State of Change

The Economic Impact of Technology-Based Industries in Washington State

June 2008

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Technology Alliance

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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 at least 14.6% of their employment in R&D related occupations. In Washington State in 2007, technology-based industries had an average of 43% of their employment in these occupations. In other industries just 3.1% of employment was in these occupations.

State of Washington Employment Security Department (ESD) data benchmarked against the year 2006 were used to define industries included in this study. Industries meeting this test employed over 343,000 people in Washington State in the year 2007 (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 1.16 million jobs were created due to technology-based industries, which is 40% of total covered (non-proprietor) employment in Washington State in 2007. 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 3.39 jobs for each direct wage and salary job, compared to 2.75 jobs for all industries. Labor income in technology industries averaged $117,691 in 2007, compared to the state average of $54,097, a figure 117% above the state average. Technology-based businesses contribute strongly to the export-base of Washington State, as 80% 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 334,581 private sector jobs in 2007, an increase of 249%. This compares to statewide increase in covered employment of 211% over the same time period. In 2007 there were 8,790 public sector and Federal research related jobs in Washington State, bringing total technology based employment to 343,371. Total technology based employment has grown from 6.7% to 11.8% of total state covered employment over the 1974-2007 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 2005 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 35% above the national average. Our aerospace and software/computer services sectors are the primary contributors to this high index.

If we exclude aerospace, our historically largest technology-based industry and still our largest employer, Washington is 17% above the national average, up from 13% in 2003. Non-aerospace technology-based industries have grown in Washington State in recent years at a faster pace than nationally. 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 38% above the national average. The concentration of technology based industries overall in Washington State increased slightly from the last study, from 34% to 35% of the national average, even with the increased threshold for defining technology-based industry from 10% of employment in R&D – the standard applied in previous studies – to 14.6% for the current study.

Research and development expenditures in Washington State, an important indicator of technology-based industry, outpaced the United States over the time since the last Technology Alliance economic impact study. R&D activity in Washington State as a share of Gross State Product in 2004 was 4.3%, compared with the national average of 2.4%. We have especially strong receipts and expenditures by industry and non-profits, while university and college research receipts are similar to the national average. Industry R&D accounts for the largest share of R&D dollars in Washington State (81% in 2004), with very strong receipts in the information industry. Washington has a concentration of R&D receipts that places us 9th in the U.S. in terms of dollars received, and 6th when the size of R&D expenditures in Washington State is indexed by Gross State Product. Washington's concentration of industrial 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 15th most populous state in the United States.

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I. Introduction

This report presents the fifth 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 scientific and engineering occupations distinguishes 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, 2007).

This report documents the growth and development of technology-based industries in the Washington economy up to the year 2007, as well as their impact on the aggregate state economy in the year 2007. Similar studies were released by the Technology Alliance in 1997, 1998, 2001, and 2005 benchmarked to 1995, 1997, 2000 and 2002/2003 data, respectively (Beyers and Lindahl 1997; Beyers and Nelson 1998; Beyers and Lindahl 2001; Beyers, Andreoli et al. 2005).

We start by defining the industries included in our analysis. 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. This section also presents information on the geographic distribution of technology-based industries among counties in Washington State.

Section IV analyzes the impact of these industries on the Washington State economy. Through the use of the Washington State input-output model, we present direct and indirect employment, output, income, and tax effects of technology-based industries. These impacts are then compared to the entire state economy; approximately

40% of total covered employment in Washington State can be attributed to activities within technology-based industries in the year 2007.

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

The Washington State economy continues to undergo dramatic structural transformations, mirroring the changes taking place within the U.S. and other advanced economies. First, there has been a shift in the composition of what is produced, particularly the explosive growth in service-based activities, the emergence of the New Economy, and business activity related to the Internet. Second, the methods by which these goods and services are produced are continually evolving. And third, 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 Correa 2007), (Administration 2002). However, there are numerous ambiguities 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 we undertook the first Technology Alliance study of the economic impact of technology-based industries, we spent a large amount of time deciding upon how to define the industries covered by the study. The first two reports included an appendix that reviewed historically important studies that we are not including in this version of our impact analysis. Those interested in these matters can either contact the Technology Alliance or the authors 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, to give a flavor of the variety of definitions that have been used in recent years.

The definition of “high-tech” is increasingly ambiguous 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.

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, we decided to utilize a measure that we could defend—at least 14.6% employment in R&D intensive occupations.

A similar definition was used in the first three Technology Alliance economic impact studies, using industries defined by Standard Industrial Classification (SIC) code categories. The Washington State Employment Security Department (ESD) developed a list of industries showing the proportion of employment in research and development occupations in the 1997, 1998 and 2001 studies. In the 2005 study we used a spreadsheet obtained from the ESD website that provided estimates of employment by industry and occupation for the year 2002 (Department), using the North American Industry Classification System (NAICS) rather than SIC code definitions of industries. Industries with 10% or greater employment in R&D occupations were included in those studies.

In the current study we have used a 2006 matrix of employment and occupations provided by ESD (Department 2007). This matrix defined industries through the use of the 2002 NAICS codes; these codes are slightly different than the original set of NAICS codes first utilized by the federal government in 1997. 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. 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.

We calculated the shares of employment in each industry included in the 2006 industry-x-occupation matrix that were in occupational codes for engineering, scientific and computer related occupations (codes beginning with 15, 17, and 19). We found that 7.32% of total employment in Washington State was estimated to be in these occupations in the year 2002. The 2005 study found 7.8% of covered employment was in engineering, scientific, and computer-related occupations in 2002, a figure similar to that estimated by ESD for the year 2006.

The 10% figure for engineering, scientific, and computer related occupations was chosen in the previous 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). However, the 10% figure now would lead sectors such as insurance carriers (10.48%) or social advocacy organizations (10.68%) to be included as technology-based industries.

An analysis of the occupational structure of these industries found that their inclusion was related to people working in computer-related occupations. We found that some of these occupations that are not related to research, but rather to data-base management and accounting, had grown quite strongly across many sectors of the economy. After considerable discussion with Technology Alliance staff and board members, it was decided that we should increase the threshold for the definition of technology-based employment to be at least twice the economy-wide average of employment in scientific, engineering, and computer-related occupations. This moved the threshold from 10% of employment in these occupations used in the prior studies to 14.6% in the current study.

One of the consequences of this decision to raise the threshold value for defining technology-based industries was the exclusion of some industries that were included in the last study (including petroleum refining, machinery manufacturing, electronic shopping & mail order houses, and some components of telecommunications). 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 current definitions of technology-based industry (Hecker 2005).

The industries that we included after this process of evaluation are listed in Table 1, along with the percentage of R&D employment. Figure 1 indicates that the majority (62%) of science, computer, and engineering workers are employed in technology-based industries. However, 38% are employed in other industries; the majority of these workers are in computer-related occupations.

Figure 1 Science and Engineering Jobs in Technology-Based and Other Industries, Washington State 2006

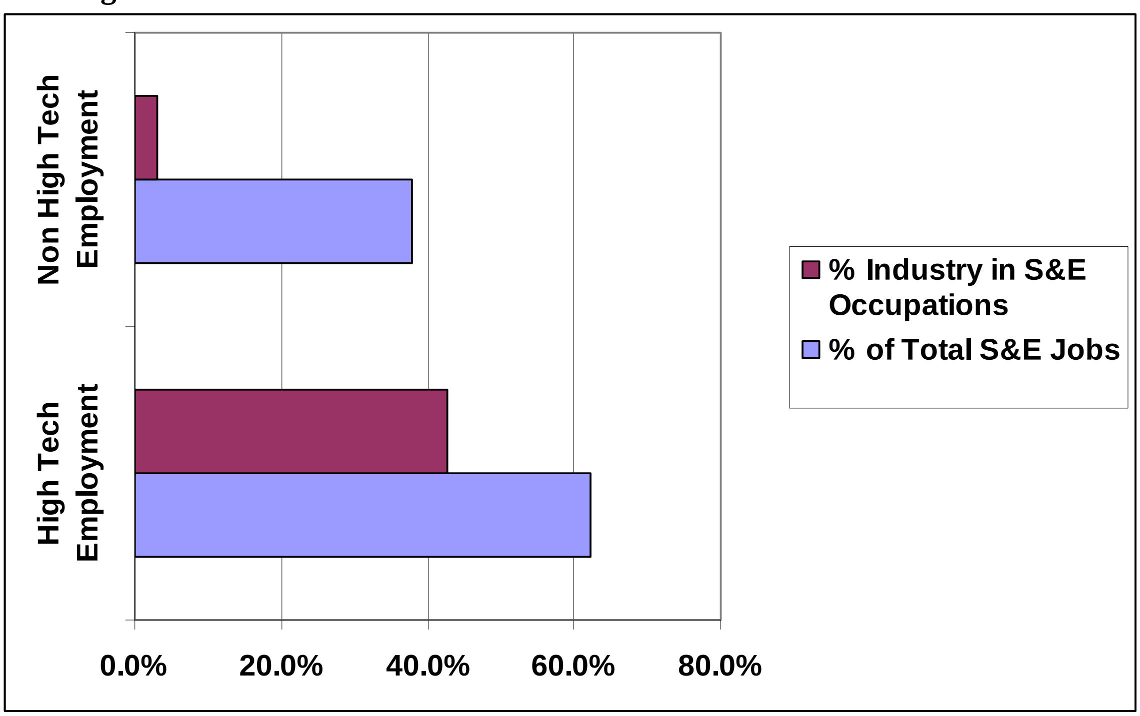

Figure 1 clearly documents the structural difference in employment in technology-based industry and in the balance of the Washington economy. In technology-based industries 42.5% of total employment is in scientific, engineering, and computer related occupations, while in the balance of the Washington economy only 3.1% is found in scientific, engineering and computer related occupations.

