 3345), and 2,313 people employed in medical equipment and supplies manufacturing (NAICS 3391). They estimate 2,679 people are employed in biotech research, which is about 14% of total employment in scientific research and development services.

Measuring the Importance of R&D Activity in the Washington Economy

The industries defined in Table 3 with high proportions of their labor force in research and development intensive occupations are also likely to have relatively high proportions of their expenditures on R&D activities. Data from the National Science Foundation (NSF) are reported annually on a wide range of indicators of scientific and engineering effort at the national and state level. Before turning to an historical and comparative account of the importance of employment in technology-based industries in Washington, the state's position with regard to these measures is reviewed.

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[1] This figure is based on Figure 8 in the Washington Research Council's Washington Life Sciences Economic Impact Study, released in November 2009.

The latest R&D data from NSF, reported in Table 4, are for the year 2007, while the primary benchmark for this study is 2009. Washington's comparative position has improved since the last study, which used data for 2004. NSF data show on a variety of key indicators that Washington State is in a strong position with regard to R&D activities, as reported in Table 4. In 2007, NSF estimated Washington-based entities used $15.1 billion in R&D funds, which was 4.85% of our gross state product (GSP); nationally, R&D was 2.7% of Gross Domestic Product (GDP). This placed us 7th among the states based on total spending, well above our position as the 13th most populous state in the country (Census 2010). This relative concentration of expenditures on R&D activities is mirrored in the next section of this report, which demonstrates that the employment concentration in technology-based industries in Washington is also well above the national average. In 2006 the concentration of doctoral scientists and engineers employed in Washington State exceeded the national average[2].

Table 4 Washington State Distribution of R&D Funds by & Users and Sources of Funds, 2007

Performer & Sources of Funds	$ Millions	2007 Rank $ Used	2007 Rank Indexed	2000 Rank $ Used	1993 Rank $ Used
United States Sources: Total Used	$15,061	7	4	8	11
A. Federal Government: Total Used (1)	$202	18	23	14	21
B. Business: Total Used (2)	$12,687	6	4	7	9
Federal Sources	$189	22	27	D	8
Business Sources (3)	$12,499	6	2	D	10
C. Universities and Colleges: Total Used (4)	$981	14	32	14	14
Federal Sources	$706	13	23	11	10
Non-federal Government Sources	$47	21	37	35	32
University & College Sources	$126	26	40	22	NA
Business Sources	$72	11	10	11	14
Non-Profits	$30	27	41	27	NA
D. Non Profits: Total Used (5)	$1179	4	5	4	5
Nonprofit FFRDC	$852	4	4	4	NA
Other Nonprofits	$327	5	5	7	NA
E, State Internal (6)	$12	7	11	NA	NA

Notes:

(1) Total funds used by the federal government from federal sources.

(2) The category previously labeled "Industry" is now called "Business" by NSF. Business totals include R&D performed by industry-administered federally funded research and development centers.

(3) Business R&D support to business performers includes all nonfederal sources of funds.

(4) For universities and colleges, funds are for doctorate-granting institutions only.

(5) For the non-profit sector, funds distributed by state and region include only federal obligations to organizations in this sector, including associated federally funded research and development centers (such as the Battelle Memorial Institute). Estimated nonfederal support to the non-profit sector is excluded from these state data.

(6) Internal performers include state agency and department employees, and services performed by others in support of an internal R&D project.

NA – Data not available. Source: NSF, 2010

[2] This conclusion is based location quotients calculated from data in NSF Science and Engineering Profiles by State 2006-2008, for employed S&E doctorate holders by state for the year 2006, and Census Bureau estimates of population by state for the same year.

Table 4 details Washington's position on a variety of measures of R&D funds. Two rank measures are provided: (1) total dollars spent, and (2) ranks based on indexed estimates of spending relative to state GSP. Washington's overall position rises from 7th nationally based on total spending to 4th nationally when viewed from an indexed perspective.

Business R&D dominated Washington R&D expenditures in 2007, as it did nationally (72% of national R&D was performed by business, while in Washington State 84% of R&D funds were used in business sectors, as defined in Table 4). Washington's position is 6th nationally in business R&D dollars expended, and 4th when indexed to GSP. In Washington, manufacturing R&D expenditures were likely dominated by funds spent by The Boeing Company on the development of new product lines, such as the new 787 airplane concept, and on military and space research.[3] Federal R&D activity in Washington State is largely the Keyport Naval Warfare Research Center and operations of NOAA.

University and college funds accrue primarily to the University of Washington and Washington State University. University and college research spending levels lead to a ranking (14th) that is closer to our population rank (13th) than is the case for other R&D performers in Washington State (all of which are well above average). However, when indexed, Washington's university and college funding position falls considerably, to 32nd in the nation, largely due to relatively weak non-federal government (e.g. state government) and university and college funding sources (such as endowments). While Washington's overall university and college research funding places us 13th nationally in the receipt of federal research funds, our position falls to 23rd once receipts have been indexed. This relatively weak position has been associated with our relatively small enrollment of higher education students and related research faculty in science and engineering (Beyers and Chee 2006).

Notable in Table 4 is the receipt of funds to non-profits, as defined by NSF, which in Washington State is dominated by funding to the Fred Hutchinson Cancer Research Center in the other nonprofits sector, and by the Battelle Memorial Institute in the nonprofit FFRDC sector. Washington's ranking as the 4th highest recipient of research funds by non-profit FFRDC's, and 5th in the other nonprofit sector, highlights the importance of these sectors to the state's R&D activities.

Although it is not possible to classify recipients of these categories of R&D funds by NAICS code, it is certain that almost all of these funds were received by industries covered in this study. Again, the impacts considered in this analysis are based on all of the business activity in the industries which have high levels of R&D employment, not only the impact of activities directly associated with R&D expenditure.[4] It should be

[3] Unfortunately, NSF does not disaggregate R&D activity by manufacturing sector due to disclosure laws.

[4] The one exception to this principle is for university research, where the impacts are confined to the impact of research-related activities, and excludes other bases for the economic impact of universities.

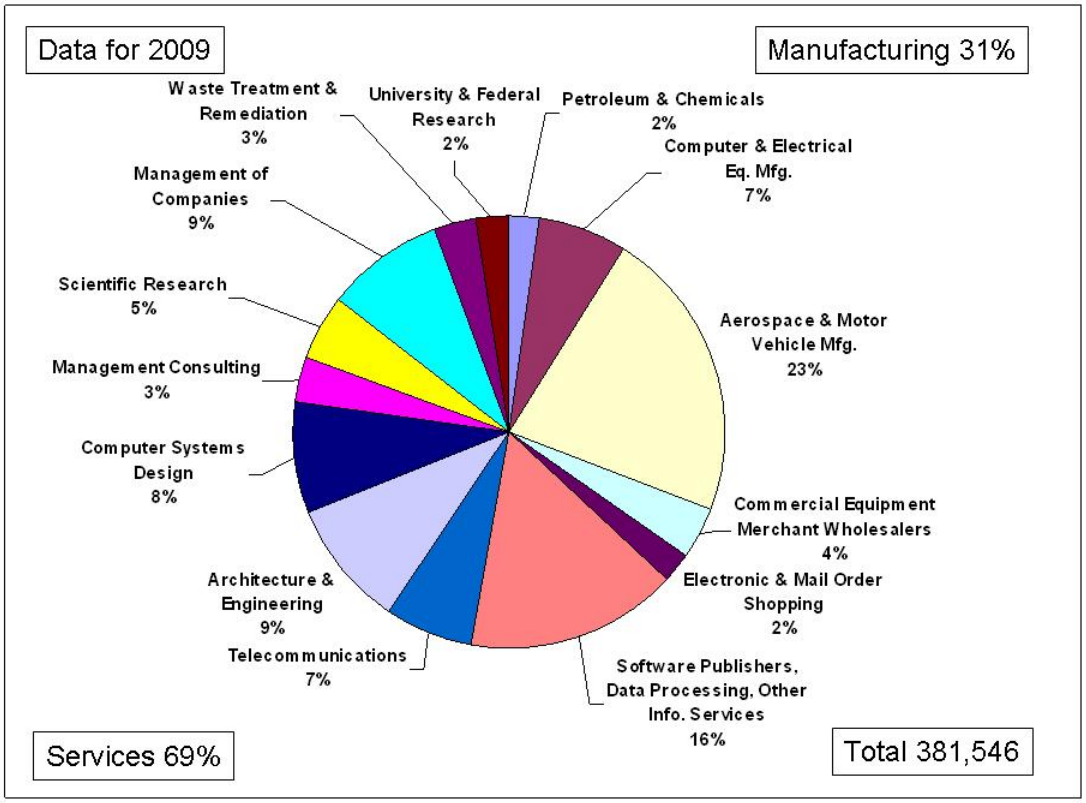
noted that Washington's position on a number of these indicators has improved, as our ranking has moved up for most measures from the spending ranks calculated in the first Technology Alliance economic impact study, as reported in Table 4.

III. Trends in Washington State Technology-Based Industry Employment and Comparison with Other States

Current Employment

In 2009, technology-based industries employed 381,546 people in Washington State, 13.2% of the state's total covered employment base of 2.9 million. As Figure 2 illustrates, manufacturing industries accounted for 31% of total technology-based jobs, with aerospace and motor vehicle manufacturing being the largest single category (23% of the total). The remaining 34,154 manufacturing jobs are divided between petroleum refining and chemicals, with 8,402 jobs, and computer and electrical equipment manufacturing, with 25,572 jobs.

Figure 2 Washington State Employment in Technology Based Industries[5]



[5] Figure 2 is based on covered wage and salary employment, plus estimates of university and federal research employment. It excludes estimates of self-employed persons in technology-based industries, as data on estimated levels of self-employment in technology-based industries were not available for the year 2009.

The bulk of technology-based employment in Washington State is found in a variety of nonmanufacturing industries. This category includes sectors that provide services—for example, architecture and engineering—and industries that produce intellectual property-based goods, software being a prominent example. The information and computer services sector (composed of software publishers, data processing, telecommunications, other information services, and computer systems design) accounts for 31% of total technology-based employment. Producer services includes architecture and engineering, scientific research and development, management and technical consulting, management of companies and enterprises, and waste remediation. Together, these sectors account for 29% of total technology-based employment.

The balance of technology-based jobs is found in commercial equipment wholesaling, which accounts for 4% of technology-based employment, and in electronic shopping and mail-order houses and university and federal research activities, each of which accounts for another 2% of technology-based employment.

Employment Trends

In the first four Technology Alliance economic impact studies, we were able to construct detailed information on employment by broad lines of technology-based industry (excluding university and federal research) back to 1974. This time series was based on the SIC classification system. With the shift to the NAICS classification system there are two important changes that make it impossible to present a harmonious estimate of employment trends in technology-based industries from 1974 to 2009. First, some of the sectors considered technology-based under the SIC system of classification were divided up into new categories in which at even the finest level of detail the SIC classification system was not commensurable with the NAICS system (the dispersal of SIC 737-computer services into parts of the NAICS information industry, and into part of computer systems design and related services, illustrates this issue). Second, the NAICS system recognized new industries that had no antecedent in the SIC system, but meet the current test of having a high concentration of scientific, engineering, and computer-related occupations. Management of companies and enterprises is a good example of this second issue.

There is a third issue that arises in making such comparisons: the changing occupational employment mix in particular industries. Whereas some industries were excluded from earlier definitions of technology-based industry, the evolution of their occupational mix has led to their inclusion under the current definition. Petroleum refining is an example of this—it did not qualify for inclusion in the 2008 study, but it is included in the current study. Even under the SIC system there were discontinuities in classification, such as the movement of much of Hanford from chemicals (plutonium) manufacturing to services in 1992.

There are no perfect solutions to these statistical issues. The easiest solution was to include in this section both the historical data in the SIC format, to provide information on the historical evolution of technology-based industries (Table 5), as well as the data in the NAICS format (Table 6). Table 6 presents data for the years in which NAICS data

are available, and while the totals do not add up perfectly to the values in Table 5, they allow us to have some evidence regarding the recent evolution of technology-based employment in the industries included in the current study.

Figure 3 presents estimates of private sector employment in technology-based industries from 1974 through 2009. This figure shows estimated aerospace employment, software and other computer services employment, and other technology-based employment. The figure illustrates the significant growth of non-aerospace technology-based employment in Washington. It uses the SIC based measures up to 2002, and uses the NAICS measures for the years 2007 and 2009.

The growth of private sector employment in Washington's technology-based industries defined on an SIC basis was steady in the aggregate, increasing from 95,910 in 1974 to 259,648 in 2002, or 171%, as described numerically in Table 5 and in more detail in Appendix IV. This compares to total wage and salary employment growth in the Washington State economy during the same period of 92%. In 1974, technology-based industries accounted for 6.7% of state employment; by 2002 this had increased to 11.3%. The inclusion of aerospace, which has demonstrated a high degree of cyclicality over the 1974 to 2002 period, masks a tremendous amount of growth in many of the non-aerospace sectors.

Biotechnology/biomedical manufacturing, an industry that was practically non-existent decades ago, had the highest percentage growth of any sector, expanding over twelve-fold between 1974 and 2002. Software and other computer services also expanded twelve-fold over the 1974-2002 time period. Aerospace has become steadily less important as a share of technology-based employment: in 1974 (as shown in Figure 3) almost 55% of private-sector technology-based employment was in this sector; by 2007, by 2002 its share had fallen to 23%.

It is also important to note the structural transformations that have occurred within the software and computer services industry. At the end of the 1970s, software and other computer services employment was dominated by data processing services undertaken on mainframe computers. The adoption of minicomputers and personal computers led to a significant decline in employment in data processing, evident in the large drop in employment in this industry between 1980 and 1982. Simultaneously, software and computer programming activity for personal computers started to become more and more important in Washington State, and the industry began to expand again and is now dominated by software production. This history demonstrates that cyclical changes in technology-based employment are not confined to aerospace in Washington State.