University and Federal Research

Two categories included in Table 1, 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.

Table 1 Technology-Based Industries in Washington State

NAICS	Industrial Description	% R&D
	Technology-Intensive: R&D Employment over 30%	
5112	Software Publishers	70.1%
5415	Computer Systems Design and Related Services	68.8%
5413	Architectural and Engineering Services	68.8%
5417	Scientific Research and Development Services	54.4%
5161	Internet Publishing and Broadcasting	45.3%
518	ISP & Data Processing	36.9%
3364	Aerospace	36.5%
	University and Federal Research Laboratories	(Not covered in ESD database: see text)
	Other Technology Industries: R&D Employment 14.6% - 30%	
334	Computer Manufacturing	29.9%
2212	Natural Gas Distribution	26.5%
5416	Management and Technical Consulting Services	23.4%
5629	Remediation and Other Waste Services	23.1%
325	Chemicals	21.4%
335	Electrical Equipment	18.4%
4234	Commercial Equipment Merchant Wholesalers	18.2%
5511	Management of Companies and Enterprises	18.0%
5172	Wireless Telecommunications Carriers	17.0%
5622	Waste Treatment and Disposal	16.4%
5414	Specialized Design Services	16.1%
	All Industries	**42.5%**

The analysis of technology-based industries in Washington State used occupational categories considered as R&D intensive by the National Science Foundation (NSF). Table 2 lists examples of these occupational classifications. There were 95 occupational categories in total included in the ESD industry-x-occupation matrix that we considered to be R&D related occupations.

Table 2 Selected Examples of R&D Intensive Occupations

Occupational Code*	Occupational Description
151011	Computer and Information Scientists, Research
151031	Computer Software Engineers, Applications
151032	Computer Software Engineers, Systems Software
171011	Architects, Except Landscape and Naval
172031	Biomedical Engineers
172081	Environmental Engineers
172011	Aerospace Engineers
173023	Electrical and Electronic Engineering Technicians
191041	Epidemiologists
191042	Medical Scientists, Except Epidemiologists
194021	Biological Technicians
194023	Chemical Technicians

Source: Washington State Employment Security Department
*U.S. Department of Labor Occupational Codes

Biotechnology & Medical Technology

Biotechnology and medical technology are not identified separately in the NAICS codes shown in Table 1. 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. WBBA estimates that almost 20,000 people were employed in biotechnology and medical technology in Washington State in 2006[1]. ESD and U.S. County Business Patterns data show 2,220 people employed in drug manufacture (NAICS 3254), 3,576 people employed in electromedical apparatus manufacturing (NAICS 3345), and 3,478 people employed in medical equipment and supplies manufacturing (NAICS 3391). This leaves about 10,700 people employed in the research component of this sector, which is about 57% of total employment in scientific research and development services.

[1] This figure is cited in the 2006 WBBA Annual Report, available online at their website WBBA (2006). http:wabio.com/industry/annrpt/annrpt_overview.htm. Accessed 6/18/2008

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

The industries defined in Table 1 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, we review the state's position with regard to these measures.

The latest data from NSF are for the year 2004, while the primary benchmark for this study is 2007. Washington's comparative position has changed slightly since the last study; that study used NSF data for the year 2000. 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 3. In 2004, NSF estimated Washington State entities used $10.9 billion in research and development funds, which was 4.3% of our gross state product (GSP; nationally, R&D was 2.4% of Gross Domestic Product (GDP) in the year 2000). This placed us 9th among the states (based on total spending), well above our position as the 15th most populous state in the country. This relative concentration of expenditures on R&D activities is mirrored in the next section of this report, which demonstrates that the

Table 3 Washington State Distribution of R&D Funds by Users and Sources of Funds, 2004

Performer & Sources of Funds	$ Millions	2004 Rank $ Used	2004 Rank Indexed	2000 Rank $ Used	1993 Rank $ Used
United States Sources: Total Used	$10,936	9	6	8	11
A. Federal Government: Total Used (1)	$222	17	23	14	21
B. Industry: Total Used (2)	$8,840	6	4	7	9
Federal Sources	$146	21	26	D	8
Industry Sources (3)	$8,694	6	6	D	10
C. Universities and Colleges: Total Used (4)	$897	14	29	14	14
Federal Sources	$706	12	16	11	10
Non-federal Government Sources	$41	25	36	35	32
University & College Sources	$71	30	49	22	
Industry Sources	$50	15	17	11	14
Non-Profits	$29	25	36	27	
D. Non Profits: Total Used (5)	$978	4	5	4	5
Nonprofit FFRDC	$693	5	4	4	NA
Other Nonprofits	$285	5	5	7	NA

Notes:

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

(2) Industry totals include R&D performed by industry-administered federally funded research and development centers.

(3) Industry R&D support to industry 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.

D – Data not disclosed. NA – Data not available. Sources: NSF, 2004; Shackelford and Jakowski 2007 employment concentration in technology-based industries in Washington is also well above the national average. In 2004 the concentration of doctoral scientists and engineers employed in Washington State exceeded the national average (NSF 2007).

Table 3 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 GDP. Washington's overall position rises from 9th nationally based on total spending to 6th nationally when viewed from an indexed perspective.

Industry R&D dominated Washington R&D expenditures in 2004, as it did nationally (71% of national R&D was performed by industry, while in Washington State 81% of R&D funds were used in industrial sectors, as defined in Table 3). Washington's position is 6th nationally in industry R&D dollars expended, while from an indexed perspective Washington industry R&D spending was 4th nationally. 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.[2] Nonmanufacturing industry R&D was largely in wholesale and retail trade (e-commerce), professional services, and the information sector (including software). Federal R&D activity in Washington State is largely the Bangor 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 (15th) 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 29th in the nation, largely due to relatively weak non-federal government (e.g. state government) and university & college funding sources (such as endowments) to Washington universities and colleges. While Washington's overall university and college research funding places us 12th nationally in the receipt of federal research funds, our position falls to 16th 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 3 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 in 2004 as the 5th 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 we are not able 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

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

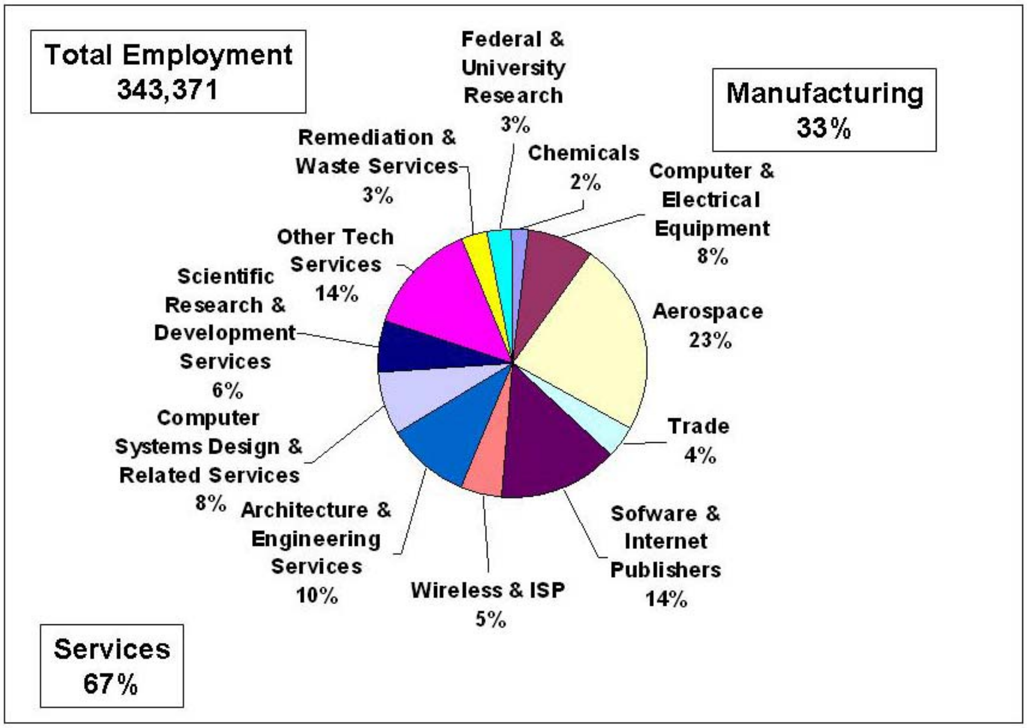
covered in this study. Again, the impacts considered in our analysis are based on all of the business activity in the industries which have high levels of R&D employment, not only the impact of activities directly associated with R&D expenditure.[3] It should be noted that Washington's position on a 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 3.

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

Current Employment

In 2007, technology-based industries employed 343,371 people in Washington, or 11.8% of the state's 2,900,000 total covered employment base. As Figure 2 illustrates, manufacturing industries accounted for 33% of these technology-based jobs, with aerospace being the largest single category, representing 23% of total jobs. The 32,781 non-aerospace manufacturing jobs are divided between 5,919 jobs in chemicals and 26,862 jobs in computer and electrical equipment manufacturing.

Figure 2 2007 Washington State Employment in Technology-Based Industries



Source: Washington State Employment Security Department, NOAA, Keyport Naval Warfare Research Center, University of Washington, Washington State University

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[3] The one exception to this principle is for university research, where we have only considered the impact of research-related activities.

The bulk of technology-based employment in Washington State is found in a variety of service industries. This category includes not only sectors that provide services—for example, architecture and engineering—but also industries that produce intellectual property-based goods, software being a prominent example. The information sector (composed of software and internet publishers, wireless telecoms and ISP's), and computer systems design accounts for 26% of total technology-based industry employment. Producer services includes architecture and engineering, scientific research and development, and other services (management and technical consulting, management of companies and enterprises, and waste remediation). These producer services sectors account for 33% of total technology-based employment.

The trade sector includes commercial equipment wholesalers; these establishments wholesale 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. Together, these industries account for 4% of technology-based employment. University and federal research activities account for another 3% of technology-based employment.

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 were not available for the year 2007.

Employment Trends

In the four previous 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 there have been two important changes that make it impossible to present a harmonious estimate of employment trends in technology-based industries from 1974 to 2007.

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. Internet service providers are 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 that excludes them from the current definition of technology-based industry, while under the earlier bases for defining technology-based industry these industries were included. Petroleum refining is an example of this issue—it does not qualify for inclusion in the current study but was included in the previous studies. 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 is no perfect solution to this statistical issue. The easiest solution is to include in this section both the historical data in the SIC format, to provide information on the historical evolution of technology-based industries, included in Table 4, as well as the data in the NAICS format in Table 5. Table 5 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 4, 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 2007. This figure shows estimated aerospace employment versus the total, illustrating 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 year 2007.

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 4 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, its share had fallen to 23%.

It is 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.

Other sectors with high growth rates in Table 4 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 electronic 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 4 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 classified in Waste Management and Waste Remediation (NAICS categories 5622 and 5629). These industries are included in the current study.[4]

[4]Department of Energy employment in the Hanford region was 346 in 2003; it is likely at a similar level in 2007. ESD reports 552 people employed in the administration of air and water resources and waste management in Washington State in 2006. It also reports 742 federal employees in Benton County in 2006, many of whom are likely Department of Energy employees.

Table 4 Employment History for Washington State Technology-Based Industries, 1974 - 2002
(Private employment; SIC-based definitions)

Manufacturing Industries	% Chg 74-02	2002	2000	1998	1996	1994	1992	1990	1988	1986	1984	1982	1980	1978	1976	1974
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, 1974-2007 (excluding government or university research activities)

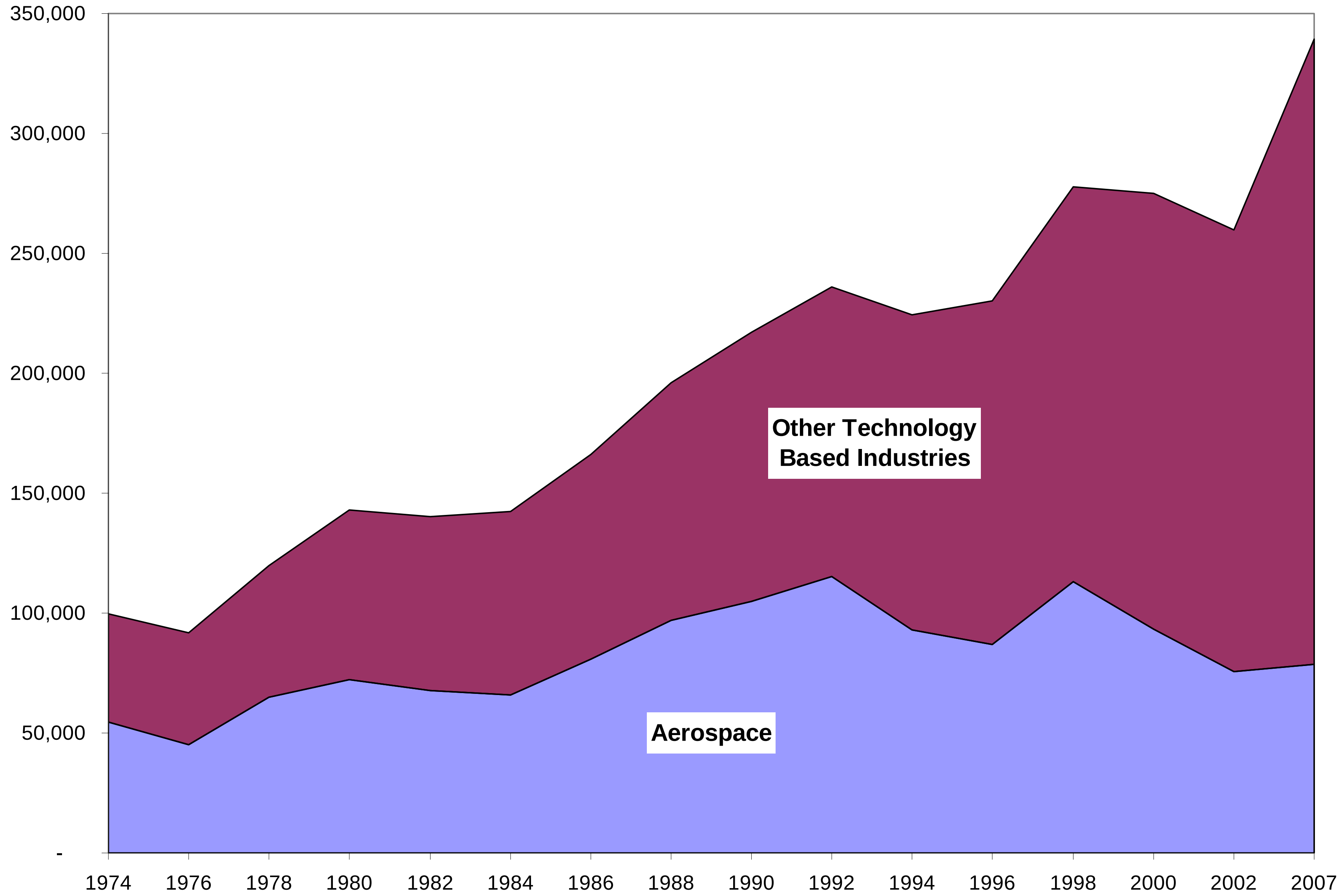


Table 5 presents estimates of employment for the 1998-2007 time period by NAICS definitions used in this study. More detail on the history of employment by NAICS codes is found in Appendix V. NAICS codes were changed in 2002, rendering some sectors non-comparable (NC) due to these definitional changes. This table documents the rapid growth of employment in software publishers and computer systems design, scientific research and development, waste management, and natural gas distribution. 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 5 Employment Trend for NAICS Technology-Based Industries

	% Change 1998-2007	2007	2005	2002	2000	1998
Manufacturing						
Chemicals	11.3%	5,919	5,202	5,798	4,842	5,320
Computer Manufacturing	-52.7%	22,576	22,003	25,948	45,554	47,720
Electrical Equipment	16.1%	4,286	4,206	3,782	3,500	3,691
Aerospace	-30.4%	78,667	65,096	75,667	93,221	112,962
Services						
Natural Gas Distribution	82.0%	1,267	1,226	1,506	350	696
Commercial Equipment Wholesalers	NC	14,277	13,774	14,399	NC	NC
Software Publishers and Computer Systems Design	274.2%	75,638	62,629	58,603	51,719	27,590
Internet Publishers, Wireless, and ISP	NC	19,128	18,675	18,469	NC	NC
Business Services	-11.80%	82,519	75,320	69,854	90,769	93,464
Scientific Research and Development	197.8%	18,765	18,090	16,354	10,936	9,489
Waste Management	161.6%	11,539	11,646	9,539	8,695	7,140
Total	NC	334,581	297,867	299,919	NC	NC
(Estimate for 2000 and 1998)				*at least:*	*309,586*	*308,072*

Source: Washington State Employment Security Department
Notes: Excludes university and federal research employment. A portion of the scientific research and development sector is related to biotechnology. In 2006 this segment included approximately 10,700 jobs. Historical data on the level of biotechnology research employment are not available.