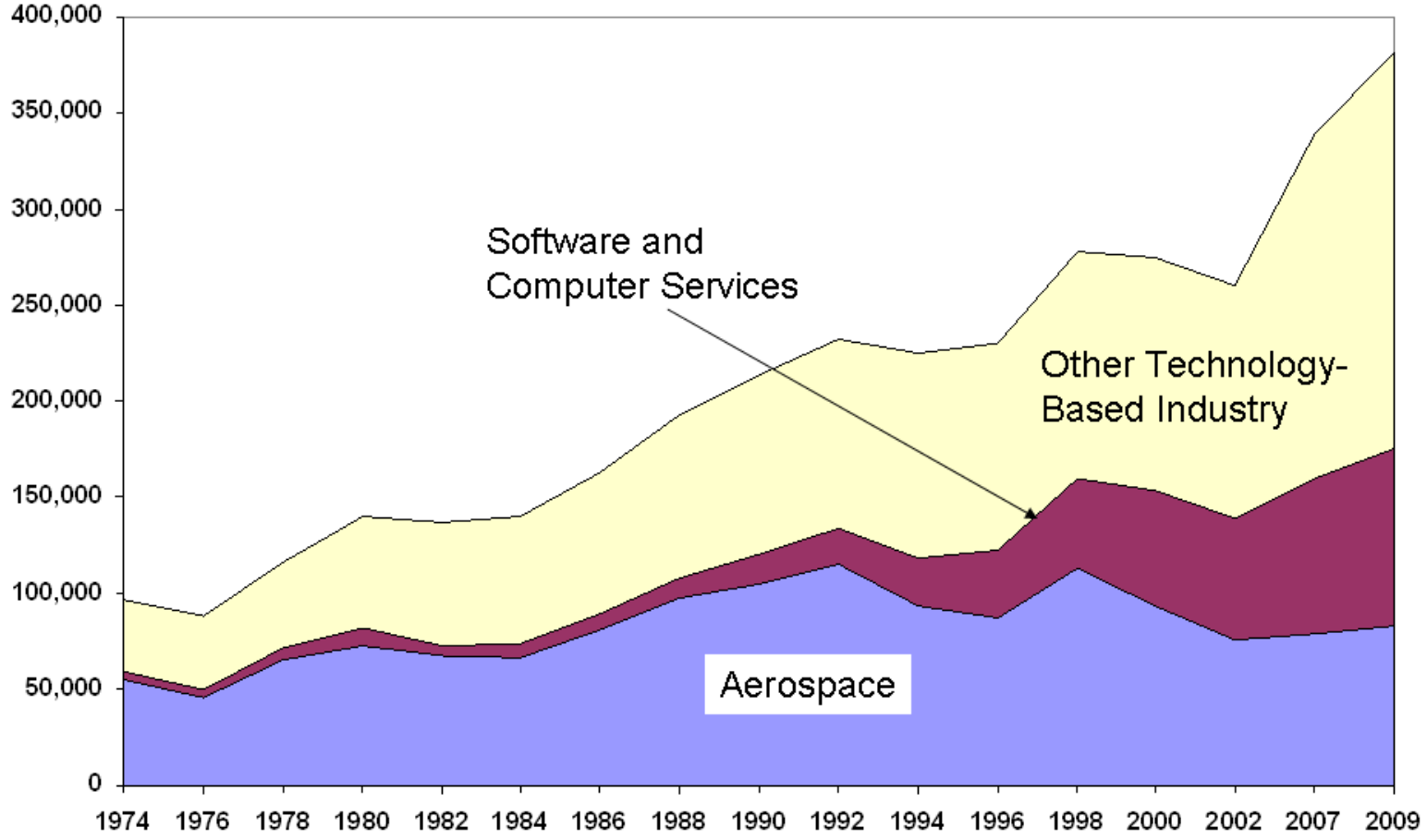
Table 5 Employment History for Washington State Technology-Based Industries, 1974-2002 (Private Employment; SIC-based definitions)

	% Chg 74-02	2002	2000	1998	1996	1994	1992	1990	1988	1986	1984	1982	1980	1978	1976	1974
Manufacturing Industries																
Aerospace	**37%**	75,667	93,221	112,962	87,024	92,911	115,126	104,860	96,963	80,675	65,824	67,794	72,406	65,014	45,257	54,646
Computers and Electronics	**296%**	19,389	23,642	23,776	21,128	17,808	15,361	15,800	15,275	15,675	17,050	14,518	11,211	7,559	5,030	4,899
Motor Vehicles and Machinery	**16%**	11,885	15,685	15,199	15,711	15,500	12,275	13,471	12,554	8,040	7,745	12,068	10,384	9,643	8,747	10,208
Specialized Instruments and Devices	**228%**	7,388	8,324	8,573	7,927	7,144	8,023	9,099	8,447	7,258	6,691	4,922	4,295	1,996	2,338	2,254
Chemical Production and Petroleum Refining	**-26%**	5,369	5,792	5,679	5,849	5,894	6,202	14,386	13,473	12,870	11,914	10,696	10,128	9,390	6,978	7,277
Biotechnology/Biomedical Manufacturing	**1266%**	8,375	7,990	7,665	6,944	6,892	6,004	4,787	4,002	2,797	1,237	1,191	755	465	505	613
Service Industries																
Engineering, Research, and Consulting Services	**506%**	68,637	60,327	57,580	50,617	47,606	50,135	36,012	31,308	27,276	21,698	20,614	20,738	15,504	14,747	11,311
Software and Other Computer Services	**1239%**	62,938	60,009	46,254	34,983	25,194	18,851	14,990	10,737	8,453	7,350	5,089	9,854	6,109	4,627	4,702
TOTAL	**171%**	259,648	274,989	277,688	230,183	224,490	231,977	213,405	192,759	163,044	139,509	136,892	139,771	115,680	88,229	95,910

Sources: U.S. County Business Patterns and Washington State Employment Security Department

Notes: Excludes university and federal research employment. A portion of the engineering, research, and consulting sector is related to biotechnology. Historical data on the level of biotechnology research employment are not available.

Figure 3 Growth of Employment in Technology-Based Industries in Washington State, 1974-2009 (excluding government or university research activities)



Other sectors with high growth rates in Table 5 include engineering, research, and consulting services (506%), reflecting the rapid growth of other types of business services in the state and U.S. economy (as well as a reclassification of activities at the Hanford site, discussed below), computers and electronics manufacturing (296%), and specialized instruments and devices (228%). Motor vehicles and machinery, a sector which many might not consider high technology but exceeded the 10% threshold of employment in R&D occupations under the SIC definitions used in previous reports, showed very modest growth at 16%.

A Note on Hanford

The 26% decline in employment within chemical production and petroleum refining in Table 5 reflects the reclassification of activities from plutonium production to environmental remediation at the Hanford site. From the Second World War until 1989, the Hanford works was a major contributor to national defense weapons production, through the manufacture of plutonium. Over this long span of time, the federal government instituted a management structure for the Hanford nuclear facility that employed a contractor to operate the plutonium production process. This industrial activity was classified in SIC 281, Industrial Inorganic Chemicals. In addition to nuclear materials production activity, research emerged as an important component of the Tri-Cities economy, led by the research activities of the Battelle Memorial Institute. Battelle managed (and still manages) the Pacific Northwest National Laboratory and also operates a separate research program affiliated with Battelle's larger mission as a research enterprise.

With the end of plutonium manufacture and the shift of the federal effort at Hanford towards environmental cleanup, the classification of the employees who were considered part of the inorganic industrial chemicals manufacturing industry were shifted to Research and Testing (SIC 873). This change of classification was undertaken by ESD in 1991. In our historical employment series for SIC 281 and 873, the impact of this change of classification is evident. In the ongoing cleanup efforts at Hanford in recent years, most employment has been reclassified again, and is now in Waste Management and Waste Remediation (NAICS categories 5622 and 5629). These industries are included in the current study.[6]

Table 6 presents estimates of employment for the 1998-2009 time period by NAICS definitions used in this study. More detail on the history of employment by NAICS codes is found in Appendix V. NAICS codes were changed in 2002 and 2007, rendering some sectors non-comparable (NC) due to these definitional changes. This table documents the rapid growth of employment in software publishers and computer systems design, scientific research and development, waste management, and electronic

[6]Department of Energy employment in the Hanford region is currently less than 500 (http://www.hanford.gov/page.cfm/AboutUS, accessed May 7, 2010). ESD reports 557 people employed in the administration of air and water resources and waste management in Washington State in the 2nd quarter of 2009. It also reports 837 federal employees in Benton County in 2006, many of whom are likely Department of Energy employees. This federal employment is not included in this study.

shopping and mail order houses. The aerospace employment cycle is evident in this table as well, with a large drop in aerospace employment between 1998 and 2005, and a rebound after 2005. The employment history in business services is affected by the reported data for management of companies, which shows a large drop in levels between 2000 and 2002. A similar drop is recorded in computer manufacturing. These changes may be related to reclassifications of establishments as a result of changes in NAICS classification principles.

Table 6 Employment Trends for NAICS Technology-Based Industries

Table 6	% Change 1998-2009	2009	2007	2005	2002	2000	1998
Manufacturing							
Petroleum Refining	27.93%	2,606	2,444	2,314	2,726	2,030	2,037
Chemicals	8.94%	5,796	5,919	5,202	5,798	4,842	5,320
Computer Manufacturing	-54.86%	21,539	22,576	22,003	25,948	45,554	47,720
Electrical Equipment	14.15%	4,213	4,286	4,206	3,782	3,500	3,691
Aerospace	-26.58%	82,932	78,667	65,096	75,667	93,221	112,962
Motor Vehicles	-36.14%	894	700	1,400	700	700	1,400
Services							
Commercial Equipment Wholesalers	NC	14,195	14,277	13,774	14,399	NC	NC
Electronic Shopping & Mail-Order Houses	88.13%	8,906	10,833	9,614	9,586	6,613	4,734
Software Publishers, Data Processing, and Computer Systems Design	193.3%	87,425	79,643	65,445	60,488	54,486	29,803
Telecommunications & Other Information Services	8%	30,256	*26,140*	*25,717*	*30,988*	*32,975*	*30,200*
Business Services	-11.97%	82,273	80,282	74,183	68,126	88,347	91,273
Scientific Research and Development	101.47%	19,117	18,765	18,090	16,354	10,936	9,489
Waste Management	67.47%	11,958	11,539	11,646	9,539	8,695	7,140
Total	NC	372,110	NC	NC	NC	NC	NC
(Estimate for 1998 through 2007)		*At least:*	*356,071*	*318,690*	*324,101*	*351,899*	*345,769*

Source: Washington State Employment Security Department, U.S. County Business Patterns
Notes: Excludes university and federal research employment. A portion of the scientific research and development sector is related to biotechnology. In 2008 this segment included approximately 2,679 jobs. Historical data on the level of biotechnology research employment are not available.
Note: Other Information services not estimated except for 2009 due to changes in NAICS definitions. Data for 1998-2007 in telecommunications and other information services are estimates only for telecommunications.

Concentration of Technology-Based Industries in Washington State

Washington State's concentration of technology-based employment has increased significantly over the past several decades. In 1985, our relative share of private sector technology industries was 10% above the national average; by 1997, this share had increased to 42% above the national average (Beyers and Lindahl 1997; Beyers and Nelson 1998; Beyers and Lindahl 2001). In the wake of the downturns in aerospace employment after 1998, and impacts on technology-based industry of the business cycle

in 2001-2002, the concentration of technology based employment declined somewhat in Washington State. In 2007, the latest year for which national data by state were available, Washington's concentration of technology-based industries was 37% above the national average.

Table 7 identifies "location quotients" for each of the NAICS technology-based sectors. The location quotient is a simple measure of the relative concentration of a particular industry in a certain region compared to the concentration of that industry for the nation as a whole. A value less than 1.0 indicates that an industry is underrepresented in a state or region, a value over 1.0 indicates a higher level of concentration than the nation, and a value around 1.0 indicates that the concentration of an industry within the state or region is similar to that within the national economy[7]. Table 7 uses two measures of employment: U.S. County Business Patterns, and the U.S. Census Bureau Nonemployer Statistics. The nonemployer data are derived from tax returns filed with the Internal Revenue Service by self-employed persons, in which they self-identify the industry from which they are receiving self-employment income.

Table 7 Location Quotients in Washington Private Sector Technology-Based Industries, 2007

	County Business Patterns	Self-Employed	Combined
Petroleum Refining	1.629	0.223	1.624
Chemicals	0.318	1.060	0.330
Computers	0.999	1.447	1.015
Electrical Equipment	0.292	1.113	0.309
Aerospace & Motor Vehicle Manufacturing	5.024	1.220	5.071
Commercial Equipment Merchant Wholesalers	0.951	1.047	0.964
Electronic Shopping & Mail-Order Houses	0.790	1.563	0.956
Software Publishers & Computer Systems Design	2.292	1.421	2.157
Telecommunications	1.224	0.843	1.227
Data Processing & Other Information Services	1.011	1.156	1.033
Business Services	1.114	1.292	1.138
Scientific R&D	1.403	1.192	1.406
Waste Management	2.114	0.568	2.050
All Technology-Based Industries	1.372	1.304	1.372

The 2007 data for technology-based self-employment indicate that their number was 8.8% of the numbers of people reported in County Business Patterns; this compares to 15.3% economy-wide on this same measure. Thus, technology-based industries have a lower share of self-employed workers than in the economy as a whole. The number of self-employed persons in the United States has gradually increased in recent years; their

[7] U.S. Census Bureau data are used in this section of the report, rather than Washington State Employment Security Department data, because the calculations in this section of the report must be compared to other states in the United States.

inclusion in the statistical basis for calculating location quotients does not change Washington's overall concentration, but it does provide a broader basis for calculating these indices.

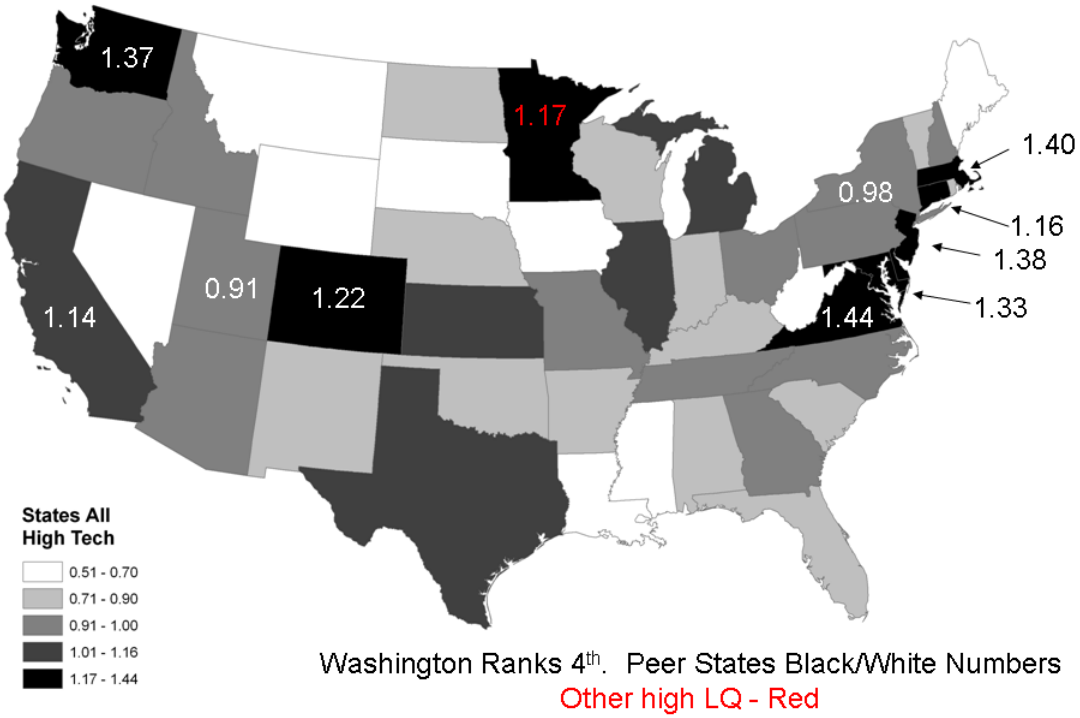
The strongest concentration of technology-based industry in Washington State is in aerospace and motor vehicle manufacturing, with a location quotient of 5.02. No other sector included in this study approaches this dominance. Software publishers and computer systems design have a concentration 2.3 times the national average, while waste management has a concentration twice the national average. Petroleum refining, computer manufacturing, telecommunications, data processing and other information services, business services, and scientific R&D are all above the national average in concentration. Appendix III presents location quotients for more detailed industries than those contained in Table 7, and these data make it clear that Washington's position is due to aerospace in which our location quotient is 7.4, while in motor vehicles our location quotient is only 0.2.

Figures 4 through 6 depict the concentration of technology-based industries in Washington State, compared to other states. These figures also show specific location quotients for Technology Alliance peer states, along with values for some other states with high location quotients that are not peer states (in red type).

The location quotient for all technology-based employment in 2007 placed Washington 4th in its relative concentration of technology-based industries (surpassed by Virginia (1.44), Massachusetts (1.40), and New Jersey (1.38). Massachusetts is heavily concentrated in computer and electronics manufacturing, software, scientific research and development, and computer systems design. Virginia has strong concentrations in architectural and engineering, computer systems design, scientific research and development, and management and technical consulting services. New Jersey has strong concentrations in chemicals, commercial equipment merchant wholesalers, telecommunications, management of companies, and computer systems design.

California has multiple concentrations of technology-based industries, including computers and electronics, aerospace, software, and research, while Colorado has a high concentration in telecommunications, software, wholesaling, and waste management. Maryland has high concentrations in architecture and engineering, computer systems design, scientific research and development services, and management and technical consulting services. Utah has concentrations in aerospace, electronic shopping, software, waste management, and data processing. Connecticut has strong concentrations in electrical equipment, aerospace, and other information services. New York has a strong concentration of employment in other information services.

Figure 4 Location Quotients for Technology-Based Employment in the U.S. (industries with greater than 15.6% employment in R&D occupations)



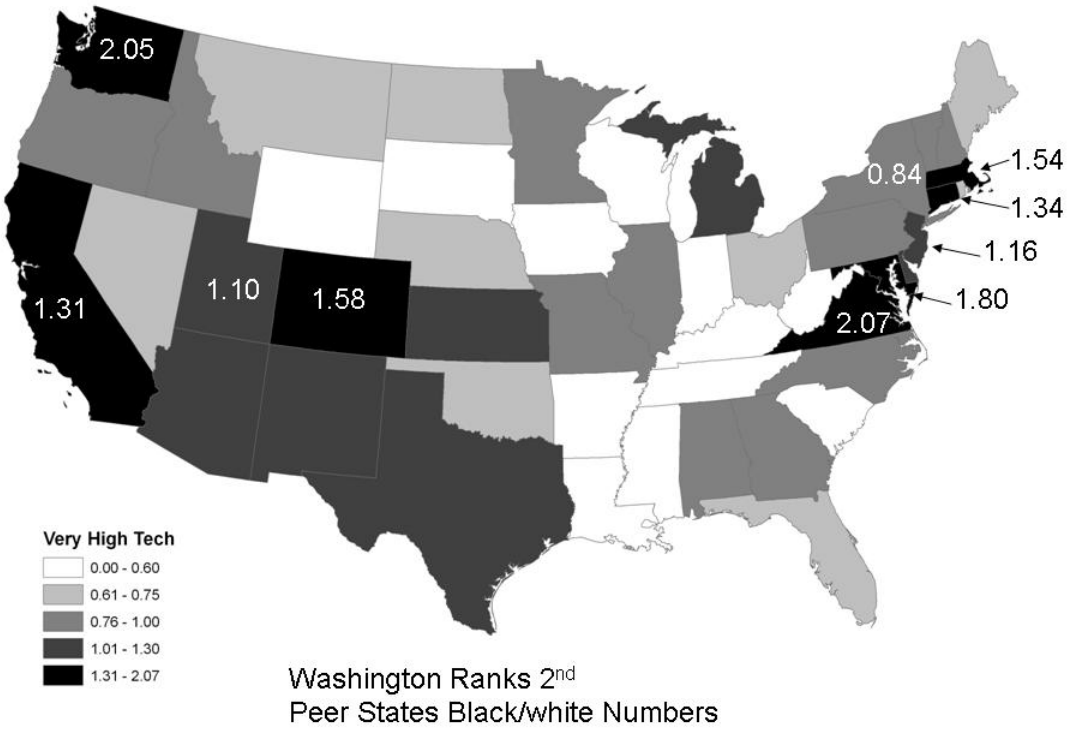
In the 1997 Technology Alliance economic impact study, Washington ranked 6th in the U.S. in its location quotient for technology-based industries, based on data for the year 1993. In the 1998 study we were propelled to the top of the nation in our concentration of these industries, a ranking based on data for 1995. Washington retained this position in the 2001 study, using national data for 1997. In the 2005 study, our position slipped to 3rd and then, in the 2008 study we ranked 4th, fueled primarily by employment losses in the aerospace sector since its peak in 1998.

It is not possible to tease apart precisely the relative contributions to Washington's shifting position in industry detail due to the shift from the SIC to the NAICS classification schemes, and changes in the definition of technology-based industries in these studies. However, with the growing importance of services in the definition of technology-based industry used in these studies, it is clear that states such as Virginia, Maryland, Connecticut, and New Jersey are strong competitors with their proximity to the nation's capital and our leading financial center, New York City. Washington's position is strongly impacted by our very strong concentration in software publishing—our location quotient is 6.65, more than double that of the closest other state (Massachusetts, with a value of 2.96).

Figure 5 identifies patterns of industries that are "technology-intensive," or those industries with greater than 30% of employment in R&D occupations (see Table 3 for a list of these sectors). The inclusion of aerospace and software publishers in this category

(27% of employment in R&D occupations within Washington State are in these two sectors), is responsible for our very high concentration—the second highest index in the nation after Virginia (2.07).

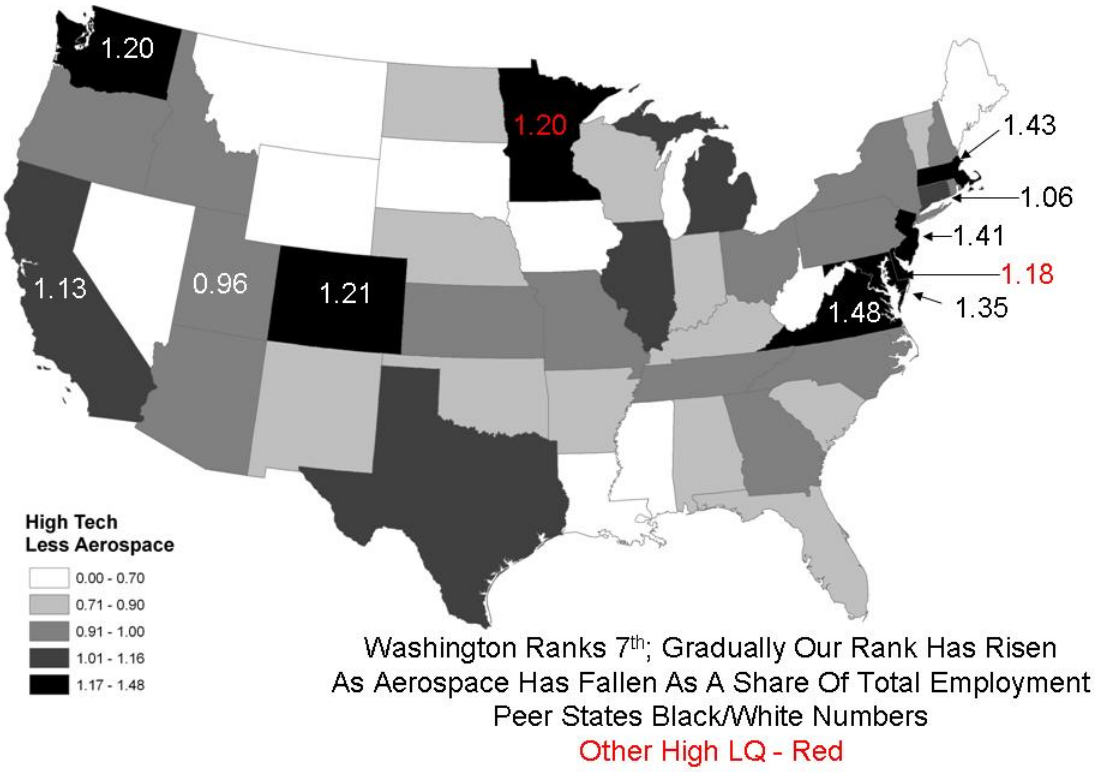
Figure 5 Location Quotients for Technology-Intensive Employment in the U.S. (greater than 30% employment in R&D occupations)



Finally, the strong contribution of aerospace to the high location quotients for Washington State depicted in Figures 4 and 5 is more sharply evident when the sector is excluded from the calculation, as shown in Figure 6. Without aerospace Washington ranks 7th, with a location quotient of 1.20, using the technology-based definition (15.6% or greater employment in R&D).

In part, this is a reflection of the state's low concentration in machinery, chemicals and petroleum, and selected trade and business services. While Washington State enjoys an almost unsurpassed dominance in its concentration of aerospace employment (only Kansas has a higher location quotient than Washington), the state is currently not a national center of non-aerospace technology-based manufacturing. The industries that pull us up to the national average are computers and electronics, software, research, and waste management. States that are in the highest class interval in Figure 6 have concentrations in computers and electronics, software, research, and telecommunications.

Figure 6 Location Quotients for Non-Aerospace Technology-Based Employment in the U.S.



Size Distribution of Technology-Based Establishments

County Business Patterns provides establishment counts by size category, while the Nonemployer Series provides estimates of proprietorships. These data are presented in Table 8, and in Figures 7, 8 and 9. These data indicate that 15,083 technology-based establishments in Washington State employed a total of 388,027 people in 2007, an average of 26 employees per establishment[8]. The Nonemployer series contains 37,252 individuals, most of whom are reported in services, with 42% of the total reported in NAICS 5416, consulting services.