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 share of technology based employment has declined somewhat in Washington State. However, in 2007, Washington's concentration of technology-based industries was 35% above the national average, as reported in Table 6.

Table 6 identifies "location quotients" for each of the NAICS technology-based sectors in 2005, the latest year for which national data by state were available. 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 an industry within the state or region is similar to the concentration of that industry within the national economy[5]. Table 6 uses a source of data not used in prior Technology Alliance economic impact studies to measure location quotients—the U.S. Census Bureau Nonemployer Statistics. These are data 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 6 Location Quotients in Washington Private Sector Technology-Based Industries, 2005

	County Business Patterns	**Nonemployer**	**Combined**
Manufacturing			
Chemicals	0.30	0.96	0.31
Computers	1.08	1.44	1.09
Electrical Equipment	0.37	1.11	0.39
Aerospace	7.13	1.02	7.16
Services			
Natural Gas Distribution	0.29	1.13	0.31
Software Publishers & Computer Services	2.12	1.28	1.97
Internet Publishers, Wireless Telecomm. & ISP	1.91	1.19	1.86
Commercial Equipment Merchant Wholesalers	0.98	1.12	0.99
Business Services	0.96	1.34	1.02
Scientific Research and Development	1.38	1.32	1.38
Waste Management	2.34	0.49	2.35
Total Technology Industries	**1.35**	**1.31**	**1.35**

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

[5] 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.

The 2005 data for technology-based self-employment indicate that their number was 11.2% of the numbers of people reported in County Business Patterns; this compares to 16.7% economy-wide on this same measure. The number of self-employed persons in the United States has gradually increased in recent years; their inclusion in the statistical basis for calculating location quotients does not change Washington's overall concentration, but it does provide a somewhat broader basis for calculating these indices.

As Table 6 indicates, the U.S. aerospace industry is heavily concentrated in Washington State, with a location quotient of 7.16. No other sector included in this study approaches this dominance. Software publishers and computer services; internet publishers, wireless telecommunications and ISP; computers and electronics manufacturing; waste management; and scientific research and development sectors were all above the national average in concentration. Appendix III presents location quotients for more detailed industries than those contained in Table 6.

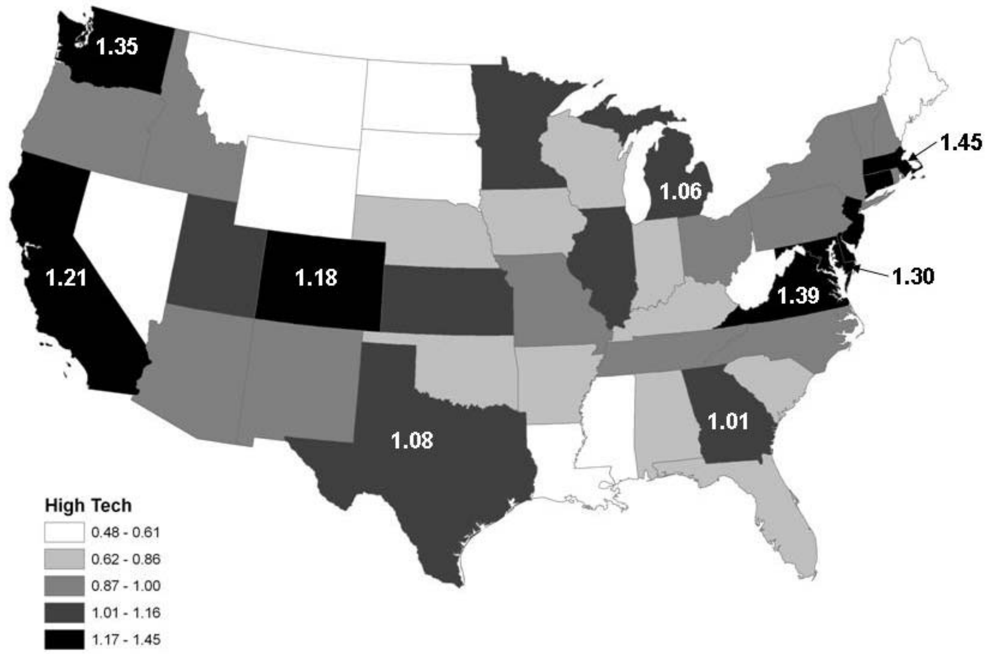
Figures 4 through 6 depict the concentration of technology-based industries in Washington State, compared to other states. These figures also show specific location quotients for Technology Alliance peer states. These figures are for 2005, the year with the most recent data available for all 50 states and the District of Columbia at the necessary level of detail.

The location quotient for all technology-based employment in 2005 placed Washington 4th in its relative concentration of technology-based industries (surpassed by Massachusetts [1.45], New Jersey [1.40], and Virginia [1.39]). Massachusetts is heavily concentrated in computer and electronics manufacturing and software industries, while the concentration of employment in New Jersey and Virginia reflects their strong position in the service industry segments of technology-based industries.

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. Georgia has relatively high concentrations in aerospace and telecommunications. Maryland has high concentrations in architecture and engineering, computer systems design, scientific research and development services, and management and technical consulting services. Michigan has strong concentrations in architecture and engineering, management and technical consulting services, and scientific research and development services. Texas has high location quotients in natural gas distribution, aerospace, computer manufacturing, internet service providers and data processing, and wireless telecommunications.

Among the other states with above-average concentrations, Connecticut and Kansas both have a high concentration of aerospace employment (the latter boasts a significant presence on the part of The Boeing Company), while the District of Columbia is highly service-oriented.

Figure 4 Location Quotients for Technology-Based Employment in the U.S. (Greater than 14.6% employment in R&D occupations)

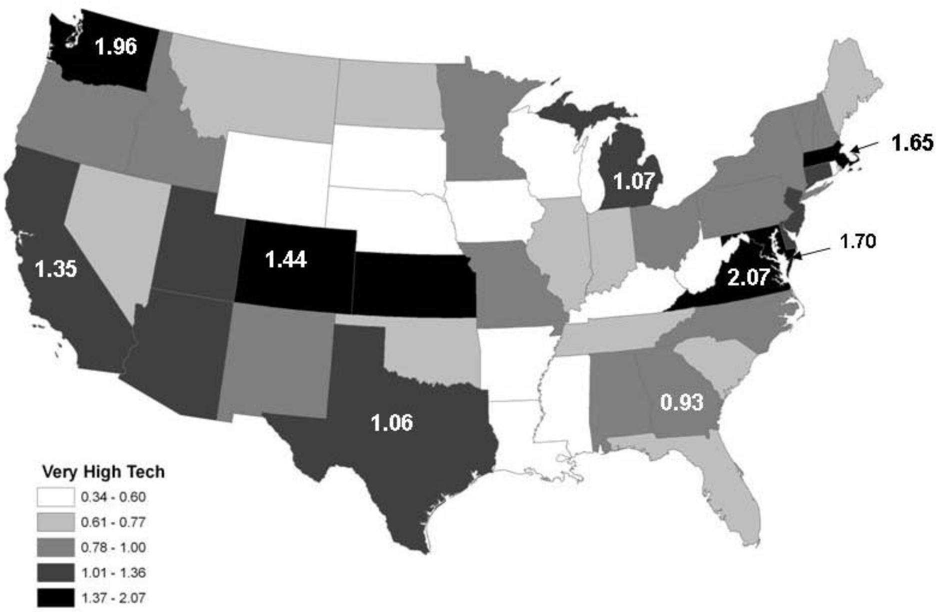


In the 1997 Technology Alliance economic impact study, Washington ranked 6th in the U.S. in its location quotient for technology-based industries, based on data for the year 1993. In the 1998 study we were propelled to the top of the nation in our concentration of these industries, a ranking based on 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 current study, 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 more industry detail due to the shift from the SIC to the NAICS classification schemes. However, with the growing importance of services in the definition of technology-based industry used in this study, it is clear that states such as Virginia, Maryland, Connecticut, and New Jersey are strong competitors in the services, 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 5.98, nearly double that of the closest other state (Massachusetts with a value of 3.37).