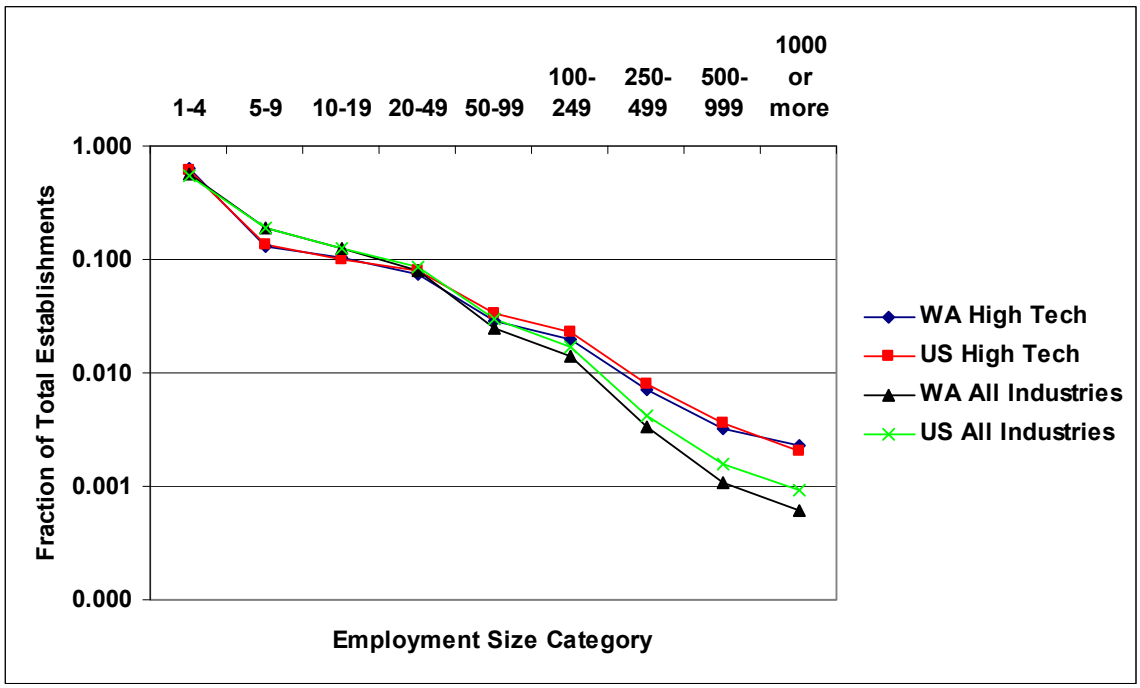
Figure 7 indicates the very skewed distribution of establishment size, with 85% of the total establishments employing fewer than 20 people. In contrast, Figure 8 shows the estimated total employment by size category, using the estimated size per establishment reported in Table 8.[9] Figure 7 is presented in a semi-logarithmic format, and includes the size distribution of technology-based establishments in Washington State and the United

[8] The year and data base for County Business Patterns differs from the Employment Security Department covered employment series, used as the benchmark for this study. Therefore, the totals are not the same, but they are quite similar.

[9] The estimated size for the category over 1,000 employees was calculated by subtracting total employment in the smaller size categories from the total employment, and calculating the average employment for the remaining employees.

States, as well as the distribution for employment in all industries. This figure clearly indicates (1) a similar size distribution for technology-based establishments in Washington State and in the United States, and (2) the fact that Washington and U.S. technology-based industries have a "tail" of larger establishments (over 100 employees) than is the case for all establishments.

Figure 7 Size Distribution of Technology-Based Establishments (excludes self-employed)



Figures 8 and 9 provide very different pictures of the distribution of employment than presented in Figure 7. While 85% of the establishments are estimated to have fewer than 20 employees, these establishments account for 14% of total employment. In contrast, the 0.2% of the establishments that have more than 1,000 employees account for 38% of total employment.

Table 8 Size Distribution of Technology-Based Establishments in Washington State

Industry code	Industry code description	Total Establish-ments	1 to 4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1000 or more	Non-employer
324	Petroleum and Coal Products Manufacturing	47	17	5	7	8	3	3	3	1	0	8
325	Chemical Manufacturing	252	93	54	50	33	10	10	1	0	0	199
334	Computer and Electronic Product Manufacturing	358	132	56	38	60	27	24	7	13	1	268
335	Electrical Equipment, Appliance, & Component Manufacturing	115	51	15	15	22	8	2	2	0	0	150
3361	Motor Vehicle Manufacturing	9	3	4	0	1	0	0	0	1	0	20
3364	Aerospace Product and Parts Manufacturing	117	29	17	16	13	11	17	6	3	5	42
4234	Professional & Commercial Equipment and Supplies Merchant Wholesalers	847	449	148	118	85	25	14	5	2	1	214
4541	Electronic Shopping and Mail-Order Houses	478	324	73	43	20	11	6	1	0	0	2501
5112	Software Publishers	424	192	66	53	59	21	19	7	3	4	664
517	Telecommunications	1,020	526	151	166	80	40	27	19	7	4	547
5182	Data Processing, Hosting, and Related Services	382	228	44	49	29	17	8	5	1	1	835
519	Other Information Services	51	35	3	3	6	2	0	2	0	0	1338
5413	Architectural, Engineering, and Related Services	3,341	2,033	521	410	253	81	33	7	1	2	5747
5415	Computer Systems Design and Related Services	2,626	1,916	280	194	142	43	35	8	5	3	8076
5416	Management, Scientific, and Technical Consulting Services	3,229	2,702	244	152	91	24	12	4	0	0	15728
5417	Scientific Research and Development Services	510	255	83	59	56	27	17	7	3	3	803
5511	Management of Companies and Enterprises	998	364	168	153	139	69	64	23	8	10	0
5622	Waste Treatment and Disposal	46	10	9	11	9	3	3	0	0	1	37
5629	Remediation and Other Waste Management Services	233	119	46	30	28	6	3	0	1	0	74
	Total # of Establishments	15083	9478	1987	1567	1134	428	297	107	49	35	37252
	Estimated Size	25.73	2	7	13	35	70	140	350	700	4337	
	Total Employment	388027	18956	13909	20371	39690	29960	41580	37450	34300	151811	

Source: U.S. Census Bureau County Business Patterns and Nonemployer Statistics

Figure 8 Total Employment by Size Category, Technology-Based Industry

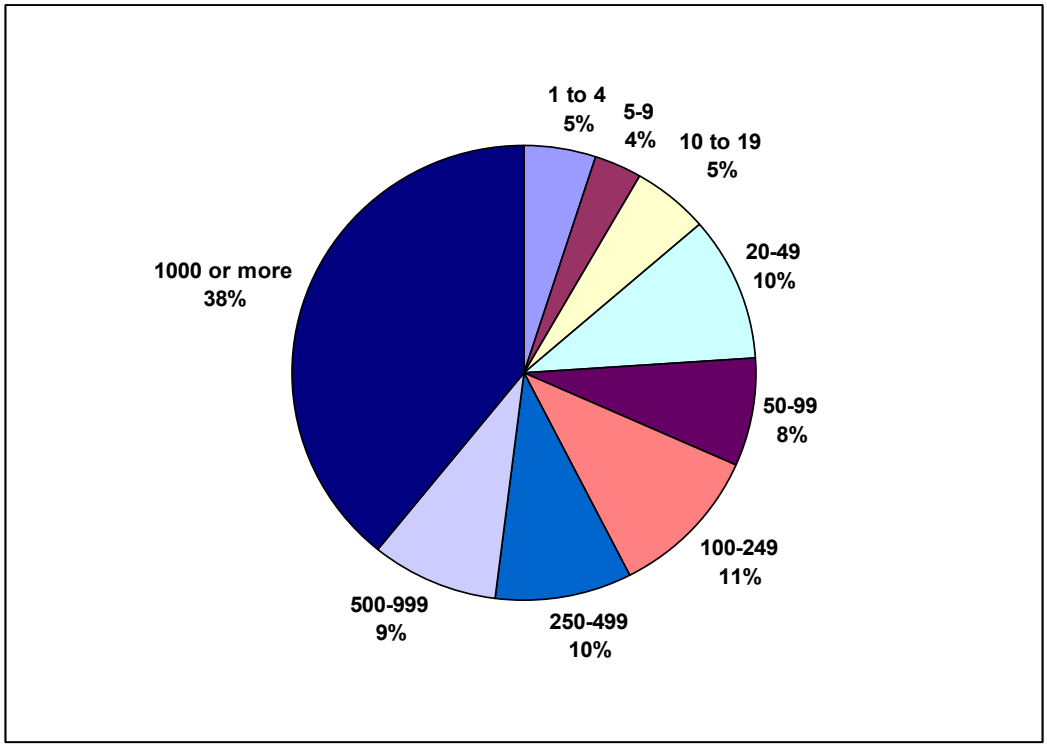
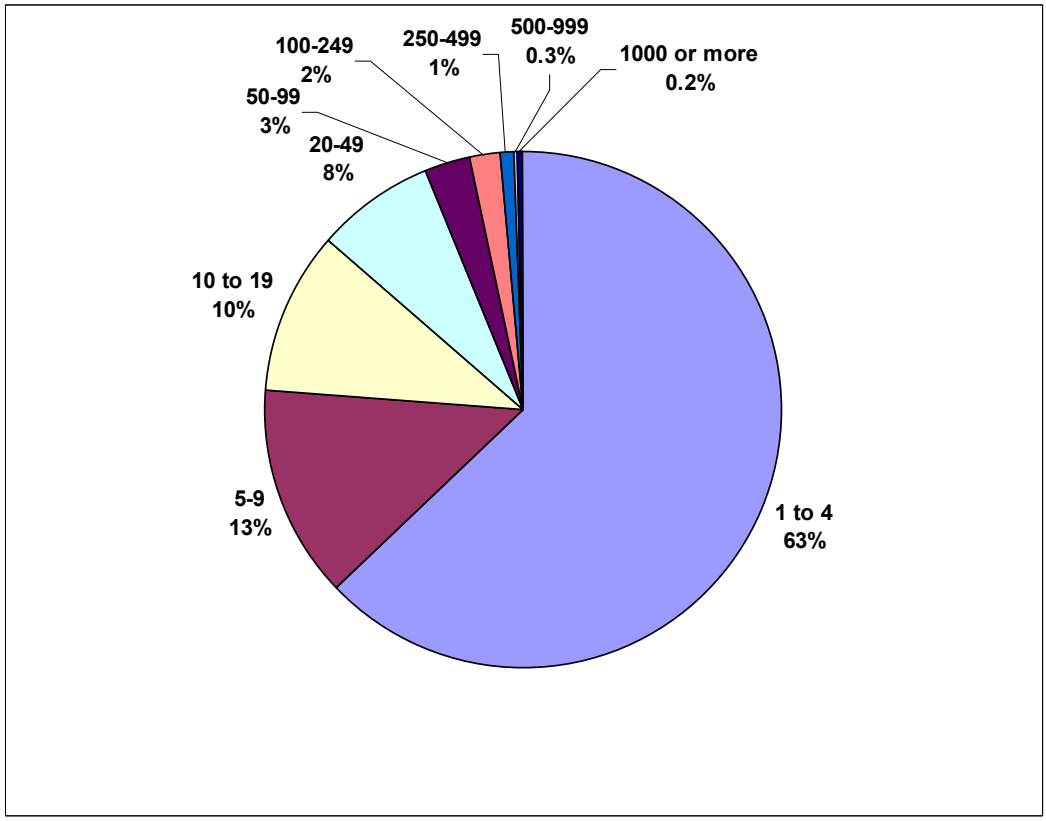


Figure 9 Number of Establishments by Size Category



University and Federal Research

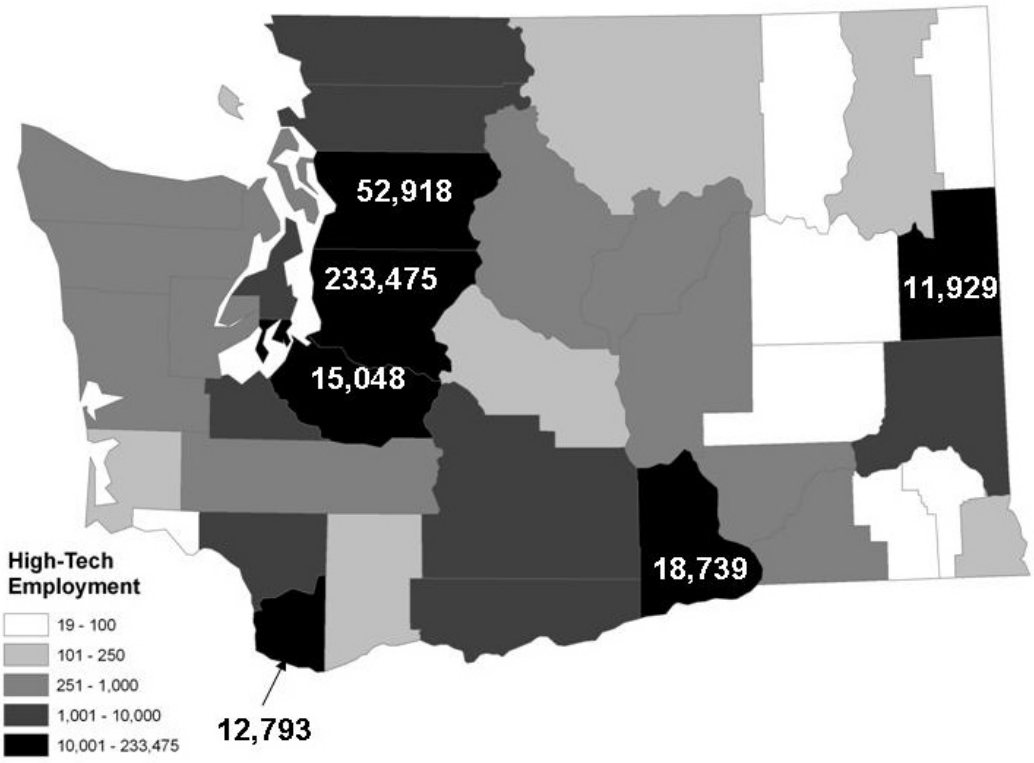
The historical trends described in this section, and the maps showing the concentration of technology-based employment, exclude employment in university and federal research organizations due to a lack of historical information on these entities. The University of Washington and Washington State University provided special tabulations of their research-related expenditures and employment for the year 1997, including direct outlays associated with research grants and contracts and associated indirect costs. It was assumed that these cost distributions have not changed for the purposes of this study.

It is estimated that 9,436 people were employed at university and federal research establishments in 2009, as measured on an FTE basis. At the UW, grant and contract activity has expanded significantly over time, rising from $179 million in 1975 to $535 million in 2009 (as measured in constant 1982-1984 dollars). Grant and contract income at the UW was $1.15 million in fiscal year 2009, of which $670 million was for research. The balance of these grant and contract funds were obligated for training, fellowships, and other activities (including institutes and conferences). The UW is currently the 2nd largest university recipient of federal research funding in the U.S. and the largest recipient among public institutions.

Distribution of Technology-Based Jobs in Washington State

While employment in technology-based industries is concentrated strongly in the Seattle-Everett metropolitan area (where aerospace employment is primarily located), there are firms located in every county in the state. Figure 10 shows the distribution of employment in 2009. Outside of King and Snohomish counties, there are also relatively large numbers of employees in Pierce (15,048), Benton (18,739), Clark (12,793), and Spokane (11,929) counties. Fourteen of the 39 Washington counties have at least 1,000 persons employed in technology-based industries, while 33 counties have at least 100 persons employed in these sectors. Appendix VI contains estimates of technology-based employment by county in Washington State.

Figure 10 Technology-Based Employment in Washington Counties



Summary

Washington State's technology-based industries have grown substantially in the past three decades, such that in the aggregate they now represent over 13% of total employment (including university research and federal laboratories). While aerospace and computer services continue to play a dominant role and are the primary reason that Washington has one of the highest concentrations of technology-based industries, other sectors have emerged that contribute to further diversification of the state's economy. As the next section will describe in detail, these industries now represent a substantial component of Washington State's economic base.

IV. Economic Impact Analysis

While technology-based industries in Washington State employed more than 381,000 people in 2009, there are broader impacts on our economy beyond direct employment. These larger "multiplier" effects occur as a result of businesses within these industries selling their goods and services outside the state, making intermediate purchases within the state, and providing payments to employees in the form of wages and other labor income, a large portion of which is spent on other goods and services within the state economy.

To calculate these larger impacts, input-output models are used, which provide a detailed representation of the economic linkages within a particular regional or national economy. We have used the Washington State input-output model to calculate the impacts of technology-based industries on the Washington economy for the year 2009 (Beyers and Lin 2008). Before describing results from this analysis, a brief discussion of the input-output methodology is presented. A technical appendix on modeling is included as Appendix II.

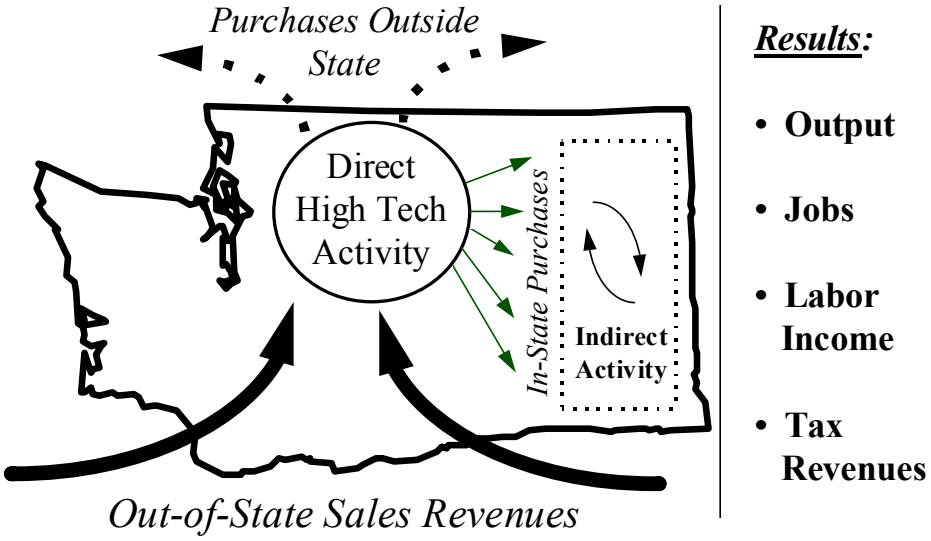
The Washington State Input-Output Model

Washington State has invested in the construction of seven regional input-output models beginning in 1963, with the latest model released for the year 2002. These models describe where Washington industries sell their products and where they purchase the inputs needed to make their products. The structural relationships contained in these models are used to estimate the indirect impacts associated with industrial production. The models are divided into "sectors," which have distinctive patterns of inputs, or purchases of goods and/or services regionally. These distinctive purchasing patterns lead to varying multipliers. The widespread application of regional input-output models to impact analyses stems from their ability to pinpoint these differing levels and patterns of impact by industry.

Figure 11 is a schematic that describes the general structure of a regional input-output model. Demands for the products or services of individual industries lead to the direct purchase of inputs to make products and services. These direct purchases are made from suppliers located inside Washington State but are also procured in non-Washington markets. For example, Boeing imports all the jet engines assembled into aircraft from elsewhere in the United States or abroad, but they also purchase some services and manufactured goods in Washington State and make large payments to their labor force.

Within the regional economy, the purchases of goods, services, and payments to the labor force have "ripple effects." For businesses, these ripple effects begin when they procure inputs to produce the products or services they sell to a client. "Second-round" and "third-round" effects take place as other industries are drawn into the production process indirectly to produce output ultimately delivered to the business. Similarly, labor force earnings are spent on consumption of goods and services, such as food, housing, cars, clothing, etc. These expenditures also have ripple effects, which are captured in regional input-output models.

Figure 11 Schematic of the Washington State Input-Output Model



Through the use of a generalized form of the direct structural relationships found in a regional input-output model, it is possible to trace out the summarized impact of the demand from any given industry on all industries. These impacts are measured as (1) the level of business activity (or output) generated in all industries, (2) the number of jobs created in all industries, (3) the level of labor income earned in all industries, and (4) tax revenues in all industries. Separate measures of impact were calculated for each of the NAICS codes shown in Appendix V, and aggregated to the industrial groupings used in Table 4. Details of this computational process are discussed in Appendix II.

Impact Results

Results from the impact analysis are presented first in the aggregate and then with more detail related to particular segments of technology-based industries in Washington State. Table 9 presents direct and aggregate impact results. Some 381,546 jobs, $133 billion in sales, $838 million in taxes, and $42 billion in labor income were directly attributable to technology-based industries in Washington State in 2009.[10] These values increase significantly once the indirect effects are added from the input-output model calculations. Direct and indirect employment impacts total 1,208,189 jobs; overall output impacts equal $238.9 billion, with $76.7 billion in labor income. The aggregate level of state sales and use, business and occupation (B&O), and local sales and use taxes are estimated to be $5.3 billion.[11] Later in this section, we will disaggregate these large impacts into the contributions of individual sectors.

[10] Direct tax impacts are estimated business and occupation tax collections.
[11] Total tax impacts are much higher than direct tax impacts, as they include sales taxes generated from the spending of labor income, as well as direct and indirectly generated business and occupation tax revenues.

Table 9 also presents estimates of multipliers: the multiplier represents simply the relationship between the direct effects and the sum of the direct and indirect impacts. To interpret these multipliers, we can say, for instance, that for every technology-based job in Washington State, there are a total of 3.17 jobs created in the state economy.

Table 9 Direct and Total Impacts

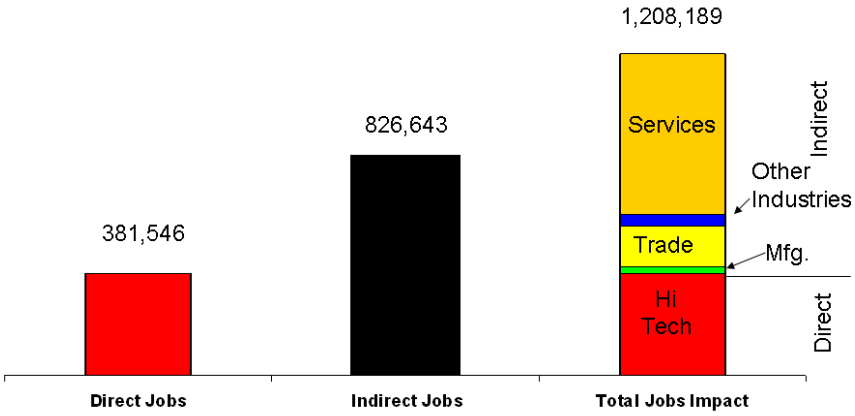
$ in Millions		% Change from 2008 Study in Nominal $
Direct Impacts		
Sales	$132,959	18%
Employment	381,546	11%
Labor Income	$42,025	4%
Taxes	$838	-21%
Total Cumulative Impacts		
Sales	$238,392	16.1%
Employment	1,208,189	3.8%
Labor Income	$76,706	7.4%
Taxes	$5,328	-6.5%
Multipliers		
Sales	1.79	
Employment	3.17	
Labor Income	1.83	

The input-output model provides estimates of output, income, and employment impacts in each industry in the economy due to the demands related to each individual technology-based industry. The impacts in Table 9 could be presented at this level of detail, but a simpler view of these impacts is presented in Figure 12, which shows the total direct and indirect employment effects.

Of the 826,643 indirect and induced jobs created in the Washington economy, some 24,755 of these are in manufacturing, with the balance spread across a wide variety of services and other industries. These impacts reflect the strong leveraging impact of labor income earned by workers in technology-based industries, income that is well above the state average per worker as will be documented shortly. The expenditure of this labor income robustly stimulates the trade, services,[12] and other industry[13] sectors in the input-output model.

[12] Services includes transportation and warehousing; information; finance, insurance, and real estate; professional services; educational services; health services; arts, recreation and accommodation services; food services and drinking places; and other services.
[13] The other industry group includes: agriculture, agricultural services, forestry, fishing, logging, mining, utilities, and construction.

Figure 12 Total Direct and Indirect Employment Impacts



Industries have varying impacts on regional economies, as measured by business activity, employment, and income through input-output models. The magnitude of these impacts is a function of their connectivity to these economies. The industries included in this study have major differences in their impacts, as documented in Table 10. Table 10 presents the total employment impact multiplier and labor income per job by industry. This table also identifies industry variations in the proportion of purchases made in Washington State and the share of out-of-state sales. Variations in labor income levels per job and in-state purchases each influence multiplier levels, contributing to the multiplier effect of these sectors on the Washington economy.

Table 10 Key Indicators for Technology-Based Industry Sectors

	Employment Multiplier	Labor Income Per Job	% In State Purchases	% Out of State Sales
Manufacturing				
Aerospace & Motor Vehicles	2.71	$104,072	8.0%	97.0%
Computers & Electronics and Electrical Equipment	2.84	$89,793	19.8%	88.5%
Chemicals & Petroleum Refining	4.76	$93,644	19.1%	59.6%
Services				
Software Publishers, Data Processing, and Computer Systems Design	3.93	$149,703	20.0%	84.3%
Telecommunications & Other Information Services	4.31	$95,516	37.1%	12.9%
Commercial Equipment Merchant Wholesalers	3.05	$106,044	17.3%	40.4%
Electronic Shopping & Mail-Order Houses	3.09	$107,902	20.1%	15.1%
Scientific Research &Development	2.73	$106,452	18.2%	67.9%
Architecture & Engineering, Management Consulting, and Management of Companies and Enterprises	2.58	$98,482	18.2%	67.9%
Waste Management	3.37	$89,950	31.6%	85.0%
University & Federal Research	1.99	$57,791	27.0%	94.9%
All Technology-Based Industries	3.17	$110,145	16.9%	75.2%
All Washington State Industries	2.84	$57,654	24.3%	39.8%

Table 11 presents summary impacts by sectoral groups of technology-based industries, followed by a brief discussion of the impacts of each sector. Total impacts are as reported in Table 9.

Table 11 Summary Impacts by Sector

	Sales ($ millions)	Employment (# jobs)	Labor Income ($ millions)	Taxes ($ millions)
Manufacturing				
Aerospace & Motor Vehicles	$66,077.3	227,325	$14,780.0	$990.0
Computers & Electronics and Electrical Equipment	$11,251.7	73,075	$4,406.0	$277.6
Chemicals & Petroleum Refining	$22,350.8	39,961	$2,220.0	$220.0
Services				
Software Publishers, Data Processing and Computer Systems Design	$52,895.2	343,216	$23,456.5	$1,548.2
Telecommunications & Other Information Services	$26,637.6	130,477	$7,440.1	$560.5
Commercial Equipment Merchant Wholesalers	$8,638.5	43,367	$2,726.8	$253.0
Electronic Shopping & Mail-Order Houses	$4,823.9	27,535	$1,733.1	$136.8
Scientific Research &Development	$7,501.1	52,105	$3,363.7	$218.4
Architecture & Engineering, Management Consulting, and Management of Companies and Enterprises	$28,508.4	212,094	$13,366.8	$894.4
Waste Management	$7,333.0	40,294	$2,264.3	$165.3
University & Federal Research	$2,374.1	18,739	$948.4	$64.1
All Technology-Based Industries	$238,391.5	1,208,189	$76,705.9	$5,328.4

Manufacturing

Aerospace & Motor Vehicles

The aerospace and motor vehicles sector generated over 227,000 jobs in the Washington economy in 2009, 7.8% of total state employment. Most of the impact of this sector comes from the aerospace sector which employed 82,932 people in 2009, while motor vehicles had only 894 employees. As Table 10 indicates, the aerospace and motor vehicles sector is strongly focused on markets outside Washington State. The aerospace component of this sector has a history of fluctuation, as the demand for commercial aircraft has boomed or collapsed. The year 2009 corresponded to an expanding phase in the aerospace cycle, with the sector gaining 17,836 jobs in Washington State between 2005 and 2009. However, 2009 employment fell short of the 1998 peak level of employment by 30,000 jobs.