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 1 for a list of these sectors). The inclusion of aerospace and software publishers in this category (36% 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)

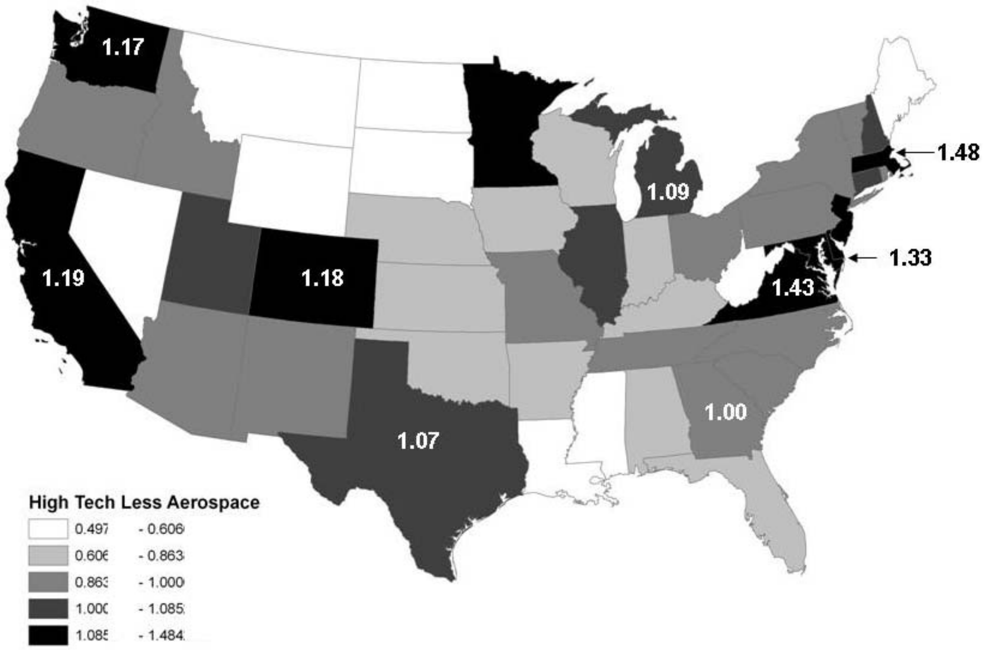


Finally, the strong contribution of aerospace to the high location quotients for Washington State depicted in Figures 4 and 5 is more sharply evident when the aerospace sector is excluded from the calculation, as shown in Figure 6.

Without aerospace Washington ranks 10th, with a location quotient of 1.17, using the technology-based definition (14.6% 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. 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.

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. Our position in the emerging service-based components of technology-based industries is varied, with strong concentrations in waste management, information technologies, and non-university or federal research. Other services sectors show weaker concentrations.

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



***Size Distribution of Technology-Based Establishments*[6]**

County Business Patterns provides establishment counts by size category, while the Nonemployer Series provides estimates of proprietorships. These data are presented in Table 7, and in figures 7 and 8. These data indicate that the 13,524 technology-based establishments with employees had a total of 315,789 employees in 2005, an average of 23 employees per establishment. The Nonemployer series contains 35,264 individuals, most of whom are reported in services, and nearly 42% of the total reported in NAICS 5416, consulting services.

Figure 7 indicates the very skewed distribution of establishment size, with 87% 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 7.[7]

[6] The total number of employees estimated in this section differs from the baseline data in this report, as CBP is benchmarked against 2005, and does not include some of the industries included in this report.

[7] 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.

Table 7 Size Distribution of Technology-Based Establishments in Washington State

NAICS		Total Estabs	1 to 4	5 to 9	10 to 19	20-49	50-99	100-249	250-499	500-999	1000 or more	Nonemployer
2212	Natural Gas Distribution	16	1	1	7	4	2	1	0	0	0	41
325	Chemical Manufacturing	237	86	54	41	35	11	8	1	1	0	148
334	Computer and Electronic Product Manufacturing	357	140	47	37	61	30	21	7	11	3	206
335	Electrical Equipment, Appliance, and Component Manufacturing	105	48	12	15	18	5	5	1	1	0	146
3364	Aerospace Product and Parts Manufacturing	109	28	16	15	19	8	10	5	3	5	24
4234	Professional and Commercial Equipment and Supplies Merchant Wholesalers	849	435	151	130	77	33	14	7	1	1	221
5112	Software Publishers	400	185	63	52	52	25	12	6	1	4	583
5161	Internet Publishing and Broadcasting	81	51	10	8	5	3	3	1	0	0	522
5172	Wireless Telecommunications Carriers (except Satellite)	370	175	81	61	11	12	15	7	5	3	78
518	Internet Service Providers, Web Search Portals, and Data Processing Services	506	292	56	71	56	10	16	4	1	0	945
5413	Architectural, Engineering, and Related Services	3,070	1,895	512	342	211	75	25	8	0	2	5614
5414	Specialized Design Services	694	586	69	27	8	4	0	0	0	0	4500
5415	Computer Systems Design and Related Services	2,228	1,622	248	174	107	38	29	6	3	1	6891
5416	Management, Scientific, and Technical Consulting Services	2,922	2,451	234	136	63	21	12	5	0	0	14646
5417	Scientific Research and Development Services	451	224	71	63	47	20	16	6	1	3	696

	Table 7, Continued	Total Estabs	1 to 4	5 to 9	10 to 19	20-49	50-99	100-249	250-499	500-999	1,000 or more	Nonemployer
5511	Management of Companies and Enterprises	885	314	150	144	137	64	42	15	10	9	0
5622	Waste Treatment and Disposal	38	9	6	7	10	4	0	0	1	1	0
5629	Remediation and Other Waste Management Services	206	107	44	20	26	5	3	1	0	0	3
	Total # Estab.	**13,524**	**8,649**	**1,825**	**1,350**	**947**	**370**	**232**	**80**	**39**	**32**	**35,264**
	Estimated Size	**23.35**	**2**	**7**	**13**	**35**	**70**	**140**	**350**	**700**	**3792**	**1**
	Total Employment	**315,789**	**17,298**	**12,775**	**17,550**	**33,145**	**25,900**	**32,480**	**28,000**	**27,300**	**121,341**	**35,264**

Sources: U.S. County Business Patterns, 2005, U.S. Nonemployer Statistics, 2005

Figure 8 provides a very different picture of the distribution of employment than presented in Figure 7; while 87% of the establishments are estimated to have fewer than 20 employees, these establishments account for 15% of total employment. In contrast, the 0.2% of the establishments that have more than 1,000 employees account for 39% of total employment.

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

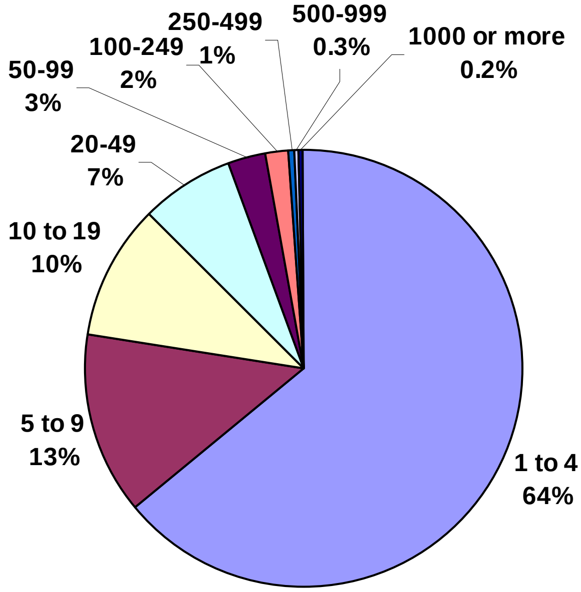
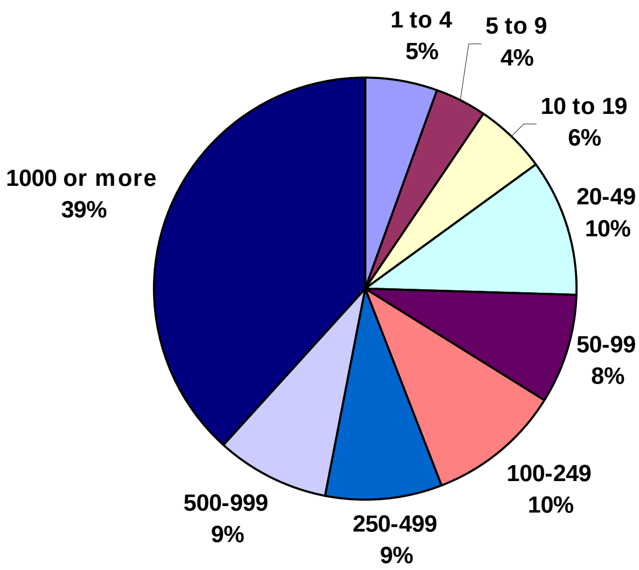


Figure 8 Total Employment by Size Category, Technology-Based Industry



The size distribution of establishments and employment in technology-based industry in Washington State is very similar to the national distribution. Washington's distribution has slightly more establishments and employment accounted for by the largest category—1,000 or more employees—due to the relatively large number of employers in these categories in aerospace and software publishing in Washington State.