While the aerospace and motor vehicles sector accounted for 23% of direct technology-based jobs in 2009, it accounted for a somewhat smaller share (19%) of total

job impacts. Although labor income levels per worker are high in this sector, it has weak backward linkages to industries in the state economy when compared to other technology-based industries. The result is a lower multiplier than found in a number of other technology-based sectors, but a level still above the state average (Pascall, Pederson et al. 1989).

Computers & Electronics and Electrical Equipment

The computers & electronics and electrical equipment sector is quite diversified. The sector is composed of manufacturers of computer and peripheral equipment; communications equipment; audio and video equipment; semiconductors and other electronic components; navigational, measuring, electromedical and control instruments; reproducing magnetic and optical media; electric lighting equipment; household appliances; electric equipment; and other electrical equipment and components. This industry supported in total over 73,000 jobs in 2009, with nearly 26,000 people directly employed in the industry. This sector has experienced significant growth over the 1974-2002 time period (296%), as indicated in Table 5 and Appendix IV, although it experienced a 13% decrease in employment between 2002 and 2009.

This industry is strongly tied to non-Washington markets, exporting 89% of its product. Its jobs multiplier of 2.84 is lower than the average for all technology-based industries, and is the same as the state average. This sector accounted for 6.7% of technology-based jobs in 2003, and 6% of all jobs created statewide by technology-based industries.

Chemicals & Petroleum Refining

The chemicals manufacturing sector includes firms engaged in organic and inorganic chemicals manufacturing; plastics materials manufacturing; pesticide and fertilizer manufacturing; biomedical products manufacturing; and paints, adhesives, cleaning, and other chemical products manufacturing. Nearly 6,000 people worked in this industry in 2009, with another 2,600 employed in petroleum refining. Together, these industries supported almost 40,000 jobs in the Washington economy.

The chemicals manufacturing sector has exhibited considerable employment change over time; Table 5 shows a large drop in employment between 1990 and 1992. This was largely due to a reclassification of people who were employed in plutonium production at Hanford into research and testing services (note the large increase in employment in this sector in Appendix IV between 1990 and 1992). Table 6 reports NAICS-based chemicals and petroleum refining employment has grown slightly since 1998, particularly in the drugs manufacturing component.

This sector has relatively slightly lower wages than all technology-based sectors (see Table 10), but it has a relatively high employment multiplier due to structural relations in this sector captured in the Washington input-output model. The petroleum refining sector sells about 45% of its output out-of-state, while the chemicals sector is more strongly focused on markets outside Washington State, selling 83% of its output in external markets. This sector was responsible for only 2.2% of the technology-based jobs

in Washington State, but supported 3.3% of the total jobs related to technology-based industries.

Services

Software Publishers, Data Processing, and Computer Systems Design & Related Services

This sector comprises establishments primarily engaged in computer software publishing or publishing and reproduction, and establishments primarily engaged in providing infrastructure for hosting or data processing services. These establishments may provide specialized hosting activities, such as web hosting, streaming services or application hosting; provide application service provisioning; or may provide general time-share mainframe facilities to clients. Data processing establishments provide complete processing and specialized reports from data supplied by clients or provide automated data processing and data entry services. It also includes establishments providing custom computer programming services, computer integrated systems design, computer facilities management, and other computer related services.

This sector supported over 343,000 jobs in the Washington economy in 2009, or 11.8% of total state employment. Directly it employed 87,425 people, with a relatively high job multiplier of 3.93. The high multiplier is related to the high labor income per worker in this sector, estimated to be $149,703, two and one-half times the state average labor income per job. This sector accounted for 22.9% of technology-based jobs, and through its relatively high multiplier, it was responsible for 28.4% of total jobs created by technology-based industries in Washington State. This sector has very strong out-of-state sales (84%), and makes in-state purchases at a slightly higher level than all technology-based industries. Reclassifications from the old SIC code to NAICS, and redefinitions of NAICS codes make it difficult to estimate growth of this sector using consistent definitions. However, Table 5 reports growth under the SIC definition of 1239% from 1974 to 2002, while Table 6 reports a tripling of employment in software publishers and computer system design from 1998 to 2009.

Commercial Equipment Merchant Wholesalers

This industry includes establishments wholesaling photographic equipment and supplies; office equipment; computer and computer peripheral equipment; software; medical, dental and hospital equipment; ophthalmic goods; and other commercial and professional equipment and supplies. This industry was not included in the first three Technology Alliance economic impact studies. Redefinitions of the classification of wholesaling in the 2002 revisions of the NAICS codes led to the inclusion of this sector because of its relatively high concentration of computer-related occupations. The NAICS definition for this industry does not mesh well with SIC-based definitions, so it is not possible to develop historical estimates of employment in this industry prior to 1998.

This industry employed over 14,000 people and supported over 43,000 jobs in the Washington economy in 2009. The sector has high earnings per worker, and a degree of export-market orientation similar to all Washington industries. This sector accounted for

3.7% of technology-based jobs in Washington State, and was responsible for 3.6% of total jobs created due to technology-based industries.

Electronic Shopping & Mail-Order Houses

This industry comprises establishments primarily engaged in retailing all types of merchandise using non-store means, such as catalogs, toll free telephone numbers, or electronic media, such as interactive television or computer. Included in this industry are establishments primarily engaged in retailing from catalog showrooms of mail-order houses. This industry employed 8,906 people in 2009, or 2.3% of technology-based employment in Washington State. It supported 27,535 jobs, which is also 2.3% of the jobs supported by technology-based industry in Washington State. This industry has grown rapidly, increasing state employment by 88% from 1998 to 2009. The Washington State input-output table does not provide an estimate of markets for sub-categories within retailing; this table reports exports of 15% in the retail sector, the figure reported in Table 10. It is quite likely that the level of out-of-state sales for the electronic shipping and mail-order house sector is well above this figure, but there are no survey data available to document the level of out-of-state for this sector.

Telecommunications & Other Information Services

The telecommunications industry is composed of establishments providing wired telecommunications, wireless telecommunications, satellite telecommunications, telecommunications resellers, and other telecommunications services. Other information services includes news syndicates, libraries and archives, internet publishing and broadcasting, web search portals, and other information services. Changes in NAICS code definitions made in 2007 have altered where some telecommunications activities are classified, with the current industry defined somewhat differently than in prior Technology Alliance economic impact studies. Due to these reclassifications there is a lack of historical data for this industry. The current industry had 30,256 employees in 2009, which was 7.9% of all technology-based employment in Washington State. This industry has a relatively high jobs multiplier, supporting 130,477 jobs or 10.8% of all jobs in the Washington economy supported by technology-based industry.

The Washington input-output table reports a low level of out-of-state sales for this industry, only 12.9%, making this sector the most strongly linked to the Washington economy of any technology-based industry. The industry's level of in-state purchases was higher than that of other technology-based industries. Labor income per worker is below the technology-based industry average, but well above the Washington state average.

Architecture & Engineering, Management Consulting, and Management of Companies and Enterprises

This sector includes establishments engaged in architecture, engineering, and related services; management, scientific, and technical consulting services providers; and establishments providing management of companies and enterprises, including headquarters services. Over 82,000 people were employed in these industries in Washington State, and the sector supported over 212,000 jobs in the Washington

economy in 2009. Earnings in this sector are slightly below the average for all technology-based industries, but well above the statewide average. This sector accounted for 21.6% of all technology-based jobs in Washington State, and it supported 17.6% of the total jobs created by technology-based industries.

This sector is not comparable to definitions based on the SIC system, but some components of it were included in earlier Technology Alliance studies of technology-based industries. Table 5 indicates that engineering, research, and consulting services had strong growth in Washington State between 1974 and 2002, while Appendix IV indicates that architectural and engineering services and management and public relations services have also had strong growth over this time period. In the SIC classification scheme, headquarters were treated as "administrative and auxiliary" establishments, and were reported as a component of two-digit industry statistics. The NAICS system reclassified these entities into NAICS code 55. This category is now called management of companies and enterprises. Research and testing services were included in this industry grouping in earlier Technology Alliance studies, but in the 2005, 2008, and the current study they are classified as scientific research and development services.

Market data for this sector based on the 2002 Washington State input-output model show that about 68% of sales are made out-of-state. Appendix V reports a sharp drop in employment in this management of companies (NAICS 55) between 2000 and 2002. This is likely related to reclassifications of establishments in the wake of the 2002 NAICS redefinitions. Unfortunately, there are no statistical reports available that document such reclassifications.

Scientific Research & Development

This sector is composed of scientific research and development services establishments, including establishments engaged in physical, engineering, and biological research, as well as those engaged in social science and humanities research. Over 19,000 people worked in this industry statewide in the year 2009, and the sector supported a total of over 52,000 jobs. Earnings in this sector are similar to the average for technology based industries. This sector accounted for 5% of technology-based industry employment, and was the source of 4.3% of the jobs supported in the Washington economy by technology-based industries.

Appendix IV reports the SIC-based system of measurement of research and testing services employment, which is not quite the same as the definition used in this study. This data series shows that this sector has had strong growth over the 1974-2002 time period. In 1992 the large jump in employment in this sector was due to the reclassification of a large number of Hanford-related workers from chemicals. In about 1995 many of these people were again reclassified into waste treatment and waste remediation. Thus, the trend of employment shown in Appendix IV is not based on an entirely consistent definition of this sector in the SIC classification framework.

Table 6 reports the doubling of employment in this sector since 1998, when the NAICS definition measurement was first reported. The data in Table 10 indicate that this

sector has about 68% of its revenues from outside of the state; this is undoubtedly a very conservative estimate, as a large fraction of the activity in this sector takes place at Hanford or in Benton County on federal account either through the Department of Energy or at the Pacific Northwest National Laboratory. Unfortunately, the Washington input-output model, which was used to develop this estimate of out-of-state sales, does not provide detail on markets for these sub-sectors.

Waste Treatment & Disposal and Waste Remediation

This sector is composed of remediation and other waste management services; it does not include establishments engaged in waste collection. The majority of employment in this sector is related to Hanford cleanup activities (waste remediation). Historically, Hanford activities were largely classified in chemicals manufacturing, when plutonium production was taking place there. When this activity ceased in the 1980's, employment at Hanford was initially reclassified into the research sector (SIC 873), and much of this activity was later reclassified into waste treatment & disposal and waste remediation (these are NAICS definitions). These reclassifications do not allow separate identification of historical series for employment in this sector in Table 5 or Appendix IV.

In 2009, this sector employed 11,957 people, and supported over 40,304 jobs in the Washington economy. This sector accounted for about 3.1% of direct technology-based jobs, and for about 3.4% of total technology-based job impacts. This sector has 85% of its revenue from out-of-state sources.

University & Federal Research

This sector is composed of research activity at the University of Washington and Washington State University, and research and development being undertaken by NOAA and at the Keyport Naval Undersea Warfare Center Division. No historical data are available for this sector. These entities receive almost all of their revenue from out-of-state, primarily from the federal government. The definition of this sector differs from the first three Technology Alliance studies, which included other components of research activity along with university and federal research. In the 2005 and 2008 studies, these other research activities are considered to be a separate sub-sector, as discussed above.

The wage level is lower than other technology-based industries, creating low multipliers. This is due to the inclusion of university research in this sector, in which a large number of graduate students are paid a relatively modest level of income compared to research staff and faculty. About 2% of the jobs in technology-based industries are in this sector, and they support around 1.6% of total jobs related to technology-based industry. Almost all of the income to this sector is derived from out-of-state sources.

V. Conclusions

This study describes the growing importance of technology-based industries in the Washington economy. In 2009 some 381,546 people were employed in these industries, and a total of 1,208,189 jobs in the state economy were supported by technology-based industries. Washington had 2,900,000 covered wage and salary jobs in 2009, and technology-based industries were responsible for 41.7% of this total. The share of employment accounted for by private sector technology-based industries has risen from 6.7% to 13.2% from 1974 through 2009, a trend that suggests that the total impact of technology-based employment on the Washington economy has expanded significantly over the past three decades.

Tax revenues from the state business and occupation (B&O) tax due to technology-based industries (inclusive of indirect effects) were estimated to be $1.76 billion in 2009. (Local B&O tax collections were not estimated in this study.) Sales and use tax revenues to the State of Washington due to technology-based industries (inclusive of indirect effects) were estimated to be $2.6 billion; and an additional $993 million in sales and use taxes were generated to local governments, for a total tax impact of $5.3 billion.

Technology-based industries directly and indirectly generated a total of $77 billion in labor income in 2009, which is 38% of total labor income earned in Washington that year. Thus, from the multiple perspectives of job creation, tax revenues, and labor income, technology-based industries account for about 40% of total activity in the state economy. A direct measure of their contribution to gross state product was not undertaken in this study, primarily because the output of these sectors enters export markets, while gross state product is predominantly composed of sales to regional components of final demand (consumption, investment, and state and local government outlays).

From a national perspective, Washington State is a center of technology-based employment and R&D activity. The concentration of employment in these sectors in Washington places us 4th in the nation (after Massachusetts, New Jersey, and Virginia), and we also ranked 4th in R&D funding (indexed against Gross State Product). Washington has increased its concentration of technology-based industries over time, from 10% above the national average in 1985 to 37% above it in 2007.

The change in the definition of technology-based industries due to the shift from the SIC system to NAICS makes it difficult to estimate growth rates for many Washington technology-based industries compared to the nation as a whole over the long run. Statistics for the SIC-based system presented in this report indicate strong growth rates in some sectors (such as computers and electronics and software and other computer services), and the increase in the relative concentration of technology-based industries in Washington State is indicative of a stronger overall expansion of employment in these sectors than in the national economy.

As technology-based employment has grown in Washington State, it has also become more diversified. In 1974, 57% of technology-based employment was in aerospace; by 2009 this share had fallen to 22%. Given the fluctuations in employment in the aerospace sector, this percentage could move up again, or it could continue to decline. However, a number of other technology-based sectors have recently experienced rapid growth, including biotechnology; software and internet publishers; computer systems design; scientific research and development; architectural and engineering services; and management and technical consulting services. Growth in these industries should help the Washington economy continue the long-term diversification of its technology-based employment.

Technology-based industry jobs are high-wage, full-time types of work. In 2009 the average level of labor income per job in technology-based industry in Washington State was $110,145, which is 91% above the average level of labor income per worker in Washington State. This high wage level is prevalent in all technology-based industries, and it leads to relatively high impact levels related to the expenditure of this income.

Technology-based industries are also strongly focused on external markets, selling 75% of their output to clients located out-of-state. This level of export sales is almost double the state average, making these industries key and growing contributors to the state's economic base. They also provide a stimulus to industries within the state economy through their purchases of goods and services needed to produce their output. The linkage pattern of these industries creates higher than average multipliers, leading to relatively high levels of impact per dollar of business activity or per directly-created job.

This study documents the fact that private sector for-profit technology-intensive industries and related private non-profit and public sector research organizations have significant economic impacts on the Washington economy. There are other measures of impact that could also be constructed to describe the contribution of these industries to the state economy, including the investment in productive capital needed to support their production process. The research and development intensity of these sectors also has a long-term impact on new business formation, as new businesses spin out of existing firms and research organizations. In industries such as biotechnology, this process has important impacts as firms move from the research to the commercialization phase of the production process. University research also results in new business formation that has lasting economic impacts on the state economy (TechTransfer 2004). Again, this study has not quantified these effects and is therefore a conservative view of the larger impacts of technology-based activities in the state economy.

While this study is based on a widely accepted definition of technology-based industry, it is clear that there are other industries and categories of economic activity that are changing the economic landscape which have their roots in or make heavy use of advanced information technologies. The demise of many early dot-com businesses is a good example of many business concepts built around information technologies. While some of these enterprises were premised on business models that have not survived, the

expansion of electronic commerce is real and now the subject of measurement by the U.S. Census Bureau.

The use of the Internet for business-to-business sales and purchases is burgeoning, and the application of information technologies in a wide array of industries has now been recognized as fueling an increase in the productivity of American industry (Atkinson and Andes 2008). The federal statistical agencies have identified key information-technology producing and information-technology using sectors that have contributed very strongly to the recent growth in gross domestic product and employment. These industries include many of the technology-based industries included in this study, but also include a number of other sectors such as motion pictures, health care, and producer services—sectors seen as vital to the so-called New Economy. Other studies of technology-based industry in the Washington State economy could possibly consider embracing the activities included in the federal "Digital Economy" studies, recognizing that these studies have a different basis than used in this study for defining the economic activities that are central to the New Economy perspective (Economics Statistics Administration 2003).

In summary, technology-based industries constitute a growing, vibrant, innovative sector in the Washington economy. They are providing good jobs for Washington residents and are contributing an increasing share of our economic base. If trends of the past years are any indicator, these industries will play an even more important role in our economy in coming decades.

Appendix I. Alternative Definitions of Technology-Based Industries: A Sampling of Recent Studies

There is a continuous stream of research focusing on technology-based industries in the United States and in other developing and developed countries. As discussed in Section I, the Technology Alliance has used an occupational classification of R&D related work as its basis for defining the scope of the industries included in this and the previous Technology Alliance economic impact studies. In this section several other recent studies are discussed, to merely highlight the diversity of approaches to this general subject.

TechAmerica

TechAmerica was formed by the merger of the AeA, ITAA, GEIA, and CSIS, which they argue is "the largest and strongest voice and resource for technology in the United States." TechAmerica is continuing to produce documents that were previously produced the American Electronics Association (AEA), at the national, state, and metropolitan area on industries it deems to be high-tech (TechAmerica 2010). AEA changed its definition of high-tech to be based on NAICS codes, and these codes are being used by TechAmerica. The TechAmerica and AEA website states: "The U.S. government has replaced its system for classifying industries. This will have significant consequences on the data AEA produces for high-tech employment and wages, particularly for Cyberstates" (American Electronics Association 2008). Their definition includes computers and peripheral equipment, communications and consumer electronics, electronic components, semiconductors, defense electronics, measuring and control instruments, electromedical equipment, photonics, telecommunications services, internet services, software publishers, computer systems design and related services, internet services, engineering services, R&D testing laboratories, and computer training. Using this definition, TechAmerica publishes documents such as Cyberstates, which provides a state-by-state national assessment of measures such as employment, earnings, exports, R&D, and venture capital investment (TechAmerica 2010). They also issue on-line press releases that highlight activity levels in each state, provide estimates of high-tech in 60 major metropolitan areas (cybercities), and are producing measures of high-tech international trade for the states. The TechAmerica's scope of high-technology industry is narrower than this study, amounting to less than 50% of the number of jobs encompassed in the Technology Alliance definition.

Bureau of Labor Statistics

The Bureau of Labor Statistics reviewed the definition of high-technology employment in a paper published in 1999. Hecker (1999) revisited the widely cited 1983 evaluation of these definitions by BLS and, using the considerable resources at the disposal of the federal statistical agencies, embraced a definition very similar to that used in the Technology Alliance economic impact studies and in this study. He writes, "For this analysis, industries are considered high tech if employment in both research an development and in all technology-oriented occupations accounted for a proportion of employment that was at least twice the average for all industries in the Occupational Employment Statistics survey " (Hecker 1999). The paper includes a useful comparison

of the industries included in this definition (they are the ones used in the first three TA studies), as well as in a number of other recent and older studies, including many reviewed in the earlier TA studies. Hecker recently revisited the definition of high-tech, given the shift in measurement to the NAICS system (Hecker 2005). His NAICS definitions are very similar to those used in this study.

Office of Technology Policy

The Office of Technology Policy (a U.S. Department of Commerce agency) published a set of indicators of state performance in science and technology using measures of funding, human resources, capital investment and business assistance, the technology intensity of the business base, and outcome measures (Office of Technology Policy 2004). Four editions of this set of indicators were published. These reports included a set of measures related to high-technology industry, including the percentage of establishments, employment, and payroll in high-tech NAICS codes; the share of establishment births in high-tech; and the net level of high-tech business formation per 10,000 establishments. Washington ranked 1st in the share of payroll in high-tech NAICS codes, 5th in the share of employment in high-tech NAICS codes, and 15th in the percentage of establishments in high-tech NAICS codes. The Office of Technology Policy defined high-technology industry by reclassifying the 1999 definition of high-technology developed by the BLS into concordant NAICS codes (Hecker 1999). Thus, the Office of Technology Policy did not use newer the industry-x-occupation data in developing their NAICS classification of high-tech industries. Their system is also based on the 1997 NAICS codes, while the current Technology Alliance study has used the 2007 NAICS codes. The industry list used by the Office of Technology Policy is similar, but not identical, to the classification used in this study. This office was abolished in 2007.

Milken Institute

The Milken Institute has produced a variety of reports that have a high-tech component to them. This organization positions itself as "….an independent economic think tank whose mission is to improve the lives and economic conditions of diverse populations in the U.S. and around the world by helping business and public policy leaders identify and implement innovative ideas for creating broad-based prosperity." (DeVol, Charuworn, and Kim, 2008) The Milken Institute publishes periodically a state index of science and technology, which was based on 77 different measures in the 2008 edition. These measures span R&D inputs, risk capital and infrastructure, human capital investment, technology and science workforce, and technology concentration and dynamism. The latter includes measures similar to those included in the Office of Technology Policy. Milken does not specifically identify the industries included in their technology concentration and dynamism indicator. Washington ranked 4th on the technology and science workforce indicator, and 8th on the technology concentration and dynamism index in 2008. These rankings are composites of individual values within these categories, so they are not directly comparable to the Office of Technology Policy measures (even if it were clear what industries Milken included in its analyses). Washington's overall rank is 5th in the 2008 edition of the State Technology and Science Index, up from 6th in 2004.

2006 Washington State Index of Innovation and Technology

This report was published by the Washington Technology Center. The authors of this report, Drs. Lee Cheatham and Paul Sommers, have used varying methodologies for determining the inclusion of industries in this report. The report has been issued almost annually. In the 2003 report they used a complex methodology for identifying sectors to be included. They started with sectors having at least 7% of occupations in a list of "technology occupations" selected by the authors, and presumably measured using the industry-x-occupation matrices generated by the Washington State Employment Security Department. Using this first pass, "Each of these potential technology SIC sectors was then examined for the individual companies included. This company-by-company scan allowed pruning of the list for those segments that had a high percentage of technology occupations but really represented delivery of routine services based on a technology" (Sommers and Cheatham 2003). Clearly, the judgment of the authors played a considerable role in this definitional process. This exercise was conducted at a four-digit level of SIC code detail. The employment in the establishments included in that study is 79% of the estimated technology-based employment reported in the current TA study. In the 2006 study they do not describe the methodology used to selected the industries included as technology-based. Their online list of industries includes most of those included in this study, but also includes sectors with less than 10% employment in the occupations used as a basis for this study. Having defined the industries included in the study, the authors then developed a series of indicators documenting innovation, competitiveness, growth, financial capacity, human potential, quality of life, and regional perspectives (Sommers and Cheatham 2006). The results show the strong position of Washington State versus other states on a variety of measures, including innovative capacity, employment growth rates, financial capacity, human potential, economic competitiveness, and quality of life. There are many similarities in their approach to measuring technology-based industries with the approach used in this report.

Washington State Innovation Assessment

This report is also produced by the Washington Technology Center (Washington Technology Center, ND). The goal of this document is to (1) "aid the state in understanding the possible impact of future research and technology investments in additional Washington business creation and jobs," (2) "Identify(ing) common research and industry strengths where cooperation and collaboration will lead to increased economic vitality for Washington State," and (3) "Creating a framework for decisions by the state as it invests in research and commercialization activities" (WTC, p. 3). The analysis includes many of the sectors included in the Technology Alliance economic impact studies, but it also activities such as bioscience, value-added agriculture, and bioengineered foods, energy, and security.

Drivers For A Successful Technology-Based Economy: Benchmarking Washington's Performance

This report was prepared by the Technology Alliance and published in 2006 (Beyers and Chee 2006). In this analysis, Beyers and Chee used the same definition of high-tech as used in the Washington State Index of Innovation and Technology. Using

this definition, sets of industry groups were defined (all high-tech, aerospace, other manufacturing, computer and data processing, and other services), and location quotients were calculated for these industry groups. State values for the location quotients were analyzed, and a set of states were selected as peers due to their concentrations of high-tech industry. Idaho and Oregon were also included in this analysis, to provide comparative measures for our neighboring states. Using these states as the basis for comparison, indicators were developed for three broad categories of benchmarks: education, research capacity, and entrepreneurial climate. This analysis is based on a NAICS-based definition of high-tech industry, while a SIC-based definition was used in the prior Technology Alliance benchmarking studies.

The 2008 State New Economy Index

This report is similar to the Washington State Index of Innovation and Technology, the Milken report, and the work of Beyers and Chee. This latest version by Atkinson and Andes has been published by the Information Technology and Innovation Foundation and the Kauffman Foundation (Atkinson and Andes 2008). They develop a set of indicators for the states, and then focus on economic development strategies for the new economy. High-tech industry is defined as by the AEA, plus the addition of biomedical sectors based on work of the BLS (Atkinson and Andes 2008).

Gauging Metropolitan "High-Tech" and "I-Tech" Activity

This paper by Chapple, Markusen, Schrock, Yamamoto, and Yu provides a nice overview of various attempts to define high-tech industry (Chapple, Markusen et al. 2004). After reviewing these approaches, they settle upon a definition very similar to that used in this study. However, they were selective:

> "In our study, we refine the widely used science and engineering measure to include managers with scientific and engineering backgrounds and certain groups of computer professionals, group we call S&T occupations. We looked closely at occupations that, at face value, appeared greasier and less glamorous than Silicon valley computer whizzes or Manhattan dot-com entrepreneurs. Examples are petroleum and automotive engineers. We consulted a number of experts in science and engineering to determine whether we would be justified in eliminating them from the set. They responded that designers of new plastic materials, fuel-efficient auto engines and new 'intelligent vehicle' systems fully deserve to be included as performing high-tech work. We did, however, exclude occupations at the assistant and technician grade. To identify I-tech industries, we used a subset of information technology-related S&T occupations. These include systems analysts, database administrators, computer professionals, and 'other' computer scientists (Chapple, Markusen et al. 2004).

These authors then used SIC code defined data for the year 1997 to develop a data base for metropolitan areas using their definition. Seattle comes off #2 in the ranking of the share of jobs in high-tech (21.1%), behind #1 San Jose (with 41.3%).

Index of the Massachusetts Innovation Economy

This document is not a study of technology-based industry as such, but it has many parallel considerations to information reported in this document, and in the State New Economy and Milken Reports. A set of peer states are selected—Washington is not one of them—and a set of indicators of performance of Massachusetts versus these peers is presented (Massachusetts Technology Collaborative & John Adams Innovation Institute 2010). Industry clusters are defined, and these include aspects of technology-based industries as defined in this report, but also other industries. It is not at all clear as to how the clusters included in this report were defined. The report has 25 indicators of performance, including some identical to those used in this study (such as R&D indexed to a per capita or per $ of GDP). The report is suggestive of directions for policy, but does not directly articulate recommendations. As indicated earlier in this report, Massachusetts is very strong in research-related measures, due to the very strong research-oriented higher education system in that state. It is less clear from this report how well Massachusetts fares on technology-based industry measures used in this report.