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.

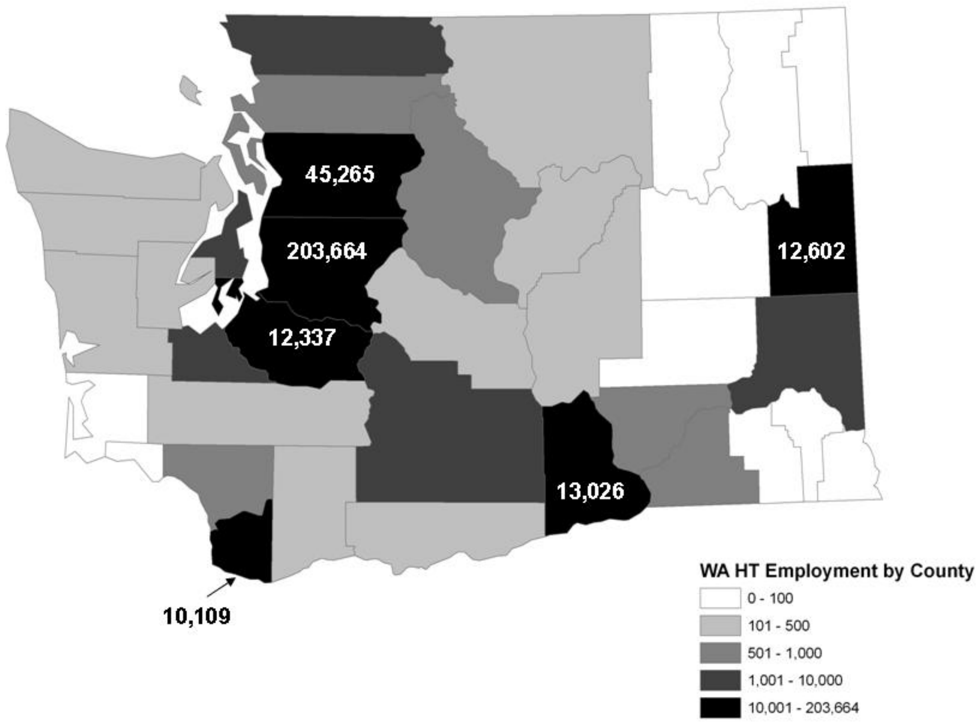
It is estimated that 8,790 people were employed at university and federal research establishments in 2007, as measured on an FTE basis. At the UW, grant and contract activity has expanded significantly over time, rising from $179 million in 1975 to $507 million in 2007 (as measured in constant 1982-1984 dollars). Grant and contract income at the UW was $932.9 million in 2007, of which $551 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 2^{nd} 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 nearly every county in the state. Figure 9 shows the distribution of employment in 2007. Outside of King and Snohomish counties, there are also relatively large numbers of employees in Pierce (12,337), Benton (13,026), Clark (10,109), and Spokane (12,602) counties. Eleven of the 39 Washington counties have at least 1,000 persons employed in technology-based industries, while 29 counties have at least 100 persons employed in these sectors. Appendix VI contains estimates of technology-based employment by county in Washington State.

Definitional changes between the 2005 study and the current study cause apparent reductions in technology-based employment in some counties between 2003 and 2007. If the definitions used to define technology-based industry had remained the same, some of these reductions would not appear. Class intervals on Figure 9 also differ from class intervals in Figure 7 from the 2005 study, making comparisons difficult for counties without absolute levels of employment reported.

Figure 9 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 almost 12% 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 employ over 343,000 people, there are broader impacts on our economy beyond these direct employment effects. 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 2007 (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.

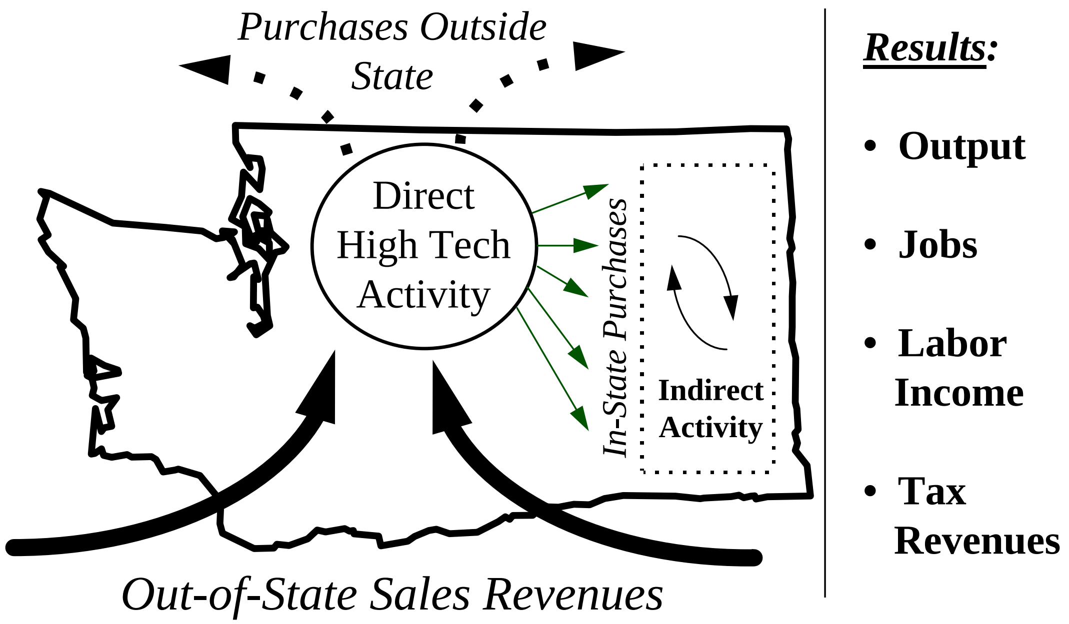
The Washington State Input-Output Model

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 10 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 10 '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 8 presents direct and aggregate impact results. Some 343,371 jobs, $112.6 billion in sales, $1.06 billion in taxes, and $29.5 billion in labor income were directly attributable to technology-based industries in Washington State in 2007.[8] These values increase significantly once the indirect effects are added from the input-output model calculations. Direct and indirect employment impacts total 1,163,423 jobs; overall output impacts equal $205.3 billion, with $71.4 billion in labor income. The aggregate level of state sales and use, business and occupation (B&O), and local sales and use taxes are

[8] Direct tax impacts are estimated business and occupation tax collections.

estimated to be $5.7 billion.[9] Later in this section, we will disaggregate these large impacts into the contributions of individual sectors.

Table 8 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 3.4 jobs created in the state economy.

Table 8 Direct and Total Impacts

		% Change from 2005 Study in Nominal $
Direct Impacts		
Sales Revenue	$112.6 billion	6.40%
Employment	343,371	9.60%
Labor Income	$29.5 billion	2.40%
Taxes	$1.06 billion	6.40%
Total Cumulative Impacts		
Sales Revenue	$205.3 billion	9.50%
Employment	1,163,423	-2.36%
Labor Income	$71.4 billion	25.20%
Taxes	$5.7 billion	20.70%
Multipliers		
Revenue	1.82	
Employment	3.39	
Labor Income	2.42	

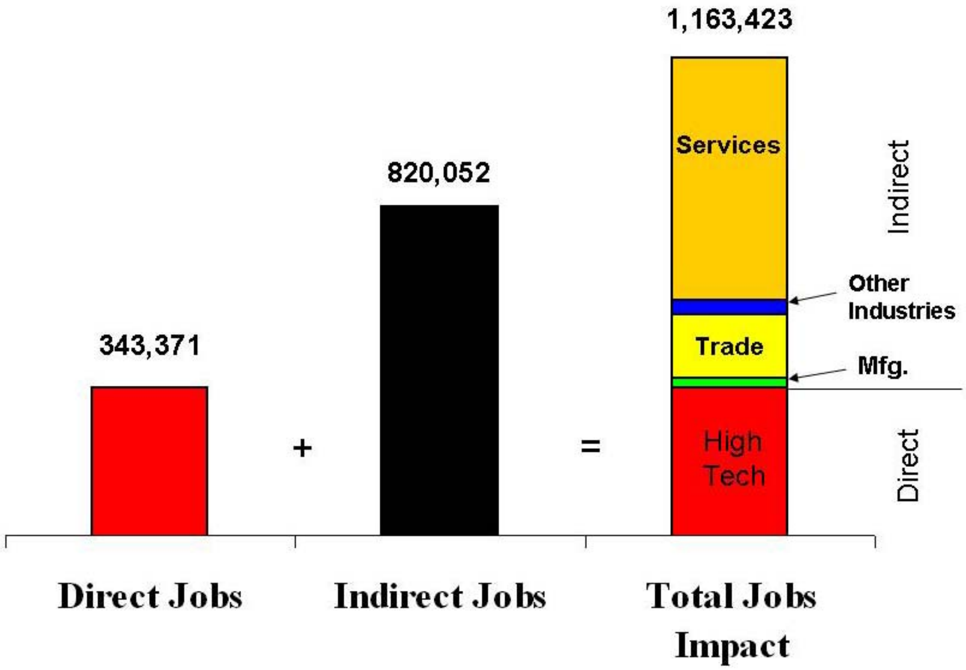
The input-output model provides estimates of output, income, and employment impacts in each industry in the economy due to the demands related to each individual technology-based industry. The impacts in Table 8 could be presented at this level of detail, but a simpler view of these impacts is presented in Figure 11, which shows the total direct and indirect employment effects. Of the 820,052 indirect and induced jobs created in the Washington economy, some 24,352 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,[10] and other industry[11] sectors in the input-output model.