Appendix II. Technical Notes on the Input-Output Model

The impact estimates developed in this study stem from the utilization of an "input-output model." Models of this type are based on static, cross-sectional measures of trade relationships in regional or national economies. They document how industries procure their inputs and where they sell their outputs. Pioneered by Wassily Leontief, who won the Nobel Prize in Economic Science for his insights into the development of input-output models at the national level, these models have become "workhorses" in regional economic impact analysis in recent decades.

Washington State is fortunate to have a rich legacy of research developing input-output models. Early work was led by Philip J. Bourque and Charles M. Tiebout. Input-output models have now been estimated in Washington State for the years 1963, 1967, 1972, 1982, 1987, 1997 and 2002. No other state in the U.S. has this rich historical legacy of survey-based or quasi-survey based regional input-output models. The current is based on work completed in 2007-2008 by a team of Washington State government staff and William B. Beyers (Beyers and Lin 2008).

Input-output models decompose regional economies into "sectors"–groups of industries with a common industrial structure. The heart of these models is "Leontief production functions," which are distributions of the cost of producing the output of sectors. Leontief augmented the national accounts schema developed by Kuznets (also a Nobel laureate in economics) to take into account the significant levels of intermediate transactions that occur in economic systems in the process of transforming raw materials and services into "finished products" or "final products." Sales distributions among intermediate and final sources of demand are used as the accounting bases for the development of the core innovation of Leontief: that these relationships can be used to link levels of final demand to total industrial output by way of a system of "multipliers" that are linked through the channels of purchase in every industry to the production of output for final demand.

This system of relationships is based on accounting identities for sales. Mathematically, the system may be represented as follows. For each industry we have two balance equations:

(1) $X_i = x_{i,1} + x_{i,2} + ... + x_{i,n} + Y_i$

(2) $X_j = x_{1,j} + x_{2,j} + ...+ x_{n,j} + V_j + M_j$

where: X_i =total sales in industry i,
X_j = total purchases in industry j
$x_{i,j}$ = intermediate sales from industry i to industry j
Y_i = final sales in industry i
M_j = imports to sector j
V_j = value added in sector j.

For any given sector, there is equality in total sales and total purchases:

(3) $X_i = X_j$ when i=j.

This system of transactions is generalized through the articulation of Leontief production functions, which are constructed around the columns of the regional input-output model. They are defined in the following manner.

Let us define a regional purchase coefficient:

$$r_{i,j} = x_{i,j}/X_j.$$

Rearranging,

$$x_{i,j} = r_{i,j}X_j$$

Substituting this relationship into equation (1) we have:

(4) $$X_i = r_{i,1}X_1 + r_{i,2}X_2 + ... + r_{i,n}X_n + Y_i$$

Each sector in the regional model has this equation structure, and since the values of X_i equal X_j when i=j, it is possible to set this system of equations into matrix notation as:

(5) $$X = RX + Y$$

This system of equations can then be manipulated to derive a relationship between final demand (Y) and total output (X). The resulting formulation is:

(6) $$X = (I-R)^{-1}Y$$

where the $(I-R)^{-1}$ matrix captures the direct and indirect impacts of linkages in the input-output model system. The input-output model utilized in the modeling for this research project was developed by a committee led by Dr. William Beyers and Dr. Ta-Win Lin, and will be published in 2008 by the Washington State Office of Financial Management. The model has 50 sectors.

A major issue that surrounds the estimation of the $(I-R)^{-1}$ matrix is the level of "closure" with regard to regional final demand components, which are personal consumption expenditures, state and local government outlays, and capital investment. It is common practice to include the impacts of labor income and the disposition of this income in the form of personal consumption expenditures in the multiplier structure of regional input-output models. The additional leveraging impact of these outlays is referred to as "induced" effects in the literature on models of this type. It is less common to include state and local government expenditures in the induced effects impacts, but it can be argued that demands on state and local governments are proportional to the general level of business activity and related demographics. In contrast, investment is

classically argued to be responsive to more exogenous forces, and is not a simple function of local business volume. In the model that we developed for this impact study we have included personal consumption expenditures as a part of the induced-demand linkages system. We have considered Washington personal consumption expenditures to be a function of labor income. The resultant Leontief inverse matrix is available from the Office of Financial Management in either the "simple" or the "complex" impact analysis spreadsheet.

Appendix III. Location Quotients for Technology-Based Industries in Washington State in 2007

	CBP	Nonemployer	Combined
324 Petroleum Refining	1.629	0.223	1.624
325 Chemicals	0.318	1.060	0.330
334 Computer Manufacturing	0.999	1.447	1.015
335 Electrical Equipment	0.292	1.113	0.309
3361 Motor Vehicles	0.172	1.220	0.178
3364 Aerospace	7.360	1.220	7.426
4541 Electronic Shopping & Mail-Order Houses	0.790	1.563	0.956
4234 Commercial Equipment Merchant Wholesalers	0.951	1.047	0.964
5112 Software Publishers	6.648	1.343	6.351
517 Telecommunications	1.224	0.843	1.227
5182 Data Processing	1.017	1.057	1.025
5191 Other Information Services	0.974	1.227	1.065
5413 Architecture & Engineering Services	1.198	1.301	1.212
5415 Computer Systems Design	1.129	1.428	1.177
5416 Management and Technical Consulting Activities	0.673	1.289	0.881
5417 Scientific Research & Development	1.403	1.192	1.406
5511 Management of Companies*	1.218	0.000	1.234
5622 Waste Treatment & Disposal	3.613	0.568	3.481
5629 Remediation & Other Waste Services	1.364	0.568	1.333

* No self-employed in this category

Appendix IV. Growth of Employment in Technology-Based Industries in Washington State, 1974-2002 (not including government or university research activities), SIC Basis of Industry Definition

SIC	Description	2002	2000	1997	1995	1992	1990	1988	1986	1984	1982	1980	1978	1976	1974
28	Chemicals except SIC 283 (drugs)	3,174	3,994	3,939	3,946	4,443	12,789	11,962	11,225	10,307	9,028	8,594	7,846	5,457	5,760
283	Drugs	2,410	2,101	1,940	1,585	853	500	442	320	317	454	165	205	213	264
291	Petroleum Refining	2,195	1,798	1,740	1,903	1,759	1,597	1,511	1,645	1,607	1,668	1,534	1,544	1,521	1,517
348	Ordnance	69	111	206	2,186	3,308	3,532	3,234	23	75	3,043	350	400	400	427
351	Engines and Turbines	100	147	144	25	75	85	131	90	111	250	57	52	30	35
353	Construction and Related Machinery	3,187	3,978	3,468	2,933	2,479	3,103	2,997	2,771	2,562	3,256	3,389	2,906	2,494	3,302
355	Special Industry Machinery	3,180	3,969	4,088	4,296	2,930	3,300	2,798	2,426	2,217	3,251	3,748	3,331	2,913	3,431
356	General Industry Machinery	1,242	1,518	1,349	1,168	983	951	824	649	697	578	545	475	507	562
357	Computer and Office Equip.	5,657	6,730	7,576	7,407	3,903	4,247	5,715	5,400	6,124	4,012	3,000	1,933	1,372	1,081
361	Electric Distribution Equip.	184	275	263	250	202	208	180	300	341	382	325	415	465	386
362	Electrical Industrial Apparatus	2,014	2,027	1,573	1,400	878	1,015	830	670	608	1,000	1,237	474	240	240
365	Household Audio and Visual Equip.	1,269	1,613	1,503	1,457	911	829	763	301	258	310	370	354	250	95
366	Communications Equipment	2,518	3,587	3,137	2,981	1,801	1,759	1,694	892	2,604	3,138	4,148	1,910	1,700	2,300
367	Electronic Components	7,323	9,071	9,375	7,261	6,508	6,662	5,302	7,012	6,065	4,595	1,194	1,613	377	386
369	Misc. Electrical Equip. & Supplies	424	341	349	372	1,158	1,080	791	1,100	1,050	1,081	937	860	626	411
371	Motor Vehicles and Equipment	4,107	5,963	5,944	5,103	2,500	2,500	2,570	2,081	2,083	1,690	2,295	2,479	2,403	2,451
372&376	Aerospace	75,667	93,221	112,962	87,024	115,126	104,860	96,963	80,675	65,824	67,794	72,406	65,014	45,257	54,646
381&382	Search/Navigation Equip. & Measuring Devices	7,229	8,182	8,301	7,713	7,797	8,922	8,250	7,101	6,471	4,642	3,690	1,935	2,287	2,214
384	Medical Instruments & Supplies	5,965	5,889	5,725	5,359	5,151	4,287	3,560	2,477	920	737	590	260	292	349
386	Photographic Equipment	159	143	272	214	226	177	197	157	220	280	605	61	51	40
737	Computer Services	62,938	60,009	46,254	34,983	18,851	14,990	10,737	8,453	7,350	5,089	9,854	6,109	4,627	4,702
871	Engineering Services	27,678	24,617	24,646	23,092	19,032	17,418	14,177	14,147	11,673	11,984	12,107	8,571	8,034	6,772
873	Research & Testing Services[14]	26,237	22,611	21,329	17,847	21,293	9,872	9,029	6,175	4,785	4,644	4,827	3,747	3,216	2,612
874	Management & Public Relations	14,722	13,099	11,605	9,678	9,810	8,722	8,102	6,954	5,240	3,986	3,804	3,186	3,497	1,927
	TOTAL	259,648	274,989	277,688	230,183	231,977	213,405	192,759	163,044	139,509	136,892	139,771	115,680	88,229	95,910

Sources: Washington State Employment Security Department; US County Business Patterns; The Boeing Company; estimates by authors

[14] Includes an estimated 6,495 employees at Hanford in 2002 classified by ESD in sanitary services (NAICS 562910, Remediation Services).

Appendix V. Growth of Employment in Technology Based Industries, 1998-2007(not including government or university research activities), NAICS Definition

		% Change 1998-2009	2009	2007	2005	2002	2000	1998
324	Petroleum Refining	27.9%	2,606	2,444	2,314	2,726	2,030	2,037
325	Chemicals	8.9%	5,796	5,919	5,202	5,798	4,842	5,320
334	Computer Mfg.	-54.9%	21,539	22,576	22,003	25,948	45,554	47,720
335	Electrical Equipment	14.1%	4,213	4,286	4,206	3,782	3,500	3,691
3364	Aerospace	-26.6%	82,932	78,667	65,096	75,667	93,221	112,962
3361	Motor Vehicles	-36.1%	894	700	1,400	700	700	1,400
4234	Commercial Equipment Wholesalers	NC	14,195	14,277	13,774	14,399	nc	nc
4541	Electronic Shopping & Mail-Order Houses	88.1%	8,906	10,833	9,614	9,586	6,613	4,734
5112	Software publishers	286.9%	51,468	47,240	41,122	35,782	27,022	12,209
517	Telecommunications		25,741	26,140	25,717	30,988	32,975	30,200
5182	Data processing and related services		4,030	4,005	2,816	1,855	2,767	2,213
5191	Other information Services		4,515	NC	NC	NC	NC	NC
5413	Architecture & Engineering Services	25.2%	35,771	34,367	31,000	29,701	28,888	28,564
5415	Computer Systems Design	107.6%	31,927	28,398	21,507	22,821	24,697	15,381
5416	Management and Technical Consulting Services	42.3%	12,942	11,436	9,870	8,239	11,685	9,093
5417	Scientific R&D services	101.5%	19,117	18,765	18,090	16,354	10,936	9,489
551	Management of Companies	-37.4%	33,560	34,479	33,313	30,186	47,774	53,616
5622	Waste Treatment & Disposal	84.0%	3,293	3,220	3,728	1,899	2,101	1,790
5629	Remediation and Other Waste Services	62.0%	8,665	8,319	7,918	7,640	6,594	5,350
	Total	NC	372,110					
At Least		19.5%		356,071	318,690	324,101	351,899	345,769

Appendix VI. Washington Technology-Based Employment by County

Alphabetical			
Adams	53	Lewis	580
Asotin	121	Lincoln	19
Benton	18739	Mason	337
Chelan	801	Okanogan	235
Clallam	635	Pacific	114
Clark	12793	Pend Oreille	62
Columbia	72	Pierce	15048
Cowlitz	1539	San Juan	184
Douglas	481	Skagit	1859
Ferry	49	Skamania	152
Franklin	795	Snohomish	52918
Garfield	50	Spokane	11929
Grant	537	Stevens	191
Grays Harbor	436	Thurston	4877
Island	806	Wahkiakum	30
Jefferson	251	Walla Walla	953
King	233475	Whatcom	5394
Kitsap	6457	Whitman	3186
Kittitas	190	Yakima	1922
Klickitat	1089		

By Employment			
King	233475	Grant	537
Snohomish	52918	Douglas	481
Benton	18739	Grays Harbor	436
Pierce	15048	Mason	337
Clark	12793	Jefferson	251
Spokane	11929	Okanogan	235
Kitsap	6457	Stevens	191
Whatcom	5394	Kittitas	190
Thurston	4877	San Juan	184
Whitman	3186	Skamania	152
Yakima	1922	Asotin	121
Skagit	1859	Pacific	114
Cowlitz	1539	Columbia	72
Klickitat	1089	Pend Oreille	62
Walla Walla	953	Adams	53
Island	806	Garfield	50
Chelan	801	Ferry	49
Franklin	795	Wahkiakum	30
Clallam	635	Lincoln	19
Lewis	580		

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