9 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.

10 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.

11 The other industry group includes: agriculture, agricultural services, forestry, fishing, logging, mining, utilities, and construction.

Figure 11 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 9. Table 9 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.

In the aggregate, technology-based industries have a strong impact on the Washington economy, because they have relatively high wage payments per worker. This strong impact is offset by an aggregate propensity for lower than average in-state purchases of goods and services but, as Table 9 shows, this is strongly influenced by the aerospace sector, which subcontracts and purchases an extraordinary proportion of its inputs in national or international markets. The stimulatory and offsetting effects of these purchases and sales relationships play out in the multipliers shown in Table 9: the average technology-based industry multiplier is 3.39, higher than the average multiplier of 2.75 for all Washington State industries.

Table 10 presents summary impacts by the sectoral groups of technology-based industries, followed by a brief discussion of the impacts of each sector. Total impacts are as reported in Table 8.

Table 9 Key Indicators for Technology-Based Industry Sectors

	Employment Multiplier	Labor Income Per Job	% In State Purchases	% Out-of-State Sales
Manufacturing				
Aerospace	2.81	$91,840	6.8%	97.4%
Computers & Electronics and Electrical Equipment	2.76	$120,516	19.8%	88.8%
Chemicals	6.41	$106,102	24.0%	82.3%
Services				
Software and Internet Publishers, Computer Systems Design	5.89	$137,542	19.9%	92.0%
Wireless Telecomm & ISP	4.00	74,299	37.0%	8.3%
Commercial Equipment Merchant Wholesalers	2.30	$83,415	17.3%	40.4%
Scientific R&D	2.23	$133,296	18.2%	67.9%
Architecture & Engineering, Management Consulting, Management of Companies and Enterprises	2.23	$149,120	18.7%	67.9%
Waste Management & Natural Gas Distribution	2.13	$66,562	19.3%	85.0%
University & Federal Research	2.13	$59,886	27.0%	94.9%
All Technology-Based Industries	3.39	$117,691	16.2%	80.2%
All Washington State Industries	2.75	$54,097	24.3%	39.8%

Table 10 Summary Impacts by Sector

	Sales ($ millions)	Employment # jobs	Labor Income ($ millions)	Taxes ($ millions)
Manufacturing				
Aerospace	$52,844.7	221,054	$12,193.6	$971.3
Computers & Electronics and Electrical Equipment	19,565.5	74,139	6,236.3	489.6
Chemicals	4,598.9	37,929	1,276.3	98.1
Services				
Software & Internet Publishers, Computer Systems Design	48,688.3	456,758	19,069.0	1,512.0
Wireless Telecomm & ISP	13,521.7	68,872	3,423.4	314.7
Commercial Equipment Merchant Wholesalers	6,353.0	32,809	2,163.4	156.6
Scientific R&D	8,596.4	41,846	4,149.0	305.6
Architecture & Engineering, Management Consulting, Management of Companies and Enterprises	42,612.7	184,017	20,387.9	1,598.3
Waste Management & Natural Gas Distribution	6,187.3	27,277	1,843.4	152.6
University & Federal Research	2,350.1	18,723	962.2	72.4
		0		
All Technology-Based Industries	$205,318.5	1,163,423	$71,704.6	$5,671.0

Manufacturing

Aerospace

The aerospace sector generated over 221,000 jobs in the Washington economy in 2003, 7.5% of total state employment. As Table 9 indicates, the aerospace sector is strongly focused on markets outside Washington State. The aerospace sector has a history of fluctuation, as the demand for commercial aircraft has boomed or collapsed. The year 2007 corresponded to an expanding phase in the aerospace cycle, with the sector gaining over 12,000 jobs in Washington State between 2005 and 2007. However, 2007 employment fell short of the 1998 peak level of employment by more than 35,000 jobs.

While aerospace accounted for 23% of direct technology-based jobs in 2007, it accounted for a somewhat smaller share (19%) of total job impacts. Although labor income levels per worker are high in aerospace, this sector 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 over 74,000 jobs in 2007, with nearly 27,000 people directly employed in the industry. This sector has experienced significant growth over the 1974-2002 time period (296%), as indicated in Table 4 and Appendix IV, although it experienced a 10% decrease in employment between 2002 and 2007.

This industry is strongly tied to non-Washington markets, exporting 89% of its product. Its jobs multiplier of 2.76 is lower than for all technology-based industries, and about the same as the state average of 2.75. This sector accounted for 7.8% of technology-based jobs in 2003, and 6.4% of all jobs created statewide by technology-based industries.

Chemicals

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 sector in 2007, and it supported almost 38,000 jobs in the Washington economy. The chemicals manufacturing has exhibited considerable employment change over time; Table 4 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 5 reports NAICS-based chemicals employment has grown slightly since 1998, particularly in the drugs manufacturing component.

This sector has relatively high wages (see Table 9), and this contributes to the high jobs multiplier in this sector. It is also strongly focused on markets outside Washington State, selling over 82% of its output in external markets. This sector was responsible for only 1.7% of the technology-based jobs in Washington State, but supported 3.3% of the total jobs related to technology-based industries in 2007.

Services

Internet Publishers, Wireless Telecommunications, Internet Service Providers and Data Processing

This sector is composed of firms engaged in providing wireless telecommunications services, internet publishing, and internet service providers, web search portals, and data processing services. This sector and its SIC-based predecessors were not included in the first three Technology Alliance economic impact studies, and some of the components of this sector are recent technological developments that have no long-run history of production (such as ISP's). Over 19,000 people were directly employed in this industry in 2007, and it supported almost 69,000 jobs in the Washington economy.

The industry has strong backward linkages in the Washington economy, which along with a relatively high level of labor income per worker contribute to a relatively high jobs multiplier (4.0), as reported in Table 9. Only 8% of this sector's output is sold in markets outside Washington State, as this sector is largely providing services to Washington residents and businesses. This sector accounted for 5.6% of technology-based jobs in Washington State in 2007, and supported 5.9% of the total jobs created statewide by technology-based industries.

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.

This industry employed over 14,000 people in 2007, and supported nearly 33,000 jobs in the Washington economy. The sector has high earnings per worker, and a degree of export-market orientation similar to all Washington industries. This sector accounted for 4% of technology-based jobs in Washington State, and was responsible for 3% of total jobs created due to technology-based industries in 2007.

Software Publishers and Computer Systems Design

This sector includes software publishers, and computer systems design and related services establishments. Table 4 and Appendix IV report on the SIC basis historical employment in software and other computer services, while Table 5 and Appendix V report historical employment in the NAICS classification system. These tables indicate the strong growth of this sector in the Washington economy over the past 35 years. Some components of the SIC-based definition were transferred to other industries with the adoption of the NAICS, but the majority of the activity included in the SIC system of industry definition is included in this sector.

In just the last nine years, since the adoption of the NAICS classification scheme, employment in this sector has nearly tripled. This sector employed nearly 77,000 people in Washington State in 2007, and supported almost 457,000 jobs. Table 10 indicates that this sector was the largest job generator among the lines of technology-based industry included in this study. It also has a high level of labor income per job, resulting in a relatively high job multiplier (5.89), as reported in Table 9. While this sector accounted for 22% of direct technology-based jobs in Washington State in 2007, it supported 39% of total jobs created by technology-based industries.

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

This sector includes establishments engaged in architecture, engineering, and related services; specialized design services; management, scientific, and technical consulting services providers, and establishments providing management of companies and enterprises, including headquarters services. Almost 83,000 people were employed in this industry in Washington State in 2007, and the sector supported over 184,000 jobs in the Washington economy. Earnings in this sector are very high, and are well above the statewide level of average earnings.

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 4 indicates that engineering, research, and consulting services have 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 2005 and the current study they are included in another classification.

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 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. This sector accounted for 24% of employment in technology-based industries and supported 16% of the total jobs created by technology-based industries in 2007.

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. Nearly 19,000 people worked in this industry statewide in the year 2007, and the sector supported a total of almost 42,000 jobs. Earnings in this sector are quite high, although the 2002 input-output model does not indicate a high jobs multiplier.

Appendix IV reports the SIC-based system of measurement of research and testing services employment, which is not quite the same as the definition of this sector 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 into this sector. 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 5 reports strong growth in this sector since 1998, under the NAICS definition. The data in Table 9 indicate that this sector has about 68% of its revenues from out of 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. This sector accounted for approximately 6% of technology-based jobs and about 4% of total jobs supported by technology-based industry in Washington State.

Waste Treatment & Disposal, Waste Remediation, and Natural Gas Distribution

This sector is composed of remediation and other waste management services, as well as the natural gas distribution sector. 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 then in about 1995 much of this activity was reclassified into waste treatment & disposal and waste remediation (these are the NAICS definitions).

These reclassifications do not allow separate identification of historical series for employment in this sector in Table 4 or Appendix IV.

In 2007, this sector employed 12,800 people, and supported over 27,000 jobs in the Washington economy. Natural gas distribution was a small component of this sector, with 1,267 jobs in 2007. This sector accounted for about 4% of direct technology-based jobs, and for about 3% of total technology-based job impacts. Table 9 indicates that 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 current and 2005 study, 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. In the current study, about 3% of the jobs in technology-based industries are in this sector, but they support around 2% 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 2007 some 343,371 people were employed in these industries, and a total of 1,163,424 jobs in the state economy were supported by technology-based industries. Washington had 2,929,800 covered jobs in 2007, and technology-based industries were responsible for 40% of this total. The share of employment accounted for by private sector technology-based industries has risen from 6.7% to 11.8% from 1974 through 2007, 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 $1.9 billion in 2003. This was 70% of total state business and occupations (B&O) tax collections. (Local B&O tax collections were not estimated in this study.) Sales and use tax revenues to the state of Washington and to local governments due to technology-based industries (inclusive of indirect effects) were estimated to be $2.8 billion, which is

35% of total collections in 2007. An additional $929 million in local sales and use taxes were generated, for a total tax impact of $5.7 billion.

Technology-based industries generated $71 billion in labor income in 2007, which is 39% of total labor income earned 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), while we ranked 9th in R&D funding. Washington has increased its concentration of technology-based industries over time, from 10% above the national average in 1985 to 35% 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. 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 2007 this share had fallen to 23%. 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 its long-term diversification of the technology-based industry sector.

Technology-based industry jobs are high-wage, full-time types of work. In 2007 the average level of labor income per job in technology-based industry in Washington State was $117,691, which is 117% 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 80% of their output to clients located out-of-state. This level of export sales is 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-run 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 was 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 Correa 2007). 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 (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 three previous studies. In this section we wish to describe several other recent studies, to merely highlight the diversity of approaches to this general subject.

American Electronics Association

The American Electronics Association (AEA) produces national, state, and metropolitan area reports on industries it deems to be high-tech. The AEA has recently changed its definition of high-tech to be based on NAICS codes. The AEA's 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 2003). Their definition includes computers and peripheral equipment, communications and consumer electronics, electronic components, semiconductors, defense electronics, measuring and control instruments, electromedical equipment, photonics, communications services, software publishers, computer systems design and related services, internet services, engineering services, R&D testing laboratories, and computer training. Using this definition, AEA 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 (American Electronics Association 2008). 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 AEA'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 and Employment Security Department

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, has embraced a definition very similar to that used in the three previous 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 three prior TA studies), as well as in a number of other recent and older studies, including many reviewed in the earlier TA studies. The Washington State Employment Security Department has embraced the BLS definitions, and has provided a very useful overview of employment in these industries in Washington State as well as geographic patterns of employment and trends in earnings (Dillingham 2000). Hecker has 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 (Policy 2004). Four editions of this set of indicators were been published. The reports includes 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 2002 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.

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 2007 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 Correa has been published by the Information Technology and Innovation Foundation (Atkinson and Correa 2007). 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 Correa 2007).

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%).

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 2005

NAICS		Location Quoteint CBP	Location Quotient Nonemployer	Location Quotient Combined
2212	Natural Gas Distribution	0.29	1.13	0.31
325	Chemicals Manufacturing	0.30	0.96	0.31
334	Computer Manufacturing	1.08	1.44	1.09
335	Electrical Equipment Manufacturing	0.37	1.11	0.39
3364	Aerospace Manufacturing	7.13	1.02	7.16
4234	Commercial Equipment Wholesalers	0.98	1.12	0.99
5112	Software Publishers	5.98	1.23	5.67
5161	Internet Publishing & Broadcasting	1.82	1.46	1.68
5172	Wireless Telecommunications	3.62	0.75	3.58
518	ISP and Data Processing	0.98	1.12	1.00
5413	Architecture and Engineering Services	1.20	1.28	1.21
5414	Specialized Design Services	0.87	1.43	1.16
5415	Computer Systems Design and Related Services	1.00	1.29	1.05
5416	Management and Technical Consulting Services	0.69	1.33	0.92
5417	Scientific Research and Development Services	1.38	1.32	1.38
5511	Management of Companies and Enterprises	0.95	**	0.95
5622	Waste Treatment and Disposal	4.39	0.49	4.40
5629	Remediation and Other Waste Services	1.31	0.00	1.32
	Total Technology-Based Industry	1.35	1.31	1.35

** No self-employed are counted in this NAICS category

Appendix IV. Growth in Employment of 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[12]	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

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

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

NAICS Code	Industry Name	% Change 1998-2007	2007	2005	2002	2000	1998
2212	Natural Gas Distribution	82.0%	1,267	1,226	1,506	350	696
325	Chemicals	11.3%	5,919	5,202	5,798	4,842	5,320
334	Computer Manufacturing	-52.7%	22,576	22,003	25,948	45,554	47,720
335	Electrical Equipment	16.1%	4,286	4,206	3,782	3,500	3,691
3364	Aerospace	-30.4%	78,667	65,096	75,667	93,221	112,962
4234	Commercial Equipment Merchant Wholesalers	NC	14,277	13,774	14,399	NC	NC
5112	Software Publishers	286.9%	47,240	41,122	35,782	27,022	12,209
5161	Internet Publishers & Broadcasters	NC	1,910	1,743	1,149	NC	NC
5172	Wireless Telecommunications	NC	13,200	12,403	12,828	NC	NC
518	ISP and Data Processing	NC	4,018	4,529	4,492	NC	NC
5413	Architecture & Engineering Services	20.3%	34,367	31,000	29,701	28,888	28,564
5414	Specialized Design Services	2.1%	2,237	1,137	1,728	2,422	2,191
5415	Computer Systems Design	84.6%	28,398	21,507	22,821	24,697	15,381
5416	Management and Technical Consulting Services	25.8%	11,436	9,870	8,239	11,685	9,093
5417	Scientific Research & Development Services	97.8%	18,765	18,090	16,354	10,936	9,489
551	Management of Companies & Enterprises	-35.7%	34,479	33,313	30,186	47,774	53,616
5622	Waste Treatment & Disposal	79.9%	3,220	3,728	1,899	2,101	1,790
5629	Remediation and Other Waste Services	55.5%	8,319	7,918	7,640	6,594	5,350
	Total	NC	334,581	297,867	299,919	NC	NC
At Least	(NAICS Definitions Changed)	8.6%			at least	309,586	308,072

Source: Washington State Employment Security Department
NC – Not computable due to changes in NAICS classification scheme.

Appendix VI. Washington Technology-based Employment, by County

Alphabetical			
Adams	29	Lewis	407
Asotin	63	Lincoln	8
Benton	13026	Mason	244
Chelan	588	Okanogan	122
Clallam	459	Pacific	72
Clark	10109	Pend Oreille	39
Columbia	61	Pierce	12337
Cowlitz	867	San Juan	146
Douglas	253	Skagit	846
Ferry	24	Skamania	141
Franklin	557	Snohomish	45265
Garfield	0	Spokane	12602
Grant	410	Stevens	87
Grays Harbor	369	Thurston	4118
Island	628	Wahkiakum	0
Jefferson	187	Walla Walla	560
King	203664	Whatcom	4306
Kitsap	3820	Whitman	1268
Kittitas	142	Yakima	1689
Klickitat	336		

By Employment			
King	203664	Grays Harbor	369
Snohomish	45265	Klickitat	336
Benton	13026	Douglas	253
Spokane	12602	Mason	244
Pierce	12337	Jefferson	187
Clark	10109	San Juan	146
Whatcom	4306	Kittitas	142
Thurston	4118	Skamania	141
Kitsap	3820	Okanogan	122
Yakima	1689	Stevens	87
Whitman	1268	Pacific	72
Cowlitz	867	Asotin	63
Skagit	846	Columbia	61
Island	628	Pend Oreille	39
Chelan	588	Adams	29
Walla Walla	560	Ferry	24
Franklin	557	Lincoln	8
Clallam	459	Garfield	0
Grant	410	Wahkiakum	0
Lewis	407		

